These transactions contain all contributions submitted by 15 November 2013.

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1 - INTERNATIONAL TRAINING CENTRE, TECNATOM, Spain

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1 - EDF Energy, United Kingdom

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The Spanish Nuclear Society has provided valuable services to nuclear education and training to the large and varied nuclear workforce responsible for the safe and reliable operation of the Spanish nuclear fleet, its contractors and service and equipment suppliers. Since its inception, the Society has promoted, supported and contributed to nuclear education and training during its General Annual Meetings, in organizing specific informative and training courses and through its official monthly publication Nuclear España. The Society has been present in most of the activities described below.

1. The early years

The decision of a country to develop a nuclear power programme, establish a moratorium on new builds, decide to close or renew the operating plants is taken by the government upon considering the advantages, as well as the technical and economic demands and international requirements that nuclear energy implies. This decision requires a high level of understanding and experience, which is generally absent in new entrant countries. Valid advice is obtained from the International Atomic Energy Agency and other international organizations. In all cases, it is highly recommended that a team of nuclear experts on nuclear legislation, economics, technology demands, international requirements and education and training needs is promptly created.

In the early days, in Spain, as in many other countries, a National Nuclear Energy Board was created in 1951. In 1964 the Nuclear Energy Law was enacted. The law created an Institute for Nuclear Studies, strongly connected with some of the most advanced universities, where courses on the different aspects of nuclear science and technology were conducted, in cases with the participation of foreign experts. A wise policy of mobilisation permitted Spanish experts to be trained in the most advanced countries mainly France, the United Kingdom, United States and Germany. This effort permitted the country, in 1972, to have in operation the three units of the so called first generation of nuclear power plants.

2. The years of euphoria

In 1972 the government promulgated an ambitious National Electrical Plan which envisaged the development of 15 GW in 11 nuclear units. That Plan prompted the electrical utilities to look for suitable sites and prepare for issuing international bids to then suppliers. Close to 20 different sites were selected for license and prospection for sites were done along the Spanish coasts and in the major rivers. The utilities decided to jointly establish a bid for six units to enter into operation from 1982 to 1986. Four of these six units, Almaraz I and II and Ascó I and II, were built and are in operation. Apart from these four units six additional units were proposed and all of them started construction but only three of them reached operation, Cofrentes, a GE-BWR/6 in operation since 1985; Vandellós II, a W-PWR-3L in operation since 1988, and Trillo I, a KWU-PWR-3L, in operation since 1988.
2.1 Training on site selection

In my duties as professor of Nuclear Technology, I used to take my young students to visit nuclear proposed sites. When visiting nuclear sites under characterization, the students were surprised by the extraordinary efforts under development to understand the physical parameters of the site, including seismicity tests, soil morphology and composition analysis, current and extreme meteorology and hydrology, communications, population distribution, use of the land and radiation background.

They soon realized that the geology of the site had to be compatible with the demands of the plant and that the earth science and technology experts also needed to have a good understanding of the nature and demands of the plant. It was also noted that the site characterization was conducted by national experts using national machinery for the simple reason that nobody knows better the characteristics of the site and its surroundings than the national experts. The only additional specific training that the Spanish experts on the earth sciences needed was on the strict safety requirements from the site of the nuclear power plants. Through that observation it was born the national commitment on increasing as much as possible the national participation in siting, design and construction of the power plants, which at the end of the process was closed to 90 %.

2.2 Training on design and construction

When visiting plants under construction, the reaction of the students was always the same, they were surprised by the deep excavation, the dense net of reinforcing rods for the thick concrete structures and the large dimension, weight and transport difficulties of some of the components, such as pressure vessels, steam generators, pipes and pumps. They also acknowledged the large number of people participating in the construction and the many skills required. They also were surprised by the complexity of the construction and on the need of a strong and superior management system.

Sometimes I requested the students to be briefed by the engineer responsible for quality control for them to appreciate the extraordinary control on welding, concrete pouring and laying pipes and electrical cables, as well as the certification of passed for duty of materials and components.

After formulating their observations, the students complained that reality did not mach my teaching efforts on nuclear science and technology. I have to defend myself by explaining that the design, construction, procurement and assembly of the large structures, complicated systems and huge components have to be done by civil, mechanical, electric and electronic engineers with a basic knowledge of the nuclear application demanding such new structures, systems and components. In essence, these engineers have to be nuclearized. Likewise, I also had to explain that the extreme quality control on skills and materials were necessary to ensure the needed safety and reliability I was preaching on in my lectures.

Nuclear euphoria was a clear incentive to create a large number of new activities in existing and new companies, ready to provide services and equipment. It was of relevance the creation of two national companies, ENUSA to manufacture nuclear fuel, and ENSA, with capacity to design and build heavy equipment, including assembling reactor pressure vessel and steam generators and to build spent fuel containers, among other products. They were also a multitude of enterprises ready to supply turbines, electrical equipment such as generators, transformers, motors and cables, all types of valves, pipes and tanks, among other pieces of equipment. A long list of services were also established, mainly engineering companies ready to participate in the design of large parts of the plant and provide quality control and other types of services. All these activities required a long list of engineers with knowledge of nuclear
codes and standards and relevant experience, mainly acquired during the design and construction of the first units.

To train these nuclearized engineers the already mentioned Institute for Nuclear Studies conducted first two year, later on one year, courses on basic nuclear technology. Likewise the curricula in the mayor technical faculties offered courses on nuclear science and nuclear technology which provided a sufficient number of nuclearized engineers. A few of them were offered the chance of attending nuclear courses in foreign universities.

2.3 Training on operation

When visiting plants under operation, the students were astonished by the strict entrance controls, the need to be escorted by a plant official who first explained the actions to be taken in case of an emergency. When the plant was in normal operation, they noticed that the visit was limited to a few places of less interest. For PWRs and BWRs the turbine hall (generally no for BWRs because of residual radiation carried with the steam), some auxiliary buildings and the ultimate heat sink were generally visited, entrance to the main control room and spent fuel building was limited to only a few people and entrance within the containment strictly prohibited. They were disappointed with those restrictions and heavily protested against that. I had to explain that safety and security reasons prohibited such entrances.

Those that had a chance to visit the main control room were surprised by the limited number of operators, the complexity of the control panels and the silence and order of the people working there. Those who entered into the spent fuel pool commented on the extraordinary radiation controls, the need to dress overalls, hardened shoes and hats, globes and other individual protection devices, as well as to secure that the visitor will not loose any foreign material.

In all cases, the students noticed that very few people were seen around buildings and they did not believe that there would be a few hundred people working in the premises at that time. They also appreciated the discipline and the order that was present in the plant. They recognized that the operating plant was very close to the theory they were learning mainly on nuclear safety and radiation protection.

After the visit, during the debriefing session, we had the opportunity of discussing what they have learned. The most appreciated issue was about the order and discipline that they observed and the needed leadership that was considered necessary to achieve that. It was explained to them that work in the operation of a nuclear power plant was similar to that of a symphony orchestra, but with hundreds of players at the same time. There was a conductor, the plant director; a first violin, the management line, and the players, the many skills necessary to keep the plant in a safe and reliable condition. There was also a kind of musical script, the operating procedures for the different operational modes. It was also clarified that the plant operation is a continuous concert which has to last for sixty or more years, since commissioning to decommissioning, 24 hours a day, only the players work in turns.

In one occasion we have the rare opportunity of visiting a plant during an outage for refuelling. That gave us the opportunity of a brief visit to the reactor containment. At that time there were close to one thousand people working at the plant at a given time; nevertheless, although a large number of people were seen all over the place, the same order and discipline than in normal operation was observed. The most repeated observation related to the management of so many people performing hundreds of different activities at the same time. It was explained that any outage is well prepared, months in advanced, all activities are previously closely defined and scheduled to avoid interferences and a lot of training is performed to make it sure that the plant staff and the contracted companies knew with precision what to do, how it should be done and how to prove that it was done correctly.
Nuclear engineering is clearly seen in any operating nuclear power plant and during an outage, but the students very early discovered that the type of nuclear engineering demanded during operation was not the one most of them wanted to undertake, mainly because it was not perceived as creative, as in design or research; the operating persons are given the operating procedures and all they have to do is to play them in tune. It may take them more than four years to obtain the necessary initial knowledge and experience, mainly working in simulators, and the operators have to comply with a continuous effort in keeping their abilities.

The plant owners soon realized that the current university courses were not sufficient and that the operating personnel needed a different type of training, very close to the plant they have to operate. The Electrical Utilities with nuclear interest promptly recognized the need and decided to convert the old Tecnatom in a company owned by them to provide engineering services for the new builds mainly in the areas of training, quality assurance and in-service inspection. To that purposes Tecnatom acquired two simulators for the PWRs and BWRs already being built, as well as in-service inspection equipment for large components, namely reactor pressure vessels and steam generators. Tecnatom decided to develop its own technology through an intense successful period of research and development to gain technology independency.

3. The nuclear moratorium

The 1984 National Energy Plan established a moratorium on the construction of new nuclear power plants and cancelled the construction of five nuclear units, some of them in an advanced status of construction. This decision was a tremendous blow to the previous euphoria and limited nuclear activities to maintaining the operation of the current eight units. Since that time, no new nuclear utilities have been built or proposed in Spain.

The Plan also created an independent regulatory authority, the CSN, from the former Department of Nuclear Safety in the Nuclear Energy Board then charged on licensing and inspection. The Plan converted the Nuclear Energy Board in a National Research Centre for Energy, Environment and Technology, CIEMAT, with the dismantling of most of the nuclear research facilities. The Institute for Nuclear Studies was converted into an Institute for Energy Studies. The Plan also created a national institution for waste and spent fuel management, ENRESA, and declared open the nuclear fuel cycle.

The moratoria substantially decreased the interest for nuclear studies and the number of university degrees dwindled considerably. Only the new regulatory body and the national agency for waste management were active in demanding graduates for their activities. To serve that purpose, the Chair of Nuclear Technology in the Engineering Faculty of the Madrid Polytechnic University created a successful 50 hours course on radioactive waste management, under the auspices of ENRESA and with the help of CIEMAT, which is maintained along the years.

Tecnatom, forced to limit their activities to provide services to the plants in operation, decided to intensify their international activities through cooperation with the IAEA, INPO; EPRI and other international institutions. The international activities of Tecnatom in training and in-service inspection amounted in 1990 to about 40% of the total.

3.1 Education and training for the regulatory body

The creation of the regulatory body increased the need for training on nuclear safety and radiation protection. The regulatory body has to provide the limits and conditions under which the license holder has to select and characterize the site, review design and construction, oversight commission, operation and decommission of the plant. It
has to do it through a satisfactory and complete set of regulations. It also has the duty of overseeing all these activities though an elaborated programme of permanent and selected inspections and periodic safety reviews and operating experience.

When visiting a plant in operation, my students were told that the plant in operation is constantly observed by the regulator, that each player has to be in tune with the procedures that the player will be dismissed from the team when deviating and that the whole orchestra will be penalized, that is the plant license holder. Any of the many physical variables must have a clearly specified value margin; any unforeseen deviation of the limit of any of the variables puts the whole system out of tune and the whole operating orchestra is in disarray until the initial desired situation is recovered.

When these functions are presented to students, they expressed two different opinions. On one side, having that authority pleases many of them; on the other side, this type of policy work is not considered attractive to others. It has to be explained that regulatory work is aimed to assure that the power plant does not represent any unacceptable risk to the health and safety of the workers, the surrounding population and the environment. The regulatory body has to act independently from any other type of interest; formally respond to any application for a license and respect the intentions and desires of the applicant when formulated in accordance with the established regulations.

The regulatory functions are close to courts of justice so that the following attributes are considered of paramount importance: independence of judgement, respect for the interest of the regulated and knowledge of the subject to be regulated. This implies that education and training of the regulatory body is bounded by three requirements: 1) an in depth and well balanced knowledge of nuclear science and technology and consolidated experience on the different phases in the life of the nuclear power plant; 2) when enacting regulations or establishing limits and conditions for a licence, a respect for the consequences of the regulations and the for the limits and conditions impose to the applicants for a license, and 3) when verifying compliance with regulations, a consideration of the reasons given by the license holder to explain any incompliance.

### 3.2 Education and training on decommissioning

The creation of Enresa increased the need for experts on waste management and decommissioning. When visiting plants under decommissioning, Vandellós I in the past and the Zorita plant at present, the first reaction of the students is of sadness. It is difficult to understand why such high technology installations has to be demolished just to recuperate the original green site, mainly if the plant has been closed down for political, not for technical and economical reasons, as it is frequently the case.

The students easily recognize that the symphony has ended; there is no more nuclear process, apart from the decay of the radioactive nuclides there present. They also observed that the minimum five year long decommissioning process also requires a well orchestrated organization, experienced expertise and sophisticated tools for cutting and moving the activated large components, pressure vessels, steam generators, pumps and pipes. The scarification and demolition of thick, highly reinforced concrete walls also requires expertise, skill technicians and sophisticated tools.

All those activities have to be performed under the presence or radioactive materials which demands strict radiation protection measures in two ways: the first one to protect the workers from external radiation and potential internal contamination; the second to manage the radioactive waste which is produced and to separate highly radioactive long life waste from intermediate life and low level wastes and valid non-contaminated materials which could be recycled.

All these operations require many nuclearized engineering disciplines and radiation protection experts. In general, the cited course on radioactive waste management
conducted by the Chair on Nuclear Technology and some specific courses on radiation protection conducted within the CIEMAT Institute for Energy provided sufficient details and expertise to the needed nuclearized engineers and to the radiation protection experts.

4. The nuclear renaissance

The arrival of the new century brought the appreciation that nuclear energy was a needed commodity. Nevertheless, in Spain, the so called thermal gap prevented new nuclear builds. The Spanish electricity generation mix included a large fraction of renewables-wind and solar-and a large number of gas in combined cycles. The existing operating plants were sufficient to cover the base demand and the rest was covered by renewables backed by the gas stations. This situation did not reduce the interest for nuclear and electrical utilities and the regulatory organization started to consider plant life extension, not yet consolidated.

The number of students interested in nuclear grew considerably and the universities created new nuclear related masters, mainly under the impulse received from ENEN.

The regulator decided that each nuclear power plant should have a dedicated training centre in the proximity of the site, with a full scale simulator. The utilities called on Tecnatom to build and populate such centres and installations in each one of the nuclear sites. These activities increased the capabilities of the company and a notorious increase was noticed in the international training projects.

The 2011 Fukushima Daiichi accident has created an uncertainty in the future development of nuclear power in Spain. For the moment, all the units have passed the European Stress Tests and are ready to comply with the required modifications and additions and be prepared for a long life.

5. The final government decision

Soon after the beginning of the life of the nuclear power plant, certainly well before decommissioning, a spent fuel management system has to be in place. This implies a significant national decision which has to be respected by all governments. The spent fuel can be declared as radioactive waste and stored in a geological repository or considered as a valid source of fissile material and be reprocessed.

Countries not able to take a final decision can select the temporal storage of spent fuel within the plant premises or in national storage facilities away from the power plants. In any case, there should be a national expertise on the technical, economical and international implications and requirements related to spent fuel management and in managing the highly radioactive wastes produced by the nuclear power plant and the recycled fuel. Most nuclear countries have created national institutions to cover these needs which have to staff with well training personnel on waste and spent fuel management.

The Spanish government has recently decided to build a central temporal spent fuel Storage facility, ATC, where all Spanish spent fuel will be guarded during sixty o more years. The site has already being selected and it is now in the characterization phase. A site and construction permit is being prepared.

For the ATC project there will be a demand for experts on the earth sciences, as well as on the design and construction and future operation of the storage facility. The experience already gained is considered as a good basis for a high national participation in those coming activities. But these activities can not be the end of the government responsibilities, at some time the government has to decide on the final policy to mange the stored spent fuel.

Madrid, 22 October 2013.
Agustín Alonso

18/11/2013
Plenary
MAINTAINING NUCLEAR COMPETENCE WITHIN THE EUROPEAN UNION

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ABSTRACT

The ENS Higher Scientific Council (HSC) is concerned about the current negative developments within some Member States of the EU and the consequential reduced perspectives in the field of nuclear energy technology, education, research and development. The HSC believes that the use of nuclear energy provides an essential contribution to the secure, clean and affordable energy supply for electricity generation, and that this will remain for at least the rest of this century.

The HSC, therefore, strongly recommends that within the EU the resources that are allocated to nuclear education and training and to nuclear R&D reflects the increasing globalization of nuclear power and the needs of Member States that will have nuclear power or decommissioning programmes for decades to come.

In addition, the HSC recommends that the nuclear industry should actively encourage the setting up of knowledge transfer mechanisms to ensure that the knowledge, know-how and experiences of the current generation of professionals within the industry is not lost to the young people entering nuclear careers. Mobility programmes to support and encourage young professionals to work across the EU to gain wider experience of nuclear power operations should be set up. These activities should help young professionals working in the nuclear technology field to expand long-life networks and business connections and thereby be better prepared for the challenges of the 21st century.

1. Introduction

The ENS Higher Scientific Council (HSC) is concerned about the current negative developments within some Member States of the EU and the consequential reduced perspectives in the field of nuclear energy technology, education, research and development. The HSC believes that the use of nuclear energy provides an essential contribution to the secure, clean and affordable energy supply for electricity generation, and that this will remain for at least the rest of this century.

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2. Background

2.1 Use of Nuclear Energy in Europe –Education, Training and R&D

The use of nuclear energy for electricity production within the European Union is mixed with some countries planning to enhance the use of nuclear energy, some aiming to maintain their current programmes and others intending to withdraw from the use of nuclear energy and decommission their nuclear facilities. Irrespective of whichever path is being taken the provision of suitable qualified and experienced people to undertake the necessary tasks associated with the design, construction, commissioning, operation and decommissioning, is of vital importance not only to the safety and security of the nuclear industry, but also to its sustainability.

The uncertainty within the European Union over the use of nuclear energy over the past thirty years as a result of a combination of worries caused by nuclear accidents and the abundance of cheap gas has resulted in the stagnation of the nuclear industry in many countries. This stagnation and the perceived lack of a long-term future has had an adverse impact on the attractiveness of the nuclear industry to young engineers and scientists. The lack of interest from young people in the industry and the lack of support from some Member States and from the EU as a whole has had a consequential knock-on effect in the universities, higher education colleges and technical training schools. The number of universities and colleges delivering nuclear education programmes has declined.

A consequence of all this is that the age distribution of the workers in the nuclear industry is now biased toward the upper end with many likely to retire in the next 10 years. This presents all Member States with nuclear power programmes with a problem irrespective of which trajectory they are on. Even countries planning to withdraw from nuclear power and decommission their plants will need nuclear engineers and scientists for many decades to come to safely decommission the nuclear power plants, manage the spent fuel and radioactive waste.

The current state of affairs presents the EU with a number of challenges:

1. How to capture the knowledge of those in the nuclear industry who will retire in the next decade so that all their experience and the lessons learned by the nuclear industry will not be lost.
2. How to make the nuclear industry attractive to young engineers and scientists so that the aspirations of Member States; whether to expand their use of nuclear power, maintain their current programmes or withdraw from nuclear power and decommission their nuclear power stations and other nuclear facilities; can be met for decades into the future.
3. How can the decline in the nuclear education and training programmes be reversed and universities and colleges be persuaded to develop and deliver the necessary nuclear engineering and science programmes to provide the nuclear workforce of the future.

Meeting these challenges will not be easy, it will take commitment and resources.

3. The Renaissance Challenge
At the beginning of this century the growing recognition of climate change and the need to decarbonize the generation of electricity was becoming obvious. The perception of nuclear power changed and it became seen as a major source of “CO₂ free” electricity production. Many countries initiated new nuclear programmes to cope with the future electricity needs. However, the short timescales needed to deliver the new power station programmes highlighted a number of challenges. It was immediately obvious that there were insufficient manufacturing facilities to meet the potential demand and it was also obvious there would be skill shortage not only in the supply chain but also to design, construct, commission, operate the new facilities, and to decommission the old plants.

Organizations such as NEA, IAEA, and the JRC, published a number of reports [1-8] indicating the loss of knowledge and experience due to ageing and retirement of staff. In the UK because of its extensive nuclear programme lasting over 6 decades the challenge was not only to decommission its old nuclear power stations and other fuel cycle related sites, but also to maintain its existing programme and deliver a new nuclear power programme. The COGENT sector skills council, in conjunction with the National Skills Academy for Nuclear, produced three excellent reports on the skills needed to deliver the UK’s nuclear programme up to 2025 [9, 10, 11].

4. The Fukushima Effect

The accident at Fukushima had mixed implications for the EU. Some accepted, without being complacent, that the accident could have been avoided and that their nuclear power plants and the nuclear safety regulatory frameworks were sufficiently robust. Others, such as Germany, Switzerland and Belgium, in spite of successfully using nuclear power for some 50 years, decided to shut-down earlier or not extend their nuclear power plants lifetime. These decisions have caused young engineers and scientists in the affected countries to again question the attractions of a future in nuclear power. Young, talented people are not surprisingly leaving for other sectors.

The EU Member States that have turned their backs on nuclear power are contributing to the demise of nuclear R&D and education within Europe. However, the situation is not uniform across the EU and some Member States have recognized the dangers, such as the report from the Science and Technology Committee of the House of Lords [12] in the United Kingdom. The UK has also recognized the need to rebuild its specialist nuclear related education and training [13] to meet the projected skills shortfall.

5. European Energy Needs

Europe depends on nuclear energy for 27% of its electricity generation [14]. If Europe is to maintain its standard of living, meet the challenges from climate change and the need to reduce greenhouse gas emissions, together with the increasing global demand for fossil fuel, the contribution from nuclear power will have to increase throughout the rest of this century. The challenge to maintain European prosperity and at the same time reduce dependency on fossil fuels will only be met by an appropriate mix of affordable energy sources. Nuclear energy is a proven, reliable and affordable means of generating electricity without having an adverse impact on climate change. On a global scale the use of nuclear energy is increasing. The projected growth in the use of nuclear energy in the developing world will make the large-scale use of nuclear power a reality as developing countries increase their prosperity. Europe should welcome this as a positive contribution to the protection of our planet and be prepared to contribute to this growing market opportunity.
The continued, safe and secure, use of nuclear energy to support both European and global electricity supply will require well-educated and trained people with a deep knowledge of nuclear related technologies for decades to come. The continued supply of such people will require Europe to have comprehensive science and engineering education capability and robust nuclear R&D programmes at national and EU levels.

6. Funding Challenges

The lack of enthusiasm for the use of nuclear energy for electricity production in some parts of the EU has meant that nuclear fission energy related budgets are being cut. Nuclear fission R&D budgets within Europe which have effectively been reduced in the past decade are now under more pressure because of the lack of political commitment and realism regarding the need for the use of nuclear power to ensure that Europe has an adequate energy infrastructure in the coming decades.

7. References

[13] National Skills Academy for Nuclear, UK Nuclear Education, Skills & Training Directory, NSAN 2013, enquiries@nuclear.nsacademy.co.uk
Towards a new governance for Euratom research and training programmes in nuclear fission and radiation protection

Georges VAN GOETHEM and Ulrik VON ESTORFF
European Commission, DG Research and Innovation and DG Joint Research Center

ABSTRACT AND KEY MESSAGES

In a rapidly changing world, research and training (R&T) in nuclear fission and radiation protection is faced with a number of scientific-technological and socio-economic challenges that require a new type of governance. In the EU, those challenges are, for example, technological developments aimed at optimising the role of nuclear fission in the energy mix and the related competence building process.

Faced with a number of common issues regarding Euratom R&T, the main stakeholders are discussing needs, vision and implementation instruments. Foocussing on education and training (E&T), which is also the focus of this paper, the commonly accepted approach can be summarized as:

1 – Analysis of needs of society and industry: e.g. what kind of knowledge, skills and competences should be taught to meet the end-users’ demand in the nuclear sector?
2 – Convergence towards a common vision: e.g. towards a new governance for Euratom R&T, aiming at a better scientific support for nuclear decision making in the EU
3 – Development of common instruments: e.g. synergy of national and Euratom E&T schemes aimed at academic recognition and lifelong learning and cross-border mobility.

The above approach is aligned with the “Europe 2020 strategy for smart, sustainable and inclusive growth”. As a result, a new way of “making / teaching science” is proposed, closer to the end-users, aiming at the construction of robust, equitable and socially acceptable systems. A new type of "European governance" for R&T is thus under development, based on improved participation, openness, accountability, effectiveness and coherence.

1 – INTRODUCTION: DRIVERS AND ENABLERS FOR CHANGES IN EURATOM RESEARCH AND TRAINING (R&T)

One of the main goals of the Euratom R&T programme, in compliance with the Euratom Treaty (1957), is to contribute to the sustainability of nuclear energy by generating the appropriate knowledge (research) and developing the required competences (training). The focus is on the continuous development of a common nuclear safety culture, based on the highest achievable standards, as this is also one of the main lessons learnt from the "stress tests" conducted in the EU after the Fukushima accident (Great East Japan Earthquake, 11/03/2011). This is done of course in synergy with national programmes in the EU and with IAEA and OECD/NEA.

Drivers = EU policy (top down) and "end-user requirements" (bottom up)

The drivers for changes introduced in the upcoming Euratom research and training programme are of two types: (1) EU policy (top down) and (2) "end-user requirements" (bottom up).

(1) EU policy to improve the synergy within the Knowledge Triangle

The “Europe 2020 strategy for smart, sustainable and inclusive growth” was launched by the European Commission (EC) in 2010 as a set of seven “Flagship Initiatives”. Of particular interest are the EC Communications dedicated to research (2011), energy (2011) and education (2010), all aiming at meeting the above objectives of "smart, sustainable and inclusive growth".

As a result of the above Communications, the EC is proposing a number of research and training actions related to energy technologies under the upcoming Horizon-2020 (2014-2020). In this paper, the emphasis is on nuclear fission energy (Euratom programme), and, in particular, on the synergy in the nuclear sector, within the Knowledge Triangle, between (1) research, (2) innovation and (3) (higher) education and training (E&T), i.e.:

- research: knowledge creation, usually in RTD organisations (public and private)
- innovation: technological applications usually in industry and services
- (higher) education and training: knowledge transfer and competence building.

(2) End-user requirements of scientific-technological as well as socio-economic type (non exhaustive list based on the "2012 Interdisciplinary Study" – see Section 2.2)

➢ scientific-technological end-user requirements for Euratom R&T

- continuous improvements in (1) Sustainability (e.g. minimize nuclear waste and reduce the long term stewardship burden); (2) Safety (e.g. eliminate the “technical” need for offsite emergency response) / (1) and (2) are at the heart of Euratom R&T programmes

- continuous improvements in (3) Economics (e.g. have a life cycle cost advantage over other energy sources); (4) Proliferation resistance and physical protection (e.g. provide increased protection against acts of terrorism) / (3) and (4) are left traditionally to industry and governments

- towards a better scientific support for nuclear regulations in the EU; multi-sectorial approach (e.g. integration of nuclear generated electricity in smart grids); emphasis on a common nuclear safety culture, based on technical and organisational excellence

➢ socio-economic end-user requirements for Euratom R&T

- long-term solutions to (1) possible shortage of nuclear skilled professionals and ageing population; (2) decision making processes over long time scales ("from cradle to

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2 Europe 2020 strategy: http://ec.europa.eu/europe2020/index_en.htm
grave may exceed 100 years”) and amid tough international competition in a global economy

- long-term solutions to (3) rebuilding the public confidence climate regarding nuclear technologies (a new way of “making / teaching” science); (4) coherence of national policies (including R&T) regarding the role of nuclear fission in the energy mix

- towards the construction of robust, equitable and socially acceptable systems; a common language between the worlds of education and of work, using the EU tools for E&T (e.g. ECVET) and taking into account the new sociological characteristics.

- **Enablers = European Technological Platforms and Euratom R&T programmes**

The enablers for changes introduced in the Euratom research and training programme are principally the European Technological Platforms (ETP) and a number of authoritative expert associations as well as the Euratom R&T programmes.

The ETPs bring together the main stakeholders of nuclear fission research, namely:

- research organisations (e.g. public and private sectors, industrial and radio-medical)
- systems suppliers (e.g. nuclear vendors, engineering companies, medical equipment)
- energy providers (e.g. electrical utilities, co-generation plants for process heat)
- nuclear regulatory authorities and associated technical safety organizations (TSO)
- higher education and training institutions, in particular universities
- civil society (e.g. policy makers and opinion leaders), interest groups and NGOs.

Traditionally, the implementation of the Euratom research and training programmes is left exclusively to the EC, principally in the form of:

1. **indirect actions** (carried out by private and public research organisations in the Member States, co-funded by and under the umbrella of EC DG RTD, Brussels – see CORDIS)
2. **direct actions** (conducted in the laboratories of EC DG JRC, that is, principally: ITU located in Karlsruhe (DE); IET distributed between Petten (NL) and Ispra (IT); and IRMM located in Geel (BE)).

2 – **Scientific-Technological and Socio-economic Challenges for Euratom R&T**

2.1 Governance: participation, openness, accountability, effectiveness and coherence

The EC has established its own concept of governance in the *White Paper on European Governance* issued on 25.7.2001, in which the term "European governance" refers to the rules, processes and behaviour that affect the way in which powers are exercised at European level, particularly as regards openness, participation, accountability, effectiveness and coherence. These five "principles of good governance" reinforce those of subsidiarity and proportionality (see also Laeken European Council of 14 and 15 December 2001, and, in particular, the *Laeken Declaration on the future of the Union*).

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5 “The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies” - [http://ec.europa.eu/dgs/jrc/index.cfm](http://ec.europa.eu/dgs/jrc/index.cfm)
The five principles of good governance are further defined as follows:

- **Openness.** The Institutions should use a language that is accessible and understandable for the general public.
- **Participation.** Improved participation is likely to create more confidence in the end result and in the Institutions which deliver policies.
- **Accountability.** The Institutions must explain and take responsibility vis-à-vis those affected by their decisions or actions.
- **Effectiveness.** Policies must be effective and timely, delivering what is needed on the basis of clear objectives and an evaluation of future impact.
- **Coherence.** Coherence requires political leadership on the part of the Institutions to ensure a consistent approach within a complex system.

Ethics considerations are of course very important in this context. At this stage, it is worth recalling the authoritative Ethics report, issued on January 16, 2013, by the European Group on Ethics (EGE) and published together with the “2012 Interdisciplinary Study” (see Section 2.2), called: "Ethical framework for assessing research, production, and use of Energy" (Ethics Opinion n°27). The EGE which is a team around the Bureau of European Policy Advisers (BEPA), reporting directly to the President of the EC, was asked by Mr. Barroso on 19/12/2011 to contribute to the debate on a sustainable energy mix in Europe by studying the impact of research on different energy sources on human well-being. In their conclusions, the EGE recommends achieving a fair balance between four criteria - access rights, security of supply, safety, and sustainability - in light of social, environmental and economic concerns. Interesting recommendations are also made regarding “educational projects” related to “the responsible use of energy” (excerpt of Ethics Opinion n°27 in footnote 7).

The creation of the European Technological Platforms (ETPs) in general is an application of the above five "principles of good governance". The ETPs play an increasingly important advisory and implementation role, in particular, in the Euratom R&T programmes.

Another important contributor to Euratom energy policy and legislation is the European Nuclear Energy Forum, launched in November 2007 (ENEF has three Working Groups: “Opportunities”; “Risks”; “Transparency”). With regard to the need for a better understanding of the skills gaps in the nuclear industry and in research organisations, the ENEF (WG “Risks”) was active in the creation of the European Human Resources Observatory - Nuclear Energy (EHRO-N): the implementing agent of the EHRO-N is EC DG JRC. They published, for example, in May 2012 a report about the shortage of nuclear skills: "Putting into Perspective the Supply of and Demand for Nuclear Experts by 2020 within the EU-27 Nuclear

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7 Excerpt of «Ethics Report» / “Recommendations” (p 63): «4. enhance the awareness of citizens (starting from an early age) regarding the need to adopt new attitudes and lifestyles for the responsible use of energy by promoting and financing educational projects and awareness-raising initiatives ...»

8 List of European Technological Platforms (reactor safety, geological disposal, emergency, radioecology, etc)
- SNE-TP = “Sustainable Nuclear Energy Technology Platform” - [http://www.snetp.eu/](http://www.snetp.eu/)
- NUGENIA = NUclear GENeration II & III Association (1921 Belgian law) - [http://www.nugenia.org/](http://www.nugenia.org/)
- NERIS = legal association c/o CEPN, established in June 2010 - [http://www.eu-neris.net/](http://www.eu-neris.net/)
- ALLIANCE = legal association c/o SCK-CEN, established in October 2012 - [http://www.er-alliance.org/](http://www.er-alliance.org/)

Energy Sector". This type of report is useful to develop the EU governance for R&T under discussion.

Besides the above ETPs, a number of authoritative expert associations are playing an increasingly important role in the Euratom research and training programmes. With regard to safety enforcement, an important role is played by the European Nuclear Safety Regulators Group (ENSREG), launched in October 2007, which is composed of senior officials from national nuclear safety authorities. This Group focuses on nuclear safety (they were also in charge of the specification of the EU "stress tests" in the NPPs), waste management and spent fuel, in synergy with the Western European Nuclear Regulators Association (WENRA), the network of Chief Regulators of EU countries with nuclear power plants (+ Switzerland). Another important association is the Heads of European Radiological protection Competent Authorities Association (HERCA), created in 2007.

The EU research strategy for radiation protection is in the hands of the Multidisciplinary European Low Dose Initiative. MELODI is a non-profit making association focussing on research related to the impact of low dose radiation (including the competing theories of "linear no-threshold" /LNT/ model and "hormesis").

Faced with a number of common challenges regarding Euratom R&T, the main stakeholders are discussing needs, vision and implementation instruments in the above-mentioned European Technology Platforms and authoritative expert associations. As a result, they developed a common approach in the main areas of Euratom research, i.e. (1) Safe operation of reactor systems; (2) Management of ultimate radioactive waste; (3) Radiation protection. This common approach is described in a series of guidance documents produced by the ETPs, called: "Vision Report", "Strategic Research and Innovation Agenda" and "Deployment Strategy". The “Vision Reports” are particularly interesting to understand the objectives fixed by the stakeholders to the scientific research communities associated to each ETP.

Focussing on E&T, the common approach developed by the above ETPs and authoritative expert associations can be summarized as follows:

1 – Analysis of needs of society and industry, in particular with regard to nuclear safety: E.g. excellent science and technology; continuous improvements in nuclear safety culture in all installations, based on technical and organisational excellence; what kind of knowledge, skills and competences should be taught to meet the end-users’ demand?

2 – Convergence toward a common vision that puts the needs in a EU perspective:

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10 List of independent authoritative expert associations (dealing with "stress tests", medical applications, etc)
- Western European Nuclear Regulators Association (WENRA) - http://www.wenra.org/
- MELODI = “Multidisciplinary European Low Dose Initiative” - http://www.melodi-online.eu/
E.g. towards a new governance for Euratom R&T, aiming at a better scientific support for nuclear decision making in the EU; need for a multi-disciplinary and multi-sectorial approach; towards excellence in all parts of the EU (nuclear capacity building)

3 – Development of common instruments that respond to the above needs and vision:
E.g. synergy of national and Euratom funding schemes for R&T (Horizon-2020, ERC, EIT/KIC, PPP, P2P, etc); implementation of ECTS (academic recognition) and ECVET (lifelong learning and cross-border mobility); other E&T instruments of “Erasmus +”.

Besides the above European Technology Platforms and authoritative expert associations, there are many other applications of the five "principles of good governance" in Euratom R&T. For example, as far as radioactive waste decision-making processes are concerned, there is an increasing effort to better identify and understand societal expectations, needs and concerns, notably at the local and regional levels. The related Euratom projects are involving, in particular, the civil society (with a significant representation of local communities, elected representatives, and NGOs, as well as social and natural scientists) together with the traditional actors in the field such as industry, Public Authorities, experts and research institutions.

As a result, a new type of governance for European R&T in energy technologies is under development, integrating the local, national and European levels of decision while involving the key non-technical and technical dimensions. This is also one of the main recommendations of the “2012 Interdisciplinary Study”.

2.2 "2012 Study - Benefits and limitations of nuclear fission for a low carbon economy"

In view of their decision on the Euratom part of Horizon-2020, the EU Council (meeting of 28 June 2011) requested that the Commission "organise a symposium in 2013 on the benefits and limitations of nuclear fission for a low carbon economy. The symposium will be prepared by an interdisciplinary study involving, inter alia, experts from the fields of energy, economics and social sciences".

As a consequence, the "2012 Interdisciplinary Study - Benefits and limitations of nuclear fission for a low carbon economy: Defining priorities for Euratom fission research & training (Horizon 2020)" 11 was launched in April 2012. This study is composed of two parts: a scientific-technological and a socio-economic part (described below). The Terms of Reference of this study were oriented towards answering “why – and how – continue developing research and training activities in nuclear fission and radiation protection at EU level?”.

The “2012 Interdisciplinary Study” and the accompanying Ethics study have been published on the occasion of and presented at the 2013 Symposium "Nuclear Fission Research for a low carbon economy" (co-organised by EC and European Economic and Social Committee /EESC/, Brussels, 26-27 February 2013). The aim was to discuss the conclusions of the study to understand better the common needs, vision and instruments under Euratom Horizon-2020.

(A) Scientific-technological part of the “2012 Interdisciplinary Study” (9 experts)

A total of 10 Topics were identified for the scientific-technological part (Topic 10 being the Synthesis), pertaining to three domains, namely:

- **EU Energy Policy** (2 Topics), namely:
  1. three pillars of the EU Energy Policy (sustainability, security of supply and competitiveness);
  2. European Strategic Energy Technology (SET) Plan
- **Euratom Treaty and other EU policies** (5 Topics), namely:
  3. Research and Development;
  4. Education and Training and Skills;
  5. EU Nuclear Safety and Security Aspects;
  6. People, quality of life and environment;
  7. Safety and Security Culture beyond EU borders
- **Principles of good governance** (2 Topics), namely:
  8. Science based policies and nuclear safety and security legislation;
  9. Ethics.

(B) Socio-economic part of the “2012 Interdisciplinary Study” (16 experts)

For the socio-economic part, a total of 6 Questions were asked, pertaining to three main domains, namely: (1) decision making, (2) risk governance, (3) Euratom research. A number of socio-economic scientists (16 in total) were selected. The civil society was also represented (including interest groups and NGOs) as follows: (1) by the EESC who is co-organising the "2013 Symposium" with the EC; (2) by some of the scientific-technological experts who used to be national regulatory experts; and (3) by experts of the various Technological Platforms and authoritative expert associations concerned as well as by non-EU experts who produced written evidence.

3 - NUCLEAR FISSION IN THE ENERGY MIX - EMPHASIS ON NUCLEAR SAFETY CULTURE COMPETENCES

It should be reminded that, in the EU (28 Member States since July 2013), the generation of electricity through nuclear fission is a fact of life. In the EU, nuclear power stations currently produce more than a quarter of the electricity and more than a seventh of the primary energy consumed in the EU. At the end of 2012, a total of 131 units were operable in 14 Member States (MS), representing a total installed electricity capacity of 122 GWe net and a gross electricity generation of 848 TWh. Twelve MS have given signs that nuclear remains in their longer-term low carbon energy strategy. One Member State (Poland) considers including it in its energy mix and another (Lithuania) is ready to re-introduce it.

Mankind enjoys many benefits from nuclear-related technologies, most notably electricity production. For generations to come, electrical, medical and other applications of ionising radiations will continue to require highly educated experts with very specific knowledge, skills and competences. Nuclear fission activities require in fact an interdisciplinary approach covering not only Science, Technology, Engineering and Mathematics (STEM) but also policy making (research, education, regulatory, industrial, economic, foreign affairs, etc). Moreover a special effort is necessary to inform the public at large and to improve public engagement in actions related to nuclear decisions.
Following the “Energy Policy for Europe” it is up to each Member State, however, to decide whether or not to pursue the option of nuclear power. This statement is aligned with the Treaty of Lisbon which places energy at the heart of European activity: the EU energy mix, which may contain renewable, fossil and fissile sources, is treated, in particular, in Article 194.

A key concern of policy makers and industry, however, is the continuous strengthening of the nuclear safety culture, as it is demonstrated e.g. in the Euratom "Nuclear Safety Directive" (EU Council, Brussels, 23 June 2009): “Whereas .... (19) The establishment of a strong safety culture within a nuclear installation is one of the fundamental safety management principles necessary for achieving its safe operation”. It is worth noting that safety culture is an issue in most of the power generation technologies, as it is stressed in the Ethics report (excerpt in footnote).

Another concern of policy makers (in particular, of regulators) and industry world-wide is that human resources could be at risk, especially because of high retirement expectations in "old" countries (with nuclear installations) and a lack of nuclear experience in "new" countries (more than 45 Member States of the IAEA have approached the Agency with an expression of interest). Whether for power generation or for medical applications, highly qualified people are needed over a long time period to build new facilities and / or to safely operate installations, and, in particular, to manage radioactive waste and to deal with radiation protection issues.

4 - EURATOM EDUCATION AND TRAINING: FROM KNOWLEDGE TRANSFER TO COMPETENCE BUILDING

In the specific field of E&T in STEM (science, technology, engineering and mathematics), both DG RTD (Research and Innovation) and DG EAC (Education and Culture) play a key role, a.o. by providing financial and organisational instruments. Of particular interest is the focus of DG EAC on Continuous Professional Development (CPD) or Vocational Education and Training (VET). The aim is to continuously improve knowledge transfer and competence building, in particular by fostering lifelong learning and cross-border mobility, thereby improving the employability across the EU (Copenhagen 2002 process, follow-up of Bologna 1999 process).

Making lifelong learning and cross-border mobility a reality is an important objective of the Education, Youth and Culture policy of the EU – see Council Conclusions on a strategic framework for European cooperation in education and training (“ET 2020”), Brussels, 12

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12 Energy policy for Europe (DG ENER)-
13 Lisbon Treaty 2007 - Article 194 .... “Union policy on energy shall aim, in a spirit of solidarity ....: ..... Such measures shall not affect a Member State’s right to determine the conditions for exploiting its energy resources, its choice between different energy sources and the general structure of its energy supply “.
14 Excerpt of the “Ethics Opinion n°27”, dated 16/01/2013 (p 59) – Section 3.6.4 Safety: “Reducing the risks down to purely technical aspects would not fulfil the requirement for an integrated approach and comprehensive assessment. Consequences in terms of the environment and health should receive the same amount of attention as the cultural, social, economic, individual and institutional implications. A safety culture embraced by governments and operating organisations is necessary in the production, storage and distribution of energy in maintaining a low level of risk.”
May 2009 15. Lifelong learning requires in fact a common EU approach for assessing and validating the learners’ qualifications by ad-hoc authorities, taking into account a variety of E&T paths (CPD programmes). Cross-border mobility, in particular, implies mutual recognition of learners’ qualifications within the EU.

In this context, the **European Credit System for VET (Vocational Education and Training) (= ECVET)** 16 was launched ten years ago and successfully tested in a wide range of service and industrial sectors (notably aeronautics and automotive). There are similarities with the Bologna process for academic education and the associated **European Credit Transfer and accumulation System (ECTS)**. ECVET’s objective is to promote mutual trust, transparency and recognition of learning outcomes, regardless of the system or context in which they were acquired. This EU policy for E&T is also aimed at facilitating the freedom of establishment (including for regulated professions), thereby enabling the free circulation of individual citizens (and, in particular, service providers) amongst the EU Member States.

At this stage, the main efforts of the ECVET policy are focussing on three issues:

1. **a common qualification approach**: a European reference system is needed to improve transparency between different countries’ national qualifications systems and frameworks (European Qualifications Framework for Lifelong Learning /EQF/)
2. **"Personal Transcript of records"** (that might be associated to a "Europass"): portfolios of documents, to be used by individuals, to describe their learning achievements and acquired qualifications in a coherent manner recognized by all potential employers in the EU
3. **taxonomy**: a common language is needed between the world of education and the world of work (European Skills, Competences and Occupations Taxonomy /ESCO/) – work on a common taxonomy has started in the nuclear sector.

In this context, it should be recalled that Euratom E&T actions are addressing primarily research and industry workers with higher education, i.e. levels 6 to 8 of the **European Qualifications Framework /EQF/ (= bachelor, master and doctorate levels or equivalent, resp.).** The focus is on CPD, taking advantage of existing instruments and best practices for E&T.

As far as training is concerned, there are two types of initiatives in the Euratom FP7 projects:

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16 Sources for EU policy in lifelong learning (DG Education and Culture, EAC-executive agency and Cedefop):
- Cedefop - The Cedefop is the "Centre européen pour le développement de la formation professionnelle" or "European Centre for the Development of Vocational Training" - http://www.cedefop.europa.eu/EN/
• interdisciplinary training workshops embedded in research and innovation FP7 projects, aiming at transferring the main results to the scientific community

• Euratom Fission Training Schemes (dedicated FP7 projects), aiming at upgrading CPD programmes towards an improved safety culture across the EU (see ENEN below).

5 - "EURATOM FISSION TRAINING SCHEMES" AND “EUROPEAN NUCLEAR EDUCATION NETWORK” (ENEN)

The "Euratom Fission Training Schemes" (EFTS) were – and are still - launched in specific areas where a shortage of skilled professionals has been identified. They are FP7 "coordination actions", taking into account the scientific-technological and socio-economic “end user requirements” and using the education and training instruments developed by the EU (ECTS /Bologna 1999/ and ECVET /Copenhagen 2002/ processes). The proposed training schemes consist of portfolios of units of learning outcomes (made not only of knowledge, but also skills and competences /KSC/) that are needed to perform jobs or functions identified by the "end-users" as being critical.

The EFTS is thus a significant development across the EU, aimed at structuring training and career development along the above ECVET lines. Those training schemes are ambitious CPD programmes (usually 3 years, total budget of circa 1 million Euro each, modular course approach). Portfolios of units (or modules) of “learning outcomes” and their description in Personal Transcripts of Records are discussed with the stakeholders. First attempts are made to develop common EU approaches for assessment and validation of portfolios related to specific jobs or functions. Some Euratom Fission Training Schemes are planning to involve European authoritative expert associations with regulatory background (e.g. ENSREG or HERCA) to discuss mutual recognition across the EU. It is clear, however, that the above mentioned "Personal Transcript" will never constitute per se a license or an official authorisation (in the legal national regulatory sense).

As a result, the Euratom research and training programme contributes to the creation and transfer not only of knowledge but also of skills and competences, taking advantage of instruments developed by various EU policies.

It is no surprise that the IAEA training programmes are based on a concept very close to the above KSC. Following the IAEA definition, competence means the ability to apply knowledge, skills and attitudes so as to perform a job in an effective and efficient manner and to an established standard (S.S.S. No. RS-G-1.4 / 2001). Knowledge is usually created in higher education institutions and in (private and public) research organizations. Skills and attitudes are usually the result of specific training and on-the-job experience, enabling one to acquire the requested competences throughout professional life. Euratom and IAEA are working together in the design and execution of joint E&T programmes.

To ensure the highest achievable standards for nuclear education and training, a non-profit association was formed in September 2003 (under French 1901 law): it is the European Nuclear Education Network (ENEN). This legal entity, located at CEA-INSTN Paris, is composed of 64 members (universities, research organisations, industry) from 18 EU Member States + Switzerland, South Africa, Russian Federation, Ukraine and Japan. As far as

17 "Building competence in radiation protection and the safe use of radiation sources" (jointly sponsored by IAEA, ILO, PAHO, WHO), IAEA 2001 (p 4) - http://www-ns.iaea.org/standards/documents/pubdoc-list.asp

18 European Nuclear Education Network (ENEN) - http://www.enen-assoc.org
international collaboration is concerned, ENEN has signed a Memorandum of Understanding (MoU) with the Joint Research Centre (JRC) of the European Commission, with the European Nuclear Society (ENS), with the International Atomic Energy Agency (IAEA), with the Nuclear Energy Agency (OECD / NEA) and with the World Nuclear University (WNU). The synergy of ENEN with national E&T networks and with the European Technological Platforms and authoritative associations is also instrumental to the success of Euratom E&T actions.

The ENEN members play a key role in the design and implementation of the above "Euratom Fission Training Schemes". As of June 2013, there are 11 EFTS in total - more are planned in the future, following the standard competitive process of EU research programmes. Here is their list together with their respective "end-users" and contractual duration:

- **ENEN-RU - Cooperation with Russia in Nuclear Education, Training and Knowledge Management**: mirror project by ROSATOM and MEPhi (Nov. 2010–Oct.2012)
- **ENETRAP II - European Network on E&T in Radiological Protection**: addressing mainly the nuclear regulatory authorities and TSOs (March 2009 - December 2012)
- **ECNET - EU-CHINA Nuclear Education and Training Cooperation**: mirror project financed by the Chinese Atomic Energy Authority (March 2011 - February 2013)
- **ENEN III Training schemes - Generation III and IV engineering**: addressing mainly the nuclear systems suppliers and engineering companies (May 2009 – April 2013)
- **TRASNUSA - Nuclear Safety Culture**: addressing mainly the health physics sector (e.g., ALARA principle in industry and medical field) (Nov. 2010 - October 2014)
- **CORONA - Regional Center of Competence for VVER Technology and Nuclear Applications**: focus on VVER personnel training (December 2011 – November 2014)
- **CINCH-II - Cooperation in education and training In Nuclear Chemistry**: focus on the European master's degree in nuclear and radiochemistry (June 2013 – May 2016)
- **PETRUS III - Program for Education, Training, Research on Underground Storage**: addressing mainly the radwaste agencies (15 January 2009 - 14 January 2012)
- **GENTLE - Graduate and Executive Nuclear Training and Lifelong Education**: focus on synergy between industry – academia (January 2013 – December 2016)
- **NUSHARE – Project for sharing and growing nuclear safety culture competence**: focus on policy makers; regulatory authorities; industry (Jan. 2013 – Dec. 2016).

Online and blended learning are also tested in some EFTS. As far as cross-border mobility of experts is concerned, it is worth drawing the attention to a potential barrier: in some EU countries, a national licensing process is requested for specific jobs or functions ("regulated" safety-related jobs, usually at higher education level).

As success stories of the implementation of ECVET (in particular, the KSC approach), the following list of jobs or functions is worth mentioning:

- "Fluid System Construction and Commissioning Engineers" (ENEN III project)
- "Radiation Protection Experts" (ENETRAP II project)
- "Medical Physics Experts" (EUTEMPE RX project).
6 - Conclusion: Towards a New Way of “Making / Teaching Science” in Nuclear Fission

The facts about energy in today's world, in particular when it comes to "Sustainable, Competitive and Secure Energy", show that energy problems cannot be taken for granted, and demand a specific governance structure, integrating non-technical and technical aspects. This is particularly true for Euratom research in nuclear fission energy and radiation protection.

The political and legislative background of Euratom research and training is based principally on the Euratom Treaty (1957), the Lisbon Treaty (2007) and the Europe 2020 strategy (2010) which encompasses the European Strategic Energy Technology Plan (2007). The SET-Plan has two major timelines (2020 and 2050), which are important for the planning, in particular, of long-term R&T actions in the energy field. Another important input is of course the set of conclusions made after the "stress tests" in all NPPs following the 2011 disaster in Japan.

Two general objectives are particularly important in this context, and are guiding the Euratom R&T priorities in all areas selected for Horizon-2020:

- towards a common nuclear safety and security culture world-wide, based on the highest achievable standards related to technical, human as well as organisational aspects

- towards scientific and technological excellence in all parts of the EU, thereby fostering a new generation of European highly qualified experts in all nuclear fission applications.

The above objectives are aligned with the “Europe 2020 strategy for smart, sustainable and inclusive growth”. As a result, the Euratom research and training programme is planning to strengthen the following priorities under Horizon-2020:

1. Contribute to the creation and transfer not only of knowledge but also of skills and competences, taking advantage of instruments developed by three EU policies, namely: research and innovation, energy and education

2. Develop a governance for Euratom R&T based on improvements in participation, openness, accountability, effectiveness and coherence, leading to a new way of “making / teaching science”, closer to the end-user needs (society and industry).

An analysis is made of the question “who are the drivers and enablers for changes in Euratom Research and Training?” The “end-user requirements” are an important driver: they are of scientific-technological or socio-economic type. The enablers are the stakeholders providing human and financial resources (e.g. the European Technological platforms and authoritative expert associations) as well as the Euratom research and innovation programmes.

Euratom E&T programmes make use of the instruments proposed under the Education, Youth and Culture policy, in particular: the European Credit System for Vocational Education and Training (ECVET). Those instruments are used in a number of "Euratom Fission Training
Schemes" (EFTS), launched as "coordination actions" by higher education institutions (usually in collaboration with the ENEN association) and by "stakeholders" (industry, research organisations, governmental bodies, etc) in areas where human resources could be at risk. The EFTS projects are contributing to the definition of requirements for recognition of certain job profiles or functions. The proposed training schemes consist of portfolios of learning outcomes (made not only of knowledge, but also skills and competences /KSC/) that will be recognised by the employers across the EU, thereby improving the employability.

(2) Develop a European governance for R&T (closer to the end-users: society and industry)

The EC has established its own concept of governance in the *White Paper on European Governance* (2001), in which the term "European governance" refers to the rules, processes and behaviour that affect the way in which powers are exercised at European level, particularly as regards openness, participation, accountability, effectiveness and coherence. Ethics is very important in this context. Interesting recommendations regarding “educational projects” related to “the responsible use of energy” were made in an authoritative report, produced in January 2013 by the European Group on Ethics (EGE) and published together with the “2012 Interdisciplinary Study”.

The creation of the European Technological Platforms and authoritative expert associations gathering the main stakeholders is an application of the above principles of good governance. It is a mix of bottom-up and top-down approaches for the management of future Euratom R&T programmes. Through their discussions on common needs, vision and implementation instruments, the stakeholders developed a common approach in the main areas of Euratom research.

There are other applications of the above principles of good governance. For example, in regions where massive investments in experimental facilities are necessary in connection with research and innovation, all local stakeholders should be involved in the decision making process. The same is true in the debates around the deep geological disposal of radioactive waste or around exposures to low doses of ionising radiation. Integrating public, policy, and expert knowledge will receive increasing attention in the nuclear fission and radiation protection research community, as it is also one of the main recommendations of the “2012 Interdisciplinary Study”.

Wherever advisable, Euratom research and training programmes will aim at a fair balance between scientific-technological and socio-economic approaches, thereby coming closer to the needs of the end-users, i.e. society and industry. As a consequence, a new way of "making / teaching science" is under development (focussing, in particular, on how to select the "Best Available Science") in order to contribute more effectively to the development of robust, equitable and socially acceptable systems.

In the specific case of Euratom research, because of the very limited available EC funding and because of the current socio-economic climate, a very strong coordination is required regarding management and financing in order to ensure stability and clear commitments from the parties involved. In other words: a strong EU governance is needed in Euratom matters.
CURRENT CHALLENGES FOR EDUCATION OF NUCLEAR ENGINEERS: BEYOND NUCLEAR BASICS

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ABSTRACT

In past decades, curricula for the education of nuclear engineers (either as a major or minor subject) have been well established all over the world. However, from the point of view of a nuclear supplier, recent experiences in large and complex new build as well as modernization projects have shown that important competences required in these projects were not addressed during the education of young graduates. Consequently, in the past nuclear industry has been obliged to either accept long periods for job familiarization, or to develop and implement various dedicated internal training measures.

Although the topics normally addressed in nuclear engineering education (like neutron and reactor physics, nuclear materials or thermo hydraulics and the associated calculation methods) build up important competences, this paper shows that the current status of nuclear applications requires adaptations of educational curricula.

As a conclusion, when academic nuclear engineering curricula start taking into account current competence needs in nuclear industry, it will be for the benefit of the current and future generation of nuclear engineers. They will be better prepared for their future job positions and career perspectives, especially on an international level.

1. A need for change?

As an Original Equipment Manufacturer, AREVA provides comprehensive solutions for new build of nuclear power plants (NPP), as well as modernization, life time extension or power upgrade of operating NPPs and supply of safety important products for NPPs, such as digital safety related Instrumentation and Control (I&C) systems.

As such, in the past years the growing number of related projects increased the demand for soon to be recruited personnel. However, due to the stagnation of the nuclear market in the 1990s, in general and in almost all countries with a considerably share of nuclear in electrical energy production, nuclear education had been kept at a level that only allowed for replacement of people leaving the nuclear sector.

Consequently, nuclear industry (e.g. nuclear operators or nuclear system suppliers such as AREVA) had to design, develop and implement appropriate training curricula to prepare newly recruited staff (both young graduates and people with a professional career) for their future job positions. Here, the focus was laid on engineers to be engaged in NPP design, construction, commissioning, operation, maintenance, or management of related projects. These engineers often had no nuclear background or experience at all.
However, even in the most desirable case of a well grounded nuclear education, experiences in nuclear projects have shown that some important competences were missing. Often this resulted in reduced team or even project performance, and consequently a need to design, develop and implement appropriate training measures on the spot to avoid long periods of job familiarization. Analyzing these experiences, and considering the current status of nuclear education curricula, it may be concluded that these should be revised to adopt currently missing key competencies.

Various factors have contributed to this need for change, i.e. better adaptation to new demands on the nuclear market: not only the societal demand for enhanced levels of nuclear safety (reinforced by the recent Fukushima incident), but also the demand for highly competitive cost and schedule schemes for new build as well as modernization projects. The latter has been further fuelled not only by reduced investment and financing possibilities as a consequence of the recent global financial crisis, but also by the recent availability of other competitive energy resources (like shale gas). Considering also the limited numbers of capable and competent vendors and the limited demand of utilities, the nuclear market has now evolved into an international market, with a restricted number of international companies acting globally, i.e. with internationally distributed subsidiaries and project teams as well as an international supply chain. Hence the ability to act efficiently in an international environment with diverse national as well as business culture is highly desirable.

2. Nuclear Safety

A nuclear safety culture, as an enveloping set of competencies and attitudes, should be established and fostered already during university education. Nuclear engineering education curricula should address nuclear safety as a starting point for all further measures. This means focusing on safety culture, national and organizational culture, national and international regulatory frameworks and their applications in regard to fostering safety culture, and how the emphasis on safety of nuclear power improves the quality of safety not only in the energy sector, but in society as a whole.

In past decades, also as a response to industrial incidents, the importance of safety culture and how to develop and foster it has been the focus of several institutions or organizations, like the International Atomic Energy Agency (IAEA), the Institute of Nuclear Power Operations (INPO), or the World Association of Nuclear Operators (WANO). As numerous guidelines, standards and related recommendations for implementation as well as accompanying information or training resulted from these activities, there is now an abundance of material available to be further transferred into educational curricula.

Safety culture should be introduced into engineering curricula at least on a more generalized level, not necessarily specific to the nuclear field. In covering this in a wider sense, the course could also be used for engineering education outside nuclear. Here, the nuclear application could serve as an example for other technologies, the application of which bear an inherent risk for people and the environment (e.g. aviation, chemical, automotive, civil construction). The course should address those topics already listed above, and case studies or examples from diverse technical applications as well as their impact on further development of the technology or of related legal and regulatory framework and associated codes and standards. As such, the course could serve as an introduction to the field of codes and standards, which is a successive topic also to be addressed in engineering curricula (see chapter 3). Role games could supplement course objectives and support a deeper and thorough understanding as well as implementation of the principles of safety culture.
Course implementation could be further enhanced by site visits to design, construction, manufacturing or operation / maintenance facilities that are appropriate for achieving the learning objectives of the course. In particular, these site visits could demonstrate examples for the implementation of safety culture in practice. Facilities will certainly be found close to any educational institute. Of course this will include contacts to other non-nuclear applications, if they are dealt with in the wider sense as mentioned above.

3. Codes and Standards

One important aspect of safety culture is the strict adherence to codes and standards to be applied in the appropriate work (i.e. engineering) environment. This implies that educational curricula should address various guidelines and standards (e.g. from the IAEA\(^1\)), regulatory codes and standards (e.g. ASME code\(^2\), IEEE\(^3\), RCC-E\(^4\) and RCC-M\(^5\), YVL guides\(^6\)). Furthermore, how to apply the relevant codes and standards in regular nuclear engineering activities should be dealt with, clarifying also the roles and responsibilities of the different stakeholders.

As material is largely available on different aspects of these codes and standards, as well as different institutions already providing introductory or advanced training on these codes and standards, suitable education courses should be developed that at least provide an overview on existing codes and standards, and on their importance for licensing and respective design and operation of nuclear facilities (also including, as example, nuclear fusion facilities like ITER\(^7\), in particular when becoming nuclear). Briefly describing the history of codes and standards development from different national points of view, as well as the different areas of application, will lead to a thorough understanding of their importance. If possible, some examples for application in nuclear engineering should be included, too.

In summary, this will greatly enhance the students’ abilities to act not only in a national environment, but also to adapt to a global environment which will become more and more harmonized in a global and very competitive nuclear market. Furthermore, this will help employees in the future to boost their global as well as institutional mobility, e.g. between research institutions, operating organizations, industry and regulatory bodies.

4. Engineering Workflow

Closely related to the application of codes and standards is the engineering workflow in the different phases of a nuclear project. Starting with design, 2 aspects have to be considered.

At first, as different technical disciplines need to work together on the upcoming project respecting the engineering workflow, numerous interfaces need to be defined between the involved trades, requiring an awareness of involved engineers on how to pass on information across those interfaces. To illustrate this on an overview level: the design of the power plant pro-

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\(^1\) see http://www-ns.iaea.org/standards/

\(^2\) American Society of Mechanical Engineers, see http://www.asme.org/

\(^3\) Institute of Electrical and Electronics Engineers, see http://www.ieee.org/index.html


\(^6\) Regulatory Guides on nuclear safety, see http://www.stuk.fi/julkaisut_maanrykset/viranomaisojen/en_GB/yvl/

\(^7\) International Thermonuclear Experimental Reactor, see http://www.iter.org/
cess(es) will result in a structure of plant systems with different components to be designed, and with supporting electrical as well as instrumentation and automation systems, and moreover with further equipment like heating, ventilation and air conditioning (HVAC) systems, all to be placed in an appropriate building with optimal layout and civil design. As a result, the input resp. requirements and the results of each specific activity have to be well understood and correlated, often in an iterative way. Here, of utmost importance is the competence to fully understand the technical interdependencies.

Secondly, the format in which input resp. requirements and the results of each specific activity have to be developed, and in particular the information content will strongly influence the performance of the engineering workflow. Typically, the results will be published as system descriptions or functional requirements, normally in different levels of design (conceptual / basic / detailed /actual), using not only a coherent structure, but also dedicated formal descriptions or symbols. In this case the requirements of codes and standards will play an important role, as well as the intended use of the design results for further activities in NPP new build or modernization projects, like procurement, manufacturing, inspection, construction, erection, commissioning, operation or maintenance.

Providing students with a global overview about the technical interdependencies in the engineering workflow, and about format, content and structure of typical engineering documentation will greatly enhance their ability to understand one important aspect of current nuclear engineering activities. And they will be better prepared for starting their engineering work, e.g. specifying functional requirements and deriving specifications from these requirements as well as applying numerical methods and codes for this purpose. Thereby they will better find their place in the nuclear work force, and better understand their roles and responsibilities in the engineering workflow, and in related activities like project management, procurement, manufacturing, inspection, construction, erection, commissioning, operation or maintenance.

5. Engineering Tools

Closely connected to an introduction to the engineering workflow are the engineering tools that are applied for this purpose. Here, the focus is not on the application of calculation methods for process or system analysis as well as specification. In the past, the rapid development of information technology together with the application of numerical methods has provided scientists as well as engineers with powerful tools e.g. for structure loads / thermal hydraulics / reactor core, fuel calculations or other simulation analysis. To some extent the basics of these codes have already been introduced into nuclear engineering education. Consequently students can already familiarize themselves with these types of tools during their university curricula.

Instead, in this context information systems that support engineering activities are of high importance. Here, the focus is on the information stored and processed, and their support of engineering workflow as well as the roles and responsibilities of different persons involved in these. These information systems / engineering tools can be considered as comparable to those that are offered by companies like Oracle or SAP, and that support the workflow and related information in nearly all business related internal processes of enterprises.

Examples of these engineering tools include those that support document management, time scheduling, plant configuration management, and the resulting material management (including logistics and spare parts), considering also the interfaces to layout design as well as other business information tools (e.g. finance and accounting)
Students should be introduced to these tools, to better understand how only the application of these tools may currently facilitate an efficient and competitive engineering workflow. One good example, like the other tools also in service in other technical applications outside nuclear, is document management. Here, a simple software system, to be used in a dedicated course on the subject of engineering tools, could easily show which type of information can be managed with it, and how this will greatly enhance the efficiency of an engineering workflow.

As the listed engineering tools are well being used outside nuclear, a cross cutting special course on engineering tools will be for the benefit of other engineering disciplines outside nuclear, too, enabling a broad application in engineering education.

6. Cooperation between Academic Institutions and Industry

As can be easily understood from the above chapters, cooperation between academic institutions and industry would optimally support the extension and adaptation of nuclear engineering education as outlined above, thereby also enhancing the link to the nuclear professional environment in support of a better consideration of students’ future professional environment.

Examples could include handover of appropriate basic material for course development, visits of nuclear sites, common workshops, or the provision of lectures by industry experts. These lectures could provide examples, case studies and data from industrial applications that are often not available at academic institutions. One example is presented in [1]. Another example refers to simulation codes (see above): in this case, industry may provide opportunities for working with these simulation codes (e.g. by demonstrations, workshops, and internships).

7. Conclusions

The chapters above have shown a concise overview about the most stringent competence needs in the current nuclear field, valid not only for nuclear suppliers such as AREVA, but also for nuclear operators, safety authorities, technical support organizations, and further service providers or other companies active in the nuclear supply chain, in particular when active on an international level.

When academic nuclear engineering curricula start taking into account these competence needs of nuclear industry, it will be for the benefit of the current and future generation of nuclear engineers. They will be better prepared for their future job positions and career perspectives, above all on an international level, in particular as regards mobility and for a lifelong professional development.

As a matter of course this will also imply a reduction of time spent on the subjects that are covered by now by the current educational curricula. In this case, a close cooperation between academic institutions and industry will be very beneficial for selecting the right balance.

8. References

(Nuclear Engineering Science and Technology, Nuclear Education and Training), Madrid, Spain, November 2013.
TRAINING OF LEADERS FOR NUCLEAR NEW-BUILD

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ABSTRACT

Most corporate strategies fail – not primarily because of poor strategy definition but due to deficiencies in strategy implementation. Nuclear new-build is no exception in this respect. This paper presents training by business simulation as a tool for successful strategy implementation in general, and its application in the nuclear power sector in particular.

1. Introduction

Why do we not see effects of our strategy? This question is asked in board rooms all over the World in all various types of businesses. The question is real – most corporate strategies fail:

- 90% of well-formulated strategies fail due to poor execution. [1]
- Only 5% of employees understand their corporate strategy. [2]
- Only 3% of executives think their own company is successful at executing strategy. [3]
- 75% of business improvement initiatives fail due to lack of execution. [4]

It is notable that research points out that definition of strategy is not the most common culprit. Executive management is often well aware of the intricacies and challenges in their business. The problem is that strategy execution is rarely up to standards.

This is not only a waste of resources; it is in fact often counter-productive. If the executive management launches a new strategy but the implementation is inferior, several negative effects often occur:

- The executive management realizes after some time that little if any changes in the behaviour of the staff has occurred. It is common to blame the strategy for being ill-founded, and a new strategy is defined, not necessarily a more successful one.
- The workers notice no real change due to the new strategy. This nurtures a cynical attitude, especially if several consecutive strategy changes have been announced from the leadership, with little or no effect due to any of them. Sooner or later, the workers might land in an attitude that “well, let them play – in a few months another programme will be launched. We have seen this before”.

Strategy is important. Execution is everything.
JP Garnier, former CEO GlaxoSmithKline

1 New adress from 2014-01-01: INBEx, Jan.Blomgren@INBEx.se, +46 76 7878 336-
2. Successful strategy execution

The largest strategic project for a nuclear power company is new-build. Building a new single-unit nuclear power plant can cost more than 5 billion Euro. Reducing the time from starting paying interests on such a huge investment to the point in time when positive cash flow thanks to electricity sales sets in is a major success factor in such a project. Obviously, this is an area when successful strategy implementation is of paramount importance.

However, as has been described above, most strategies fail, and the main culprit seems to be failure in strategy implementation and execution. So what can be done to remedy this situation? Like in so many other human activities, proper training can make a difference. It has to be recognized that the first and foremost change needed is changed behaviour. If the staff does things in the same way as before, no strategy change will take place. However, changing human behaviour is a difficult matter. Words only do not suffice; few if any change their behaviour due to new instructions, neither written nor oral.

Training a new behaviour is significantly more successful as indicated in the figure below.

![Fig. 1. Knowledge retention for various methods.](image)

As can be seen, there is a dramatic effect when going from traditional lecturing to gradually deeper involvement of the recipients. The top four layers of the pyramid have in common that
the recipient is passive, essentially consuming the information presented. In the three lower layers, the recipient is active and practices the skills being the target of the strategy change.

The most efficient learning is by teaching others, a fact many teachers can testify. Next best is practice by doing. This is also a well-established fact in teaching research.

In nuclear power, there is international consensus that operations should be practiced in simulators. This is not unique to nuclear power; various technologies like aviation and off-shore oil drilling have since long used simulators, and medical surgery is gradually coming into the game.

So when is the use of simulators for training motivated?

- There is a need to practice how to handle challenging situations.
- The situations are complex.
- Practical learning is different from what can be learnt by theory studies.

When looking through these features, it is striking that all are relevant for executive decision-making as well. The decisions to be taken by a CEO and an executive management team are often complex, challenging and hard to find a compelling answer to by studying theory. Moreover, when a new business strategy has been defined, the implementation of it also fulfils all the criteria above. For the staff requested to change their behaviour to align with the new strategy, all the challenges above apply.

![Why simulations? Because you forget where you put your car keys, but not how to drive.](image)

So can business decision-making and strategy implementation be practiced by simulation? The simple answer is yes. Many of the Fortune 500 companies in the World use business simulations as a tool to train their employees in strategy execution. If restricting to the nuclear power sector, many of the largest utilities in Europe and North America use such methods, whereas the Asian utilities have so far been less prone to use simulations in their staff competence development.

3. Nuclear business simulation

The use of simulations for executive decision-making is still in a far earlier stage. Vattenfall, the largest nuclear power operator in Northern Europe, has developed the simulation Käftudden\(^2\) to train nuclear business acumen.

In such a simulation, participants with different skills and backgrounds are composing fictitious management teams of a fictitious nuclear power plant. Typically, such a team has five members with background in operations, maintenance, finance, human resources, communication or any other discipline represented in a typical real-life management team. They are presented with a

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\(^2\) Named after a nuclear power plant planned in 1965 but never built.
case describing the state of their plant, and they are challenged by the owners to improve the performance.

Their first task is to define a strategy, including a time table, for the performance improvement process. Should we try to modernize the plant by replacing old parts or even upgrade the power production? Maybe improved maintenance of existing parts is a better option? Should we try to improve all reactors at once, or one after the other?

**Nuclear Business Acumen is the insight, knowledge and ability to manage the unique interactions between the technology, economics, human and organizational factors and safety, in a changing nuclear generation environment.**

IAEA definition

Like in real life, the budget is limited. If going for expensive purchases of equipment, less funding can be spent on staff competence development, and vice versa. Also resembling real life, the team faces a mix of planned and unexpected events. Annual outages need to be planned, and fuel failures can appear any time. However, the consequences of the latter could be reduced if a “clean-system program” had been implemented earlier in the simulation.

These teams are graded on several different parameters, like plant safety, staff competence, regulator satisfaction and business results. They need to score above a pre-set minimum in all four parameters. Thus, concentrating on one of them does not pay off. It is indeed a training in balancing all important features simultaneously, i.e., a nuclear business acumen training.

This simulation was developed as a response to previous investigations that had indicated that the best improvement potential for the company was in communication between different specializations. The technical experts were top-notch on technical matters, but had limited understanding of the business implications, which was visible in prolonged outages and procurements that in hindsight was found unnecessarily expensive. Similarly, the finance department did not fully grasp the technical implications of their decisions. For instance, the easiest way to reach short-term success in a program on cost reduction is to reduce maintenance, but in a long-time perspective this can have grave consequences.

There had been a number of initiatives to train technical experts in economy and economists in technical matters, but with little or no visible effect on the business results. Performing simulations mean a few distinctive differences comparing to the approach of separate training:

- Experts of different backgrounds meet and share their expertise. This does not happen equally well when economists study technology and vice versa.
- A larger part of the complexity of the decision-making is taken into account.
- After training, all participants have personal networks of people with different expertise. It is natural to contact your previous teammates in the simulation for consultation in real-life situations afterwards.
- Much more of the learning stays.
- Last but not least, this type of training is *fun.*
4. Boosting the effect of training

The last point should not be underestimated. Participants testify in evaluations that the exciting nature of this type of training has meant a lot not only to their learning (which they deem superior to other types of training) but also to their motivation to work in a different and more professional way when back at work after completed training.

Finally, the effect of this training can be significantly improved further by a structured combination of actions. Many managers have sent their staff to training courses and found limited lasting effects afterwards. This is corroborated by science. In an experiment two groups were sent to a training course. For one of the groups, their managers were contacted beforehand and organized the work so that staff practiced the course content in their daily work immediately after the course. The other group had no real-work connection to the training until far later in time. The knowledge retention was almost twice as high in the group that practiced their course learning in real life. [5]

This serves as food for thought for managers. The benefit of a course can be doubled just by scheduling course-training and on-the-job-training close in time. These benefits can be further augmented by considering a four-pillar model for competence development. [6]

<table>
<thead>
<tr>
<th>The four pillars of competence:</th>
<th>Daily work = on-the-job-training</th>
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<tbody>
<tr>
<td></td>
<td>Change work (project, new job)</td>
</tr>
<tr>
<td></td>
<td>Mentorship (for both parties)</td>
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<td></td>
<td>Formal Course</td>
</tr>
</tbody>
</table>

Prime success factor: Combine them

These four pillars are different in character, and the learning is different for each of them. By going into a project or moving on to a new position, you learn other things than in ongoing daily work. Being a mentor or mentee provides better opportunities for reflection and personal growth than going to a course, etc. It has been shown in research and practical experience that combining two or more of these pillars results in a much faster and deeper competence development than spending all efforts or one alone, or treating them as separate activities without utilizing the potentials for synergy.

5. Conclusion

In conclusion, successful strategy execution requires a structured approach in which the new strategy is not only well communicated, but trained. Business simulations are very powerful tools for this purpose. By combining such training with other actions, like practising the new behaviour in daily work or project work, the effects can be much stronger for the same cost. Timing is very important here; actions coordinated in time have a much higher success rate than separated ones.
6. Acknowledgments

The author wish to thank Per-Erik Ellström, professor of adult learning at Linköping University, as well as Agneta Sundén, head of human resources at the Ringhals nuclear power plant, for valuable discussions on methodologies for maximizing the impact of training. The provision of references by Katrin Fagerberg and Jonas Stalder, BTS, on strategy execution success (or rather the lack thereof) is gratefully acknowledged.

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[5] Per-Erik Ellström, professor in adult learning Linköping University, private communication.
The securitisation of nuclear energy post–September 11 and its impact on ASEAN’s nuclear aspirations

Eulalia Han

Abstract
This article examines the securitisation of nuclear energy post–September 11 and how the current nuclear terrorism discourse will influence Southeast Asia’s nuclear aspirations, and its relations with the dominant nuclear powers and international conventions on nuclear energy. The main aims of this study are to highlight the deficiencies of a United States-dominated nuclear security discourse that is focused on nuclear terrorism, and suggest that nuclear energy be desecuritised in light of such deficiencies. This could provide for a more comprehensive engagement with the issue of nuclear energy, refocusing the agenda back to nuclear security as a whole, and opening up discussions to include the concerns of other regions, such as Southeast Asia, who look to acquire nuclear technology. The study first explains the concept of securitisation through the lens of the Copenhagen School, as well as how, through speech acts, nuclear energy has been securitised alongside terrorism discourse. It then highlights the contrasting narratives between the US and Southeast Asia on the issue. The study finds that the securitisation of nuclear energy through a focus on terrorism has sidelined concerns of current and potential nuclear-power states, and could possibly discourage the latter from ratifying international conventions.

Keywords: desecuritisation, securitisation, nuclear energy, nuclear security, Copenhagen School, September 11

Introduction
The terror attacks on 11 September 2001 gave politicians and scholars reasons to reassess the security discourse that dominated the post–Cold War era. For 11 years since, governments have continued to focus defence policies on pre-emption, funding is prioritised in the areas of military and homeland security, the security debate has included terrorism as a new focal point, and the line between Islam as a religion of peace and as a religion of terror acts is now blurred. September 11 also sparked new concerns over the security of nuclear power plants and radioactive materials. The potential for nuclear and radiological terrorism has gained prominence in the minds of governments and the people, particularly when assessing current and potential nuclear power plants (Buzan 2006). After all, Osama bin Laden had considered the acquisition of nuclear power a ‘duty’ for al
Qaeda, and it is difficult to crack down on the existing nuclear black-market trade (Booth 2005; Ogilvie-White 2006; Rogers 2008).

While the Cold War was a conflict of competing ideologies among global powers and their allies, the post–September 11 ‘War on Terror’ is both military and psychological warfare between state and non-state actors. The latter ‘war’ has also significantly influenced the way issues of national security are discussed, and this extends to both traditional and non-traditional security threats. This study looks at the securitisation of nuclear energy post–September 11 and how global terrorism discourse has largely shaped current nuclear security discourse. Furthermore, it examines how the ‘Islamisation’ of acts of terror has shaped current understandings of security, including energy security.

The purposes of dividing the debate into the US and Southeast Asian perspectives is not to make these divisions more pronounced, but to demonstrate that a nuclear security debate dominated by Western conceptions of terrorism is detrimental to the goals the debate seeks to achieve in the first place. First, focusing on nuclear terrorism as a significant aspect of nuclear security tends to sideline the issue that in many parts of the world, separatist movements and rural energy poverty are more prominent issues. Second, the focus on nuclear terrorism has overshadowed the reality that major nuclear accidents have been the result of natural disasters, and human and/or technology error, rather than a ploy instigated by terrorists. The emphasis on the terrorist threat skews the allocation of national resources, presents an obstacle to comprehensive engagement with the nuclear security and safety debate, and creates a heightened atmosphere of suspicion among countries, leading to over-reactive policies and citizens.

**September 11 and the securitisation of nuclear energy**

The events of 11 September 2001 sent shockwaves around the globe. Not only did they result in the loss of innocent civilian lives, but they brought about a new dimension to understanding conflict and security: conflict can no longer be analysed through the practice of statecraft, as non-state actors can undermine the legitimacy of the state through acts of terror. It has been purported that the act of terrorism on September 11 was in itself retaliation to US supremacy, and was an act to question the US’s position as a dominant super power. Following this, ‘the 9/11 attacks have resulted in an extraordinary concentration on a particular form of transnational political violence, focusing mainly on the [al Qaeda] movement and associated Islamic jihadist groups’ (Rogers 2008, p. 172). The current War on Terror has now ‘been transformed into the “long war against Islamofascism”’ (Rogers 2008, p. 172) and could even suggest that religious affiliation is now more useful when understanding prejudice than is race or ethnicity (Sheridan 2006). For example, Muslims travelling to the US from the Middle East are automatically assigned the yellow identity under the three different risk classes (green and red meaning non-dangerous and very dangerous respectively, with yellow in-between) of the Computer Assisted Passenger Prescreening System for visitors travelling to and from the US (Lyon 2003; van Munster 2005).
On 10 June 2002, the arrest of alleged al Qaeda terrorist Jose Padilla at an airport in Chicago, US, allowed the concept of a radiological bomb (‘dirty’ bomb) to enter the consciousness of Americans and the world (Kuchibhotla & McKinzie 2004). Since then, the threat of nuclear terrorism has become a global security concern. Inherent in preventing infiltration by and propagation of international and domestic terrorist cells, there is now fear for the safety and security of nuclear power plants and materials should they fall into the possession of non-state actors. This fear has even led the US and its allies to demand transparency in relation to nuclear programs, especially in Iraq, Iran and North Korea. The securitisation of nuclear energy has, therefore, taken root since the terrorist attacks of September 11.

The fear of actors (state and non-state) gaining control of nuclear technology for offensive purposes is not new. What is new, though, is the extent to which nuclear terrorism now forms a large proportion of the nuclear security debate. This shifts the debate’s focus excessively away from that of ensuring optimal performance of nuclear technology that is resistant to human error and natural disasters. To date, most minor and major nuclear accidents are a result of human error or nuclear plants being vulnerable to natural disasters. While the nuclear black-market trade exists, the only time a nuclear bomb was used for offensive purposes was when the US dropped an atomic bomb on the cities of Hiroshima and Nagasaki in Japan at the end of World War II in 1945.

In addition, it is problematic to excessively focus on nuclear terrorism as part of the nuclear safety debate. As a result of the US-led War on Terror, the Islamisation of security and terrorism will inevitably influence the way (dominant) states think about nuclear terrorism. That is, it is dangerous for states with different political ideologies (North Korea with its Communist philosophy) or religious affiliations (Iraq and Iran both with Muslim majorities) to possess nuclear power. More specific to this study, the securitisation of nuclear energy through these lenses will affect Southeast Asia’s nuclear aspirations (where religion plays a significant role in the political and social developments in Indonesia, Malaysia, Brunei and the Philippines) and future relations with the international nuclear community. Before looking at these issues, it is necessary to highlight how this study interprets the concept of securitisation.

**Securitisation as articulated by the Copenhagen School**

Realism has been the dominant approach in security studies and studies of international relations. The approach focuses on the behaviour of actors (mainly states, companies and individuals) by assuming that international relations is a zero-sum game, as these actors are value-maximising, self-interested and rational (Burchill 2005; Smith 2005). Stephen Walt (1991, pp. 212–13) contends that Security Studies should be about the study of military conflict, and widening that agenda

... runs the risk of expanding ‘Security Studies’ excessively; by this logic, issues such as pollution, disease, child abuse, or economic recessions could all be viewed
as threats to ‘security’. Defining the field in this way would destroy its intellectual coherence and make it more difficult to devise solutions to any of these important problems.

The Copenhagen School, on the other hand, avoids studying security from a military perspective but seeks coherence by ‘exploring the logic of security itself, to find out what differentiates security, and the process of securitisation, from that which is merely political’ (Buzan 1997, p. 13). There is a subtle difference between the politicisation and securitisation of an issue: politicisation of an issue refers to placing an issue in the public domain, while securitisation usually involves presenting an issue as urgent and as one that should be dealt with decisively by credible leaders, especially at an international level (Buzan 1997; Buzan, Waever & de Wilde 1998). In exploring ‘security’ as a concept, the Copenhagen School includes the political, military, economic, ecological and economic security sectors in security studies and focuses discussions surrounding the topic of security on the sub-state, state and international system levels (Buzan 1983; Smith 2005).

This study is based on the concept of securitization as articulated by the Copenhagen School, as the main purpose is to study how terrorism discourse post–September 11 has shaped perceptions of security and, more specifically, nuclear security.

So what is meant by ‘security’ and ‘securitisation’? According to Buzan, Waever and de Wilde (1998, p. 24), security is ‘a self-referential practice’ and it is through this practice that an issue gets securitised, ‘not necessarily because a real existential threat exists but because the issue is presented as such a threat’. Securitisation then, is the ‘intersubjective establishment of an existential threat with a saliency sufficient to have substantial political effects’ (Buzan 1997, p. 14; Buzan, Waever & de Wilde 1998, p. 25). More importantly, the threat has to be successfully constructed as a threat and accepted by either a specific or wide, relevant audience (Buzan, Waever & de Wilde 1998; Waever 1995).

In language theory, the process of securitisation is called a speech act (Buzan 1997; Buzan, Waever & de Wilde 1998). A speech act ‘is not interesting as a sign referring to something more real, it is the utterance itself that is the act: by saying it something is done (like betting, giving a promise, naming a ship)’ (Buzan 1997, p. 14; Buzan, Waever & de Wilde 1998, p. 26). In this instance, it is important to consider the actors that are able to ‘speak’ security effectively and successfully, and the conditions that are required in order for an issue to become securitised. Therefore, what is essential in a security speech act is that it is ‘interesting exactly because it holds the insurrecting potential to break the ordinary, to establish meaning that is not already in the context’ (Waever 2000, p. 286).

**Terrorism discourse through speech acts post-9/11**

The ideology espoused by al Qaeda and other terrorist organisations is seen to be a threat to modern civilisation. September 11 had put an end to the post–Cold War era, solving the ‘threat deficit problem’ for the US, and ‘triggered a substantial shift in security definitions and priorities in many countries’ (Buzan 2006, p. 1103).
Almost immediately, Muslims and Arabs, or those who appear to be either, have been subjected to crude forms of racial profiling (Akram 2002; Akram & Johnson, 2002). Islam and Muslims have received considerable attention in the media since the Iranian Revolution of 1979 and the Gulf War of 1991. The terrorist attacks of September 11, however, were almost like the final reinforcement of the negative image of Muslims. This time, the revival of this fear is no longer perceived as a stereotype or a conflict taking place away from home, but the ‘Muslim threat’ is now ‘real’ and happening on home soil.

The ‘you’re either with us or against us’ rhetoric espoused by former US President George W. Bush set the precedence for how the international community should approach the War on Terror. Given that acts of terror are often viewed in relation to Islam, the securitisation of terrorism has taken a religious slant and has been ingrained in the consciousness of governments’ and people’s approaches to acts of terror and Muslims. In India, for example, thousands of Indians fled from the northeast to the southern cities as rumours had spread through text messages that they were the target of Muslims, after violent clashes in Assam between the indigenous Bodo tribe and Muslim settlers (Loh 2012; Mahr 2012).

The successful securitisation of any issue involves three components: ‘existential threats, emergency actions, and effects on interunit relations by breaking free of rules’ (Buzan, Waever & de Wilde 1998, p. 26). Since the beginning of the War on Terror, the most effective way of securing its urgency is to link local problems with the wider terrorism framing. This is effective in establishing the ‘existential threat’ in society. It has been noted that in the US, Israel, Russia, China and India, international terrorism has been viewed as a common threat, and local problems have been closely linked to the problem of terrorism so as to justify other policy initiatives (Buzan 2006). The problem of terrorism, then, is often linked with problems of drug trafficking, international crime, rogue states and the proliferation of weapons of mass destruction, forcing countries to allocate a greater portion of the nation’s budget to homeland security, with the threat of terrorism as the main focus.

The media also play a significant role in shaping terrorism discourse. In a study conducted on television’s coverage of September 11, Kellner (2002, p. 143) notes that

the mainstream media privileged the ‘clash of civilizations’ model, established a binary dualism between Islamic terrorism and civilization, and largely circulated war fever and retaliatory feelings and discourses that called for and supported a form of military intervention.

Ryan (2004) also conducted an analysis of editorials in the 10 most read newspapers in the US specifically on the War on Terror and found that Americans and their allies were described as ‘tolerant’, ‘patriotic’, ‘heroic’ and ‘generous’, while terms like ‘extremist’, ‘cowardly’, ‘jealous’ and ‘vicious’ were used to describe everyone else (pp. 376–7). It is also useful to point out that in his study, Ryan notes the distinction between describing Arabs as either ‘good’ or ‘bad’.
While terrorism, both actual and perceived, poses a security threat to the sovereignty of a state, the terrorism discourse in other parts of the world is constructed differently. In Southeast Asia, for example, while states have stepped up their homeland and military defence against a potential terrorist attack, governments have steered clear of suggesting or including religious motivations as part of the terrorism discourse. This means that the region propagates the view that acts of terror are not the result of specific religious teachings but are the result of resentment against the dominance of another culture over one’s own. This could be a direct reflection of the region’s geopolitical realities with three Muslim-majority nations (Indonesia, Malaysia and Brunei), Indonesia being the largest Muslim-majority country in the world, situated in the region. While the region remains sensitive to irrational inferences, this is not to say that their governments do not recognise that some acts of terror have been motivated by religious affiliations, but terrorism should not be seen as representative of Islam, as it is only adhered to by a minority of Muslims.

Certain Southeast Asian leaders are also more critical of the Western discourse of terrorism and have the impression that the US is waging a war on Islam and Muslims specifically (Simon 2002, p. 29; Nesadurai 2004). This started when the US applied immigration and visa restrictions on Muslim countries, Malaysia being one of them, and the war on Iraq further reinforced these ideas (Nesadurai 2004).

Some Southeast Asian countries also suggest the need to question the motivations of religious terrorism. At the XIII Conference of Heads of State or Government of the Non-Aligned Movement held in Kuala Lumpur in 2003, former Malaysian Prime Minister Dr Mahathir Mohamad traced the routes of terrorism to the injustice and oppression of Palestinians as a result of Israel’s aggression:

> The world now lives in fear. We are afraid of everything. We are afraid of flying, afraid of certain countries, afraid of bearded Asian men, afraid of the shoes airline passengers wear ... These blatant double standards [of the West], is [sic.] what infuriates Muslims, infuriates them to the extent of launching their own terror attacks. If Iraq is linked to the al Qaeda, is it not more logical to link the persecution and the oppression of the Palestinians to September 11?

(Mahathir 2003)

Sharing the same sentiments in an earlier speech at the Extraordinary Session of the Islamic Conference of Foreign Ministers on Terrorism in 2002, Mahathir defined terrorism as “acts of violence consciously committed against civilians by any actor, including states, which thus required firm US condemnation of both Palestinian suicide bombers targeting Israeli civilians and Israeli security forces targeting Palestinian civilians” (quoted in Nesadurai 2004, p. 17).

Post–September 11 public debate in both Malaysia and Indonesia also questioned if the US was at least partially responsible for ‘inciting’ the attacks as it has embarked on a unilateral and hegemonic foreign policy, and has shown indifference to causes in which Muslims are victims of oppression (Means 2009, p.
Indonesia’s response to the terrorism debate, however, has been remarkably different from that of Malaysia. During the time of the September 11 attacks, Megawati Sukarnoputri became Indonesia’s President only six weeks before the attacks and almost immediately offered her commitment to the US War on Terror. Vice President Hamzah Haz, however, said that September 11 might have been the push for the US to reflect upon their current policies and to make up for their past (Sebastian 2003; Means 2009).

In Singapore’s national document *The Fight Against Terror: Singapore’s National Security Strategy*, then Deputy Prime Minister and current Singapore Prime Minister Lee Hsien Loong cautioned that terrorism “will be a long war for Singapore and the region, and the end is not yet in sight” (quoted in National Security Coordination Centre 2004, p. 14). In this light, it has been noted that Singapore will continue to be vulnerable because of the very strong stand we have taken against terrorism, the arrests we have made to crack down on JI [Jemaah Islamiyah] in Singapore, the assistance we have extended to regional efforts against terrorist groups, and the support we have given to the American reconstruction actions in Afghanistan and Iraq.


Also important in Singapore’s National Security Strategy is the emphasis that a multiracial and ethnic Singapore should be

... careful not to link acts that are perpetrated by terrorists, whether globally or in Singapore, to the local Muslim community and cause them to be defensive for no reason other than sharing a common faith.

(National Security Coordination Centre 2004, p. 65)

At the Inter-Racial Confidence Circles forum in 2003, what Prime Minister Lee was concerned about was that an extremist minority could heighten “distrust and fear among the different communities” (quoted in National Security Coordination Centre 2004, p. 66).

There is stark contrast between the Western and Southeast Asia’s approach to the terrorist problem. The governments of Indonesia, Malaysia and Vietnam have been openly critical of the Western discourse, voicing their concerns that ‘the West-centric counter-terrorism agenda is forcing institutional change’ within regional institutions such as the Asia-Pacific Economic Cooperation (APEC), and that ‘they do not wish to be associated with the US “War on Terror”, which is widely regarded among their populations as anti-Muslim, unilateral, pre-emptive, and disproportionately military’ (Ogilvie-White 2006, p. 12). This difference is reflected in Southeast Asia’s approach to nuclear security, and, more importantly, this difference is what hinders their full engagement and adherence to existing international agreements on nuclear energy.
‘Terrorising’ nuclear energy through speech acts

The rhetoric of the threat of nuclear terrorism and of the proliferation of weapons of mass destruction gained prominence in the US and some of its ally states after September 11: now, not only is the possession of nuclear technology a problem associated with ‘rogues states’, it is a problem associated with terrorist organisations. Then Senator and now President of the US Barack Obama commented in 2008 that nuclear terrorism is “the gravest danger we face” (quoted in Mooney 2008). Prior to his presidency, former US President George W. Bush noted in September 2002, a few months before the invasion of Iraq, that the

... greatest danger our Nation faces lies at the crossroads of radicalism and technology. Our enemies have openly declared that they are seeking weapons of mass destruction, and evidence indicates that they are doing so with determination. The United States will not allow these efforts to succeed ... History will judge harshly those who saw this coming danger but failed to act. In the new world we have entered, the only path to peace and security is the path of action.

(Bush quoted in US Government 2002, p. v)

These same sentiments are shared by the former European Union’s High Representative for the Common Foreign and Security Policy, Javier Solana, who contended that

[p]roliferation of weapons of mass destruction is potentially the greatest threat to our security ... The most frightening scenario is one in which terrorist groups acquire weapons of mass destruction. In this event, a small group would be able to inflict damage on a scale previously possible only for States and armies.

(Solana 2003, pp. 7–8)

These speech acts on the securitisation of nuclear energy have been translated into domestic and international legislations. Post–September 11, the US Nuclear Regulatory Commission ‘embarked on an effort to overhaul and strengthen the security of the nation’s nuclear plants’ (US Nuclear Regulatory Commission 2011). International institutions such as the United Nations (UN) and the International Atomic Energy Agency (IAEA) commissioned and adopted new safety standards and updated existing ones, focusing mainly on the threat of nuclear terrorism as part of the nuclear security discourse. It is important to note that out of the six multilateral instruments that underpin current international nuclear security standards, four of them were adopted after September 11 to specifically take account of international concerns over the terror attacks. These six multilateral instruments are the Convention on the Physical Protection of Nuclear Material¹ (adopted in 1979, entered into force in 1987), The Physical Protection of Nuclear Material and Nuclear Facilities² (INFCIRC/225, adopted in 1999), United Nations Security Council Resolution 1373³ (adopted 29 September 2001), the

The securitisation of nuclear energy in Southeast Asia has taken on a somewhat different nature to that in the US. The governments of Southeast Asia are concerned about the threat that nuclear terrorism might pose given the existence of terrorist networks and separatist movements in the region, but the difference is that while the US largely views nuclear security through the lens of containing nuclear terrorism, Southeast Asian countries, on the whole, understand ‘the importance of nuclear security as an international norm, rather than a specific reaction to a specific threat’ (International Centre for Security Analysis 2012, p. 33).

In 2010, Singapore’s Prime Minister Lee commented that nuclear terrorism is ‘no longer an improbable threat, but a disaster which can realistically happen if stronger preventive efforts are not adopted’ (Chua 2010), but he stressed that this issue was ‘important although not urgent’ (Prime Minister’s Office Singapore 2010). Malaysian Prime Minister Najib Razak asserted that ‘the threat of nuclear terrorism is real’ (quoted in Ministry of Foreign Affairs 2010) and that Vietnam...

…did consider that the terrorist attacks of 9/11 had provided a sense of universalisation of the threat from terrorism and had thereby provided an incentive to all countries to take measure to improve nuclear security.

(International Centre for Security Analysis 2012, p. 29)

But interviews conducted with Southeast Asia’s officials by the International Centre for Security Analysis (2012) suggest that nuclear terrorism does not factor high on the priority list of nuclear security in Southeast Asia, much less allowing the concept of nuclear security and terrorism to be perceived almost interchangeably (as in the US security discourse).

Southeast Asia views nuclear security not through the perspective of terrorism, but sees adhering to nuclear security as part of fulfilling its international obligations, and a natural consideration behind any important decision. Some Southeast Asian countries do not think it is necessary to sign on to international nuclear conventions when the region is still free of nuclear power plants. More importantly, there are concerns raised over the unequal application of international agreements between states, and between Nuclear Weapon and Non-nuclear Weapon States. Very often, the ‘what about Israel?’ question is raised, especially when Israel is ‘allowed’ to remain a non-signatory to the Non-Proliferation Treaty and maintain an ambiguous and undisclosed nuclear program, while Iran faces...
sanctions and calls for transparency regarding its intentions. Along the same lines, it is important to ask if Iran’s civilian use of nuclear energy has been given enough coverage or if Iran will continue to be a threat even without its nuclear program.

Giving proper considerations to these issues is significant to informing the nuclear security debate: not only does it shed some light on why Southeast Asia is not fully embracing the current discussions and international conventions on nuclear security, but it could bring the focus of nuclear security back to the issue of security itself, and not construct it as the result of a specific threat, especially Islamic-motivated terrorism.

**Desecuritising Nuclear Energy**

The terrorism discourse in the US and some of its ally countries has insinuated the link between Islam and terrorism. There is, however, a fine line between religious-motivated violence and religion itself as the cause of violence. The motivations for terrorism are deep-seated, and focusing on Islam as the main cause of terrorism marginalises the discourse to one that understands the roots of terrorism very simplistically. Even more problematic is the exacerbation of the hostilities between Muslim-majority countries and the West, already a problem caused by the latter’s one-sided treatment of the Israel–Palestine conflict. As terrorism has often been viewed as an ‘Islamic threat’, the nuclear terrorism discourse in the US has also taken on that character.

When examining political treatment of the nuclear programs among those forming the ‘axis of evil’, namely Iraq, Iran and North Korea, the demonising of Islam is made more pronounced. For example, the US led a war on Iraq in 2003 on the grounds of suspected possession of weapons of mass destruction, and imposed international sanctions on Iran and North Korea, but only provided the North Korean government with the ‘carrot’ in terms of aid—North Korea being dominated by religions other than Islam. Though, Iraq and Iran might have given the US reasons to believe that their nuclear programs were for offensive purposes. The former government of Iraq and the current Ahmadinejad government have been ambiguous about their nuclear capabilities and have made offensive statements targeting Western dominance and allies, especially Israel's policies. These statements often suggest a possibility of a military or terror attack on the US and its allies. However, for the US to target Iran’s and North Korea’s nuclear capabilities while allowing Israel to maintain an ambiguous nuclear program questions Washington’s credibility, purposes and commitment to nuclear non-proliferation and terrorism.

One of the main problems of the current established international discourses on nuclear security is that it remains largely dominated by the US and some of its allies, focusing on nuclear terrorism as a significant portion of nuclear security. By not including other perspectives, such as those of Southeast Asia, the current nuclear security discourse may reduce the likelihood of states fully engaging in an international nuclear security strategy. States that might have already taken significant steps in ensuring the security of their current and potential nuclear technology might not necessarily sign up to established conventions, as they may be
skeptical of the purpose and legitimacy of these conventions. International conventions have to be equally applied and made more inclusive so that while acknowledging that nuclear security is about safeguarding access to the technology and radioactive materials from terrorists, they also acknowledge that it is about ensuring energy security for urban and rural communities, the security of nuclear power in regions that are prone to natural disasters and bureaucratic corruption, and the prevention of the illegal trafficking of nuclear materials by separatist movements and unauthorised personnel (Fitzpatrick 2009). These issues are more prominent in regions like Southeast Asia.

Southeast Asia is a diverse region that is made up of both developed and developing economies, different political systems and colonial history, and is home to various religious and ethnic groups. The region has experienced immense economic growth and all-round development, but it struggles to deal with problems such as piracy, illicit trafficking networks, terrorism, erratic environmental conditions, and rural poverty. These geographical, and historical and present realities, are reflected in the region’s approach towards nuclear energy and security.

At present, Vietnam has concrete nuclear ambitions to build ten nuclear reactors by 2030, with the first going online by 2020 (Fitzpatrick 2009; International Centre for Security Analysis 2012; James Martin Center for Nonproliferation Studies, Center for Energy and Security Studies and Vienna Center for Disarmament and Non-Proliferation 2012). Indonesia, Malaysia, Thailand, the Philippines, Laos and Myanmar have also expressed their interest, while Singapore has also conducted a pre-feasibility study (Woo 2012; James Martin Center for Nonproliferation Studies, Center for Energy and Security Studies and Vienna Center for Disarmament and Non-Proliferation 2012). Only Cambodia and Brunei have yet to express any nuclear energy plans. There are various considerations that factor into Southeast Asia’s decision to develop nuclear energy, including recognising the importance of diversifying the region’s energy mix; the availability of expertise; public acceptance; the ability to meet rising electricity demands; global prestige that comes with having nuclear energy; and ensuring energy security and autonomy (Fitzpatrick 2009; James Martin Center for Nonproliferation Studies, Center for Energy and Security Studies and Vienna Center for Disarmament and Non-Proliferation 2012).

Southeast Asia’s approach to nuclear security is also a reflection of its historical and present-day realities, and is in keeping with its domestic, regional and international commitments. Regional cooperation on nuclear security is already in place in Southeast Asia. Ten Southeast Asian countries are Member States of the Association of Southeast Asian Nations (ASEAN) and are signatories to the Southeast Asia Nuclear-Weapon-Free Zone Treaty. They also participate in regional security forums and initiatives such as the Forum for Nuclear Cooperation in Asia, the Asian Nuclear Safety Network and the Asia-Pacific Safeguards Network.

A study conducted on the nuclear ambitions of Indonesia, Malaysia, Singapore and Vietnam by the International Centre for Security Analysis (2012) suggests that
nuclear security is ‘taken seriously and was considered decades ago, but not necessarily because of the terrorist threat’ (International Centre for Security Analysis 2012, p. 19). The study notes that Indonesia sees nuclear security as adhering to international standards while improving domestic capabilities, and Malaysia sees compliance with international norms as part of its international obligations and necessary to access nuclear technology. In addition, Singapore does not hold strong views on nuclear security as yet due to the fact that the region is still nuclear-free, the lack of any perceived nuclear-related threat and ‘the strongly held dissociation of terrorism from nuclear matters’ (International Centre for Security Analysis 2012, p. 24). As the country that is most likely to be the first to acquire nuclear energy, Vietnam sees it necessary to meet international requirements for its nuclear plans to be successful, as observing them will also allow the development of a safe civilian nuclear energy program. The study also found that

[concern was expressed that if the US remains the only state behind an international initiative such as nuclear security—it is unlikely to succeed. Furthermore, the nuclear security agenda will look like the NPT [Non-Proliferation Treaty] if imposed by ‘arrogant Western states’.

(International Centre for Security Analysis 2012, p. 26).

Southeast Asia continues to express its interest in acquiring nuclear energy, despite the Fukushima nuclear accident that devastated Japan in March 2011. As a region that is currently nuclear-free, and bearing in mind the other problems that the region face such as natural disasters, and the existence of terrorist cells and illicit trafficking networks, ‘Southeast Asia remains a salient region in any global effort to manage nuclear security risks’ (James Martin Center for Nonproliferation Studies, Center for Energy and Security Studies and Vienna Center for Disarmament and Non-Proliferation 2012, p. 3). To fully engage the region in future regional or international nuclear cooperation initiatives, however, the overall nuclear security agenda should reflect wider concerns. As discussed, the US is seen to be the dominant voice in articulating the current international nuclear security agenda. Since the conception of the ‘axis of evil’, the US has focused on nuclear terrorism in nuclear security debates, from the invasion of Iraq in 2003 through to its policies on North Korea and the recent toughening of sanctions against Iran. The Fukushima nuclear accident should have allowed governments to refocus their attention to the safety of nuclear power plants, as it exposed the vulnerability of this technology to human error and natural disasters. Instead, the later part of 2011 saw the reinvigoration of the US’ stance against Iran’s nuclear program, bringing nuclear terrorism back to the forefront of nuclear security discussions. The problem is not demanding the transparency of Iran’s nuclear program, but the disproportionate emphasis on such issues in the international nuclear security agenda.

The desecuritisation of nuclear energy, where nuclear terrorism is no longer dominant in the discourse, is needed to bring the focus back to a comprehensive
nuclear security agenda. Fukushima and Southeast Asia’s approach to nuclear security shed light on the range of concerns of existing and potential nuclear-power countries. These concerns need to be equally addressed so as to encourage the participation of countries in international norms and cooperation surrounding nuclear energy, and to counter the perception that the US determines the international nuclear security agenda. Bearing in mind that nuclear disasters, to date, have been caused predominantly by natural disasters or human error and/or faults in technology, the desecuritisation of nuclear energy to include other security issues will also lead to well-considered solutions to nuclear-related disasters and assist aspiring nuclear-power states to focus on gathering the right intelligence and technology.

**Conclusion**

September 11 has affected the way the world approaches issues to do with safety and security. The fears of terrorism have influenced nuclear security discourse, particularly in the US, and the prevention of nuclear terrorism is high on the agenda. To fully engage the international community in the nuclear security discourse, however, international institutions should employ a more comprehensive and inclusive approach to take account of a wide range of concerns of current and potential nuclear-power states. These concerns should be reflected to provide balance in the way nuclear security is discussed. When the nuclear security debate takes on a new dimension and direction, the terrorism discourse that has dominated the Western world and international diplomacy for the past 11 years could follow suit.

**Notes**

1. In July 2005, the Convention was amended and it is now ‘legally binding for States Parties to protect nuclear facilities and material in peaceful domestic use, storage as well as transport. It also provides for expanded cooperation between and among States regarding rapid measures to locate and recover stolen or smuggled nuclear material, mitigate any radiological consequences of sabotage, and prevent and combat related offences’ (International Atomic Energy Agency 2012).

2. The Physical Protection of Nuclear Material and Nuclear Facilities states that ‘The Convention on the Physical Protection of Nuclear Material (INFCIRC/274) obligates parties to make specific arrangement and meet defined standards of physical protection for international shipments of nuclear material; co-operate in the recovery and protection of stolen nuclear material; make as criminal offences specified acts to misuse or threats to misuse nuclear materials to harm the public; and prosecute or extradite those accused of committing such acts’ (International Atomic Energy Agency 1999, p. 1).

3. Under United Nations Security Council Resolution 1373, ‘all States should prevent and suppress the financing of terrorism, as well as criminalize the willful provision or collection of funds for such acts. The funds, financial assets and economic resources of those who commit or attempt to commit terrorist acts or participate in or facilitate the commission of terrorist acts and of persons and entities acting on behalf of terrorists should also be frozen without delay’ (United Nations Security Council 2001).

4. The CCSSRS recognises that ‘a global nuclear, radiation and waste safety culture is a key element of the peaceful uses of nuclear energy and that continuous efforts are required in
order to ensure that the technical and human elements of safety are maintained at the optimal level’ and stresses ‘the important role of the IAEA in enhancing nuclear, radiation and waste safety through its various safety programmes and initiatives and in promoting international co-operation in this regard’ (International Atomic Energy Agency 2003).

5 United Nations Security Council Resolution 1540 ‘affirms that the proliferation of nuclear, chemical and biological weapons and their means of delivery constitutes a threat to international peace and security. The resolution obliges States, inter alia, to refrain from supporting by any means non-State actors from developing, acquiring, manufacturing, possessing, transporting, transferring or using nuclear, chemical or biological weapons and their delivery systems’ (United Nations Security Council 2004).

6 The Convention ‘imposes an obligation on State parties to establish the offences within the scope of the Convention as criminal offences under their national laws and to make these offences punishable by appropriate penalties, which take into account their grave nature’ (Perera 2005).

7 The 10 ASEAN Member States are Brunei, Cambodia, Indonesia, Laos, Myanmar, Malaysia, the Philippines, Singapore, Thailand and Vietnam.

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HAN— THE SECURITISATION OF NUCLEAR ENERGY POST–SEPTEMBER 11 AND ITS IMPACT ON ASEAN’S NUCLEAR ASPIRATIONS

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NUCLEAR SECURITY CURRICULUM DEVELOPMENT IN MOROCCAN UNIVERSITIES, UNIVERSITY OF CASABLANCA CASE.

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ABSTRACT

Many Moroccan universities have been developing a nuclear science and technology curriculum, in several topics, for many years, following the development of several nuclear science and technology applications in various social and economic sectors, including agriculture, industry and medicine. The main role in this development could be attributed to the Nuclear Centre of Maâmoura (CNESTEN), with the Triga reactor, and research laboratories dedicated to those applications.

U.S. department of state’s Partnership for Nuclear Security has been sponsoring this development by allowing Moroccan academic experts to participate INMM annual meetings for the last four years (2010-2013), thus giving them the possibility to meet hundreds of international security and nuclear material managers. In the 52nd INMM meeting in Palm Spring (2011), the INMM Moroccan chapter was launched; it was the first chapter.

Recently, Moroccan nuclear experts have been working with the international community to develop a nuclear security curriculum that will be taught within the Moroccan academic community.

In February 2012, the CNESTEN hosted an international workshop focused on developing a nuclear security curriculum. This event received over 40 participants, many of them from the Middle East and North Africa region (MENA). Efficient facilities, well-organised tours, interesting lectures, and well-planned following development steps have made this workshop to be very well received in the MENA region; thus allowing for the planning of another workshop which will be based on the successes of the former. With the assistance of the U.S. Department of State’s Partnership for Nuclear Security (PNS), the International Atomic Energy Agency (IAEA), and the international academic community, Morocco was able to gather experts from the MENA Region to discuss the topics related to nuclear security.

As a result of their participation in the PNS, IAEA and CNESTEN activities, several academic institutions, including the Hassan II University in Casablanca, have made remarkable efforts to include nuclear security considerations in their nuclear science and technology curriculum. In an effort to incorporate international best practices from universities all around the world into the Moroccan nuclear development, six professors have participated in an Academic Study Tour in four American nuclear security institutions, namely the University of Tennessee, the University of North Carolina, the University of Texas Austin, and the University of Georgia. We will present throughout this article the Study Tour and the shared experience. The beneficiaries of the study tour will organize the Train-The-Trainer activity in their own institution; we will also present the activity in Hassan II University of Casablanca and the proposed Nuclear Security curriculum.
1. Introduction

In Morocco, since the 60’s, the first faculty of sciences in Mohamed V University of Rabat developed the first nuclear physics courses. In the 70’s, a bachelor’s degree in Nuclear physics was performed for few students (3-4/year). Some of those students would continue their curriculum, preparing a PhD in France. In the beginning of the 80’s and with the generalisation of education in Morocco, many universities in other regions were built (Figure1) and followed the same curriculum given in the University of Rabat.

- Mohammed V University of Agdal, Rabat
- Mohammed V University of Sousse, Rabat
- Hassan II Al-Qarawi University, Casablanca
- Hassan II Mohammedia University, Mohammedia
- Ibn Tofail University, Kenitra
- Sidi Mohamed Bensaid University, Fez
- Mohamed Premier University, Oujda
- Moulay Ismail University, Meknes
- Cadi Ayyad University, Marrakech
- Ibnou Zohri University, Agadir
- Chouane-Doukkali University, El Jadida
- Hassan Premier University, Settat
- Abdellatif Essaadi University, Tangier
- Moulay Slimane University, Beni Mellal

Figure I: Moroccan universities

2. Nuclear Science and Technology Education

During the past 20 years, a Nuclear Science and Technology curriculum was developed in many Moroccan universities in different regions of Morocco: Casablanca, Rabat, Kenitra, Marrakech, Fez and Tetouan. Master’s degrees dedicated to nuclear science and technology are developed with several modules like: Radiation protection, Reactor physics and nuclear safety. Other Masters in various field applications using isotopes and nuclear techniques are promoted, such as Medical Physics in Medical faculty, Water and sustainable development in the faculty of science.

Those education and training curricula related to nuclear science and technology are developed and assured in collaboration with the CNESTEN (Centre National des Etudes des Sciences, des Techniques, de l’ Energie Nucléaire) with its Triga Mark 2MW nuclear reactor.
The CNESTEN was created in 1986, the laboratories of the Maâmoura Nuclear Centre were built in 2003, and the research reactor (Triga MarkII) installed in 2009.

The centre is working in partnership with universities (Masters and research collaboration), as it is dedicated to nuclear applications: Medical applications, Industrial applications, Water and agriculture applications. The CNESTEN is also a training centre for other national actors in several fields: Health, Industries, and Hydrology. It is also a regional training centre for the IAEA.

### 3. Nuclear Security Curriculum

#### 3.1 Why nuclear security curriculum development in Moroccan universities?

- The Moroccan national energy strategy for 2025-2030 does include a nuclear program in the energetic mix.
- Various Nuclear Techniques and applications are used in several subjects; Medical, Industrial, Water and agriculture applications.
- Nuclear Research & Development at national or international level takes growing importance.
- The necessity of the fight against illicit use / threat.
- Stay up to the best application of laws and regulations: Independent regulatory body
- The International Engagement
- The Awareness of the Nuclear Security Culture

#### 3.2 Step by step

The U.S. Department of State’s Partnership for Nuclear Security has played an important role in the development of Nuclear Security curriculum introduction in the Moroccan academic program. One can consider that the first step was the participation of a Moroccan staff in the 52nd INMM annual meeting at Palm Desert – California, July 17th 2011. There was the INMM Moroccan Chapter Launching,
The INMM Moroccan Chapter was the first in the region (Africa and Middle East). Let us indicate that the Moroccan atomic and nuclear specialists are already enrolled in associations and NGO’s promoting nuclear science and technology as:

- Association des Ingénieurs en Génie Atomique du Maroc (AIGAM)
- Association Marocaine de Radioprotection (AMR)
- Groupe Marocain des Techniques des Réacteurs (GMTR)

That experience has facilitated the creation the INMM Moroccan chapter.

During this meeting the PNS staff with the colleagues participants from MENA countries agreed to organise the Middle East and North Africa Nuclear Security Curriculum Development Workshop in Rabat Morocco from February 27th to March 2nd in Rabat – Morocco.

The participants are representing their institutions as:

- 10 Moroccan Universities represented 23 participants
- National Centre for Nuclear Energy Sciences and Techniques (CNESTEN) 6
During this workshop, many international experiences in Nuclear Security Education and training were reviewed as:

- IAEA: Educational Program in Nuclear Security Publication Recommended Courses for M.Sc
- International Nuclear Security Education Network (INSEN)
- European Master of Science Programme in Nuclear Security
- European Nuclear Security Research Network (ENSERN)
- World Institute for Nuclear Security (WINS → Wins Academy)
- Naif Arab University for Security Sciences launches Diploma Program in Nuclear Security
- Gulf Nuclear Energy Infrastructure Institute ‘GNEII’ in Khalifa University

4. Recommendations:

- The need to increase the human resources development in Nuclear Security in the university curriculum
- The creation of a university curriculum completely dedicated to N.S. is not realistic
- To integrate fundamentals of Nuclear Security in existing university accredited courses in Bachelor’s and Master’s degrees.
- The contents and the programs are to be defined by concerned professors.
- To collaborate with local, national, regional and international institutions
- Funding for courses development and public awareness – information
- Attending national and International workshop (Study Tour)

5. USA Study tour:

U.S. department of state’s Partnership for Nuclear Security sponsored the participation of six Moroccan professors in an Academic Study Tour in four US nuclear security institutions namely the University of Tennessee, the University of North Carolina, the University of Texas Austin, and the University of Georgia.
The beneficiaries are engaged in the application of the study tour organized the Train-The-Trainer activity in their own institution. We present the activity in Hassan II University of Casablanca and the proposed Nuclear Security curriculum.
EDUCATION AND TRAINING ON PHYSICAL PROTECTION OF NUCLEAR MATERIAL IN BELARUS

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ABSTRACT

Belarus is a country, which is making its first steps in nuclear energy production. Notwithstanding the historical high level of nuclear knowledge and capacity of the former USSR, which Belarus was a part of, the nuclear energy sector in today’s Belarus requires international assistance. Throughout a long period following the Chernobyl accident and the collapse of the USSR, when Belarus had introduced the moratorium on use nuclear energy, the country was losing many of specialists and much expertise. Now, having made a decision to build a nuclear power plant, we are faced by the challenge to educate and train our national nuclear energy specialists. The local expertise in this area is obsolete, and this necessitates international support and cooperation.

ISEU has been running a training programme for students in the field of nuclear and radiation safety since 2008. One of the essential parts of the programme is teaching physical protection of nuclear material. The syllabus for this course was designed using the materials from different sources: IAEA’s publications and a special Physical Protection of a Research Reactor course, cooperation with Russia and Ukraine and Belarus’ own experience.

Our course consists of three main modules, each of them having theoretical and practical parts. Besides, excursions are organized to demonstrate the functioning of the physical protection systems in State Scientific Institution "The Joint Institute for Power and Nuclear Research - Sosny" (Belarus) and Sevastopol National University of Nuclear Energy and Industry (Ukraine).

The objectives of the modules are as follows:
Module 1: Students will understand how to define physical protection system requirements;
Module 2: Students will design a new or characterize an existing physical protection system;
Module 3: Students will learn how to evaluate the physical protection system performance and then will evaluate the system created in the module 2.

To be able to provide adequate training and meet our goals, we need to acquire laboratory benches of different physical protection subsystems, which would simulate real situations. Our instructors also need an opportunity to upgrade their training. They should be involved in international collaboration and exchange of experience to increase their knowledge and understanding physical protection.

1. Introduction

In 2008, Belarus had adopted a plan for the construction of its first nuclear power plant (NPP). From that time, the country has been responding to a challenge of preparing a sufficient number of educated personnel for nuclear energy sector. During the period within the USSR, Belarus could boast of a rather high level of research and educational system in the field of atomic energy. At that time, it was planned that Belarus would build its own nuclear power plant. But the Chernobyl accident and the collapse of the USSR caused Belarus to introduce a moratorium on the use of nuclear energy. This led to losing specialists and expertise. And now Belarus lacks a young generation of specialists.
Moreover, it experiences a deficit in well-trained teachers, who had practical experience at NPPs and could impart their knowledge to the new generation. On the positive side, however, one can mention that Belarus has a good educational system for physicists, nuclear physicists, engineers, etc. and there are still some specialists originating from the Soviet scientific nuclear school. This suggests that Belarus has all the potential for carrying out the ambitious training programme for young professionals in the field of nuclear energy, provided there is a significant help from international experts and international cooperation in this sphere. Since the decision to build a nuclear power plant was taken, a training and advanced training programme for nuclear energy specialists in Belarus has started being implemented. One of the institutions called upon to provide this training is the International Sakharov Environmental University, which has been running a training programme for nuclear and radiation safety students since 2008. The university graduates will be able to fill posts and be in charge of the nuclear and radiation safety, including nuclear security and security of radiation sources in different organisations and nuclear safety at the NPP.

2. Training on physical protection in focus

One of the essential parts of the nuclear security is physical protection of nuclear material. That is why in the training programme there is a course on the *Physical Protection of Nuclear Material*. The syllabus for this course was designed using the materials from sources as follows:
- IAEA’s publications,
- Special Physical Protection of a Research Reactor course organized by the IAEA and
- Cooperation with Russia and Ukraine and Belarus’ own experience.

The course consists of three main consecutive modules (see Figure 1), each of them having theoretical and practical parts during which students acquire skills to design a new physical protection system (PPS) or to characterize an existing physical protection system, to evaluate the design or system, and to redesign or to refine the system.

![Module 1. Determination of the PPS requirements](image1)

Module 2. Design a new or characterize an existing PPS

Module 3. Evaluation of PPS

Figure 1: The structure of the *Physical Protection of Nuclear Material* course.

The content of the modules and actions entertained within each of them are briefly discussed below.

3. Module 1. Determination of the PPS requirements

The first module contains the most general information, because it comprises the documents for the physical protection of nuclear material and main definitions. The PPS requirements are defined there while developing them for a hypothetical object. To develop the requirements, students must start from by gathering information about the operations and conditions of the facility, such as a comprehensive description of the facility, operating states, and physical protection requirements as well as regulatory requirements.
The trainees then need to define the threat; it involves considering factors about potential adversaries: types of adversaries, the adversary’s capabilities, and the range of the adversary’s tactics. After that, different groups of students should identify adversaries’ targets. Determination of whether nuclear materials are attractive targets is based mainly on the type and quantity of material and the ultimate goal of the adversary. Finally, students must identify the regulatory requirements and risk management considerations. Students now know the objectives of the physical protection system, that is, “what to protect against whom.”

The main problem of this module is that the teacher does not have enough competence to evaluate the correctness of the PPS requirements. Therefore, it should be mentioned that students receive just basic skills in defining the PPS requirements for their facility.

4. Module 2. Design a new or characterize an existing PPS

The second module is to design the new system or to characterize the existing system. In this module, students are familiarized with different components of the PPS. They explore different fences, vaults, sensors, procedures, and communication devices. At the end, the students should determine how best to combine elements of the PPS to provide the three functions: detection, delay, and response that can satisfy the protection requirements.

In this module, students design the PPS for a particular facility.

The problems of this module are that in Belarus there are no training benches or set-ups for the physical protection that demonstrate the work of different components of the PPS and provide the opportunities for rehearses by implementing a variety of exercises. Having such training equipment one may facilitate understanding and training to the PPS operations more completely.

To demonstrate an existing PPS, some excursions to the State Scientific Institution "The Joint Institute for Power and Nuclear Research - Sosny" (Belarus) and Sevastopol National University of Nuclear Energy and Industry (Ukraine) were organised. In Sevastopol National University of Nuclear Energy and Industry students also learn how to handle some components of the physical protection. But from the point of view of teaching this course, it seems to be not enough.

5. Module 3. Evaluation of PPS

The third module is the evaluation of the physical protection system design. Evaluation must consider the effectiveness of a system of elements that work together to assure protection rather than regarding each element separately. Due to the complexity of protection systems, an evaluation usually requires modeling techniques.

In the theoretical part, the students acquaint themselves with different types of analysis and evaluation of the PPS. And then they use it for evaluation of the PPS at their facility.

At the end of the course, students understand the importance of the physical protection of nuclear material as a part of nuclear security and have theoretical knowledge and practical skills to design and evaluate a PPS.

6. Conclusions

Among the main problems faced by Belarus today, we should mention the appropriate training for the teachers, including the need to acquire laboratory set-ups of different physical protection subsystems, which would simulate real situations. Our instructors also need an opportunity to upgrade their training. They should be involved in international collaboration and exchange of experience to increase their knowledge and understanding of physical protection.
OUTCOMES OF INTERNATIONAL INTERDISCIPLINARY NETWORKING

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ABSTRACT

The nuclear renaissance was expected to bloom in nuclear developed states and it was supposed to lead to the development of new types of advanced nuclear units. Lack of orders, lack of determination, unhappy political decisions made those state fade into a grey future. Such hope arises from states with little or not at all experience in the field, but with a strong will to implement this form of clean energy. Nevertheless the nuclear energy remains an important option for some European countries. EU official position states that in energy sector we need: security of supply, sustainability, feasible prices and investments. Last events in the nuclear field had a strong impact on security demands from the sector. Accordingly, additional requirements are now imposed for nuclear energy. New nuclear requirements following Fukushima accident will be highlighted.

Nuclear Knowledge Management (NKM) is one of the pillars of future development and the IAEA shows support providing programs and projects in the field. The continuity of success depends on how we deal with the accumulated knowledge. All countries face NKM problems and have to deal with it. Developed countries are the main source of knowledge accumulated and face the challenge of transferring it to new generations. On the other hand developing countries must deal with knowledge caption and absorption and must deal with brain drainage. Accepting recent events and endorsing the lessons learned helped NKM make a huge step in building a better approach in E&T.

Another important pillar in efficient collaboration between developing and developed countries is represented by the regional and interregional programs between experienced states and newcomers. There are important outcomes to be achieved through joint collaboration between experts either from different countries with same nuclear background but with different expertise, or experts that have different levels of knowledge regarding Education and Training programs needed by nuclear energy option.

The interdisciplinary objective of networking is to create a multi-level nuclear program that can fulfil the needs of society, industry, R&D entities and E&T institutions.

E&T is the third important pillar in nuclear reshaping. In Romania as a result of strong international networking in projects like REFIN (Romanian Network of Excellence in Nuclear Physics and Engineering) ENEN, ENEN-II, ENEN-III, NEPTUNO, TRASNUSAFe, EURECA!, ENEN-RU, EUJEP, NEWLANCER it has been developed an efficient, flexible and modern training scheme which answers the needs of nuclear industry: NPP, regulatory bodies, dismantling, radioprotection, waste management. This scheme involves and includes reshaping of curricula and course development according to the future needs of nuclear industry, introduction of advanced courses on project topics, exchange of trainers and trainees with institutions that share same concerns about the topic, joint research and
teaching labs, student exchange for collaborative education and research.

In all these activities universities can make significant progress towards building the human capacity necessary to support next generation nuclear power units. Extended research regarding Gen 4 reactors is strongly supported by EURATOM and prototype installations are planned. Involvement of all EU countries in these complex activities should be reflected by the E&T programs too, as education is a key component that needs to be consolidated. Romania’s integration in the Gen 4 program ALFRED represents an important upgrade of the national nuclear initiative, which includes a good national strategy and support on the topic, strong research laboratories supported by good personnel, an education component aimed to provide sustainable and qualified workforce, national/international interest from stakeholders and governments and a well-informed society that needs to be aware of the benefits such program brings.

1. Introduction
   Aim of present paper is to analyse the outcomes that can be achieved through joint collaboration between experts coming from different countries, thus with different level of knowledge and different expertise background. Knowledge management plays a key role in creating and supporting skilled and well prepared personnel in nuclear industry and not only. Experts coming from countries that undergo a well-developed nuclear program based on a long history share their expertise with experts from such called newcomer countries. This expertise can be put together by various methods.

   Approaches to develop E&T based on knowledge management training schemes can be various. The paper will analyse development of E&T programme based on such joint collaboration programs.

2. What we have
   EU official position states that in the energy sector we need: security of supply, sustainability, feasible prices and investments. Last events in the nuclear field had a strong impact on security demands from the sector. Accordingly, additional requirements are now imposed for nuclear energy. New nuclear requirements following Fukushima accident are and will be highlighted, leading to improvement of projects and of legislation.

   In the last year more countries adopted plans which define the organization of activities necessary to implement a civil nuclear power program. This includes comprehensive public consultation, nuclear legislation improvement, site selection, tender procedures, licensing activities, enforcement of regulatory bodies, and last but not least, a strong approach to Nuclear Education & Training. Developed countries (EU and USA in the first row) started to cope for better business opportunities with countries formerly situated on an ‘exclusion’ list.

3. Role and place of Knowledge Management
   Building a successful nuclear energy program is based on correct and in-time shaping of E&T demands.

   Nuclear Education and Training appear to be one of the pillars of future development. Therefore attention should be oriented towards the investments being made in the E&T field, examples of national schemes taking place, bottlenecks facing the industry in the future, and ultimately showing where the industry is going in the coming years.
An analysis of tools to be used for E&T integration methodology in a development program should overview:

- A good national strategy and support of the topic,
- Strong research laboratories supported by skilled personnel,
- Education component to provide sustainable and qualified workforce,
- National/international interest from stakeholders and governments and a well-informed society that needs to be aware of the benefits such program brings.

At the same time an increased preoccupation is shown towards Nuclear Knowledge Management (NKM), which appears to be the driving force and solid tool for future healthy and efficient E&T development.

All countries face NKM problems and have to deal with it. Accepting recent events and endorsing the lessons learned helped NKM make a huge step in building a better approach in E&T. National authorities, as well as the IAEA (should) show support by providing programs and projects in the field.

The continuity of success depends on how we deal with the accumulated knowledge. Developed countries are the main source of knowledge accumulated and face the challenge of transferring it to new generations. On the other hand developing countries must deal with knowledge caption and absorption and must deal with brain drainage.

4. Transferring knowledge via networking

Building a successful nuclear energy program is based on correct and in-time shaping of E&T needs, taking into consideration key aspects as: national and international existing regulations, research infrastructure, education & training capabilities and language barriers to be tackled. Regulatory framework of a newcomer is shaped according to existing international requirements and recommendations promoted by international bodies, and regional and national authorities.

Therefore another important pillar in efficient collaboration between developing and developed countries is represented by the bilateral, regional and interregional programs between experienced states and newcomers.

States who wish to start and develop a nuclear program are considered to be newcomers. They clearly should benefit from the cooperation with experienced states and each of the parties has some expectations as a result of their collaboration.

There are important outcomes to be achieved through joint collaboration between experts either from different countries with same nuclear background but with different expertise, or experts that have different levels of knowledge regarding Education and Training programs needed by nuclear energy option. One key aspect the newcomers are looking for is the expertise record and visibility at international level.

Support and guidance by AIEA in developing the infrastructure and knowledge for nuclear education and training programs should be considered. Networking is a basic tool for that.

The interdisciplinary objective of networking is to create a multi-level nuclear program that can fulfil the needs of society, industry, R&D entities and E&T institutions. An example of international cooperation between states with long experience in nuclear education, training and research and states with less visibility is the EURATOM FP 7 project NEWLANCER-New MEMBER STATES Linking for an AdvaNced Cohesion in Euratom Research. In this project the cooperation at national and international level in different research and E&T areas aims to strengthen the capabilities of each partner/EU member state. E&T is an important pillar in
nuclear reshaping. In Romania as a result of strong international networking in projects like RFIN (Romanian Network of Excellence in Nuclear Physics and Engineering) ENEN, ENEN-II, ENEN-III, NEPTUNO, TRASNUSAFE, EURECA!, ENEN-RU, EUJEP, NEWLANCER it has been developed an efficient, flexible and modern training scheme which answers the needs of nuclear industry: NPP, regulatory bodies, dismantling, radioprotection, waste management. This scheme involves and includes reshaping of curricula and course development according to the future needs of nuclear industry, introduction of advanced courses on project topics, exchange of trainers and trainees with institutions that share same concerns about the topic, joint research and teaching labs, student exchange for collaborative education and research.

These projects showed that:
- From technical point of view, networking improves the quality of training in nuclear field, the competence of trainers and students, and permits the efficient use of the facilities and of the research infrastructures;
- The use of modern training and knowledge management methods helps the harmonization with similar education systems in view of integration with other countries with direct effects on increasing economic competitiveness, while fulfilling the sustainable development criteria.

In all these activities universities can make significant progress towards building the human capacity necessary to support next generation nuclear power units. Extended research regarding Gen 4 reactors is strongly supported by EURATOM and prototype installations are planned. Involvement of all EU countries in these complex activities should be reflected by the E&T programs too, as education is a key component that needs to be consolidated.

Romania’s integration in the Gen 4 program ALFRED represents an important upgrade of the national nuclear initiative, which includes a good national strategy and support on the topic, strong research laboratories supported by good personnel, an education component aimed to provide sustainable and qualified workforce, national/international interest from stakeholders and governments and a well-informed society that needs to be aware of the benefits such program brings.

Following developed projects represent some good example of multidisciplinary approach for networking between NMS (New Member States) and OMS (Old Member States). The ARCADIA project has been conceived so as to provide a twofold support to the further development of nuclear research programs in the NMS, targeting two major areas included in the Strategic Research and Innovation Agenda of SNETP: ESNII, through the support of the ALFRED project towards its realization in Romania, and NUGENIA, approaching remaining safety aspects of Gen III/III+ that could be built in Lithuania, Poland, Czech Republic and Slovenia. On one hand, it focuses on the identification of the primary needs for the ALFRED project, mainly to what concerns E&T, supporting Infrastructures and Regulatory aspects (and integrating – for the R&D needs – the outcomes of other research projects in a common frame of National and Regional needs); on the other hand, it investigates the existing National and Regional supporting structures – with a particular attention to the ones in Romania and in all the participating New Member States – for defining a map of competences potentially eligible to satisfy the previously identified needs. Considering a different approach, the EAGLE ((Enhancing educAtion, traininG and communication processes for informed behaviours and decision-making reLatEd to ionizing radiation risks) project aims specifically at coordinating the information and communication strategies related to ionising radiation for the general public, in order to get a better understanding of the effects of ionising radiation, taking also into consideration the lessons
learnt from the 2011 accident in Fukushima. Education, training and information to the general public are key factors in the governance of ionising radiation risks. Communication about ionising radiation with the general public has to be further improved, as highlighted also by the 2011 accident in Japan. An effort is needed to analyse the state of the art and the existing needs in education, training and information, and to coordinate the information and communication about ionising radiation at European level.

Education & Training networks between experts, gathering universities, research facilities, regulatory bodies and end users can improve existing expertise and can represent a trusted base for international cross linking. Such collaboration programs are intended to provide an efficient training scheme for future qualified personnel that is involved in nuclear field following the needs that industry has. Some good examples of international expert cooperation could be considered as European Nuclear Education Network Association (ENEN), Asian Nuclear Education and Training Network (ANENT), Latin America Nuclear Education and Training Association (LANENT). This way the benefits resulted from joint collaboration programs between experts from different countries with mature nuclear programs and experts coming from countries with a smaller or inexistent nuclear program are highlighted.

5. Conclusions

New nuclear programs did not fulfil the nuclear industry expectations. Despite lack of orders, lack of determination or unhappy political decisions certain hope arise from states with little experience in the field.

Collaboration between developing and developed countries is represented by the regional and interregional programs between experienced states and newcomers. Numerous examples were offered and these projects showed good collaboration results during a period of over a decade of continuous partnership.

As NKM is recognized as key issue of future nuclear development, IAEA strong support is shown by numerous programs provided and numerous projects encouraged. Developed countries face the challenge of transferring to new generations all accumulated knowledge and developing countries proved to be capable of absorbing it but must face the challenge of avoiding brain drainage.

Direct outcomes of international interdisciplinary networking, based on E&T needs, can be considered to be: new curricula and course development; introduction of advanced courses; exchange of trainers and trainees with institutions that share same concerns; joint research and teaching labs; student exchange for collaborative education and research.
Following an agreement between Hungary and Vietnam, nuclear training of 160 Vietnamese university lecturers was realized in four groups in years 2012 and 2013 in Hungary.

The 6-week-long HUVINETT ("Hungarian-Vietnamese Nuclear Energy Train the Trainers Course") upgrading courses consisted of two parts: in the first three weeks the participants attended lectures and performed laboratory experiments in the Training Reactor of the Institute of Nuclear Techniques of the Budapest University of Technology and Economics (BME). In the second three weeks they improved their practical skills and knowledge at the Paks Nuclear Power Plant, among others in the Maintenance Performance Improvement Center and in the Full Scope Simulator. The efficiency of the training course was demonstrated by the results of the entrance and exit tests written by the participants.

The objective of the training program was to help the 7 largest universities of the Asian country prepare for the education and training of highly qualified nuclear workforce. According to the decision of the Vietnamese government, Russian companies will build and put into operation two 1200 MW units of pressurized water reactors in Vietnam by 2020.

The paper describes the structure of the HUVINETT courses and the experience of the cooperation between the teaching experts of BME, Paks NPP and the Vietnamese universities.

1. The role and infrastructure of nuclear energy in Hungary

The Hungarian electricity consumption was about 43 TWh in 2012, showing a modest decrease in the last years because of the economic crisis. Compared with the Hungarian population (10 million), this figure corresponds to about 4 MWh electricity consumption per capita. The maximum gross peak system load was 6500 MW in 2012. The total installed capacity of the Hungarian power plants was 9 000 MW in 2012. The domestic electricity production was 35 TWh, with an import-export balance of 8 TWh.

The domestic electricity production relies significantly on the only Hungarian nuclear power plant. In the Paks NPP [1] there are four Soviet-built units operating (with VVER-440 type pressurized water reactors). The original nominal capacity of the units was 4*440 MW, but after several power upgrading measures it was increased to 4*500 MW. The units were connected to the electricity grid in the period between 1982 and 1987. Their originally planned lifetime was 30 years, but the operator (MVM Paks Nuclear Power Plant Ltd.) is realizing a lifetime-extension project, in order to obtain an operating licence for further 20 years. Unit 1 received the extended operating licence in 2012 from the Hungarian Atomic
Energy Authority. Paks NPP successfully participated in the EU-initiated stress test after the Fukushima accident.

The Paks NPP offers a unique training facility, the Maintenance Performance Improvement Center (MPIC) used mainly for the training of the maintenance and technical background staff of the plant. In the MPIC – among others – the main components (reactor vessel with its internals, main circulating pump, steam generator, fuel assemblies, different pumps and valves) of the primary circuit are available under inactive conditions.

The first nuclear reactor in Hungary, the Budapest Research Reactor (BRR) started operation in the Energy Research Center of Hungarian Academy of Sciences [2] in 1959 in the capital. The tank-type light water moderated research reactor was refurbished between 1986 and 1992. At present, the reactor has a nominal thermal power of 10 MW. The BRR is used for different research purposes, including irradiation of various materials – such as neutron activation analysis or isotope production, neutron radiography – and as a neutron source for material research applications.

Prior to the construction of the Paks units a small training reactor had been built for the establishment of competency of domestic experts and for the training of operating personnel, research and technical support staff. The Training Reactor at the Budapest University of Technology and Economics (BME) started in 1971 based on domestic design and constructed by Hungarian companies [3]. The pool-type reactor has a nominal thermal power of 100 kW, and it is designed to be operated by students as well. The Training Reactor offers a unique possibility for practical education of nuclear experts.

The establishment of the Hungarian nuclear industry was the result of a pragmatic development process. From the 1950’s Hungary intended to become an intelligent user of nuclear energy, and to own all the knowledge, education and research capacity that are necessary for the long-term safe operation of the Paks NPP units and for the competent decision-making of the related technical and economical questions. Beside the facilities, also the university and other training programs have been also developed in the last 50 years, as a result of which Hungary is now self-supplying in the field of nuclear expert education.

2. Introducing nuclear energy in Vietnam

The densely populated Asian country has a quickly developing economy (with an annual GDP increase of 5%). The electricity production in Vietnam was 117 TWh, while the installed generating capacity was 26 GW in 2012 [4]. This figure – compared with the population (92 million) – results in 1.3 MWh electricity consumption per capita, approximately one third of the respective figure of Hungary. Together with the quick development of the Vietnamese
industry the increase of electricity demand is expected: the projected electricity consumption in 2020 is 320 TWh, more than three times higher than the actual value.

The Vietnamese electricity system is based mainly on hydroelectric and fossil (natural gas and coal fired) power plants. The country is self-sufficient in natural gas production. The electricity import is quite limited: in 2012 Vietnam imported 2.5 TWh electrical energy from China.

Vietnam has now only one operating research reactor at Da Lat (DLRR) with 500 kW thermal power. DLRR is used for training and research purposes. According to a Russian-Vietnamese agreement, Russia will build a new open tank type research reactor for Vietnam with 15 MW power for mainly neutron beam application and irradiation activities. The schedule for the start of the new research reactor is 2020.

The nuclear power development plan of Vietnam (released in 2007) announced the establishment of 8000 MW nuclear power plant capacity by 2025. The first selected nuclear site is Phuoc Dinh in Ninh Thuan province in the south-east region of the country. According to the national development plans, four reactors will be constructed here, they would start operation between 2020 and 2027. These nuclear units will be constructed by the Russian Atomstroyexport according to a 2010 intergovernmental agreement. The construction of the two VVER-1000 units will start in 2014 financed by the Russian counterpart. Unit 3 and 4 will also be Russian-designed VVER type reactors, for which the dates for the commencement of the construction are not determined yet.

There is also an intergovernmental agreement in force with Japan for four Japanese, third generation units. The construction of these units is expected to start in 2015 financed by Japanese companies. The location of these Japanese reactors would be Vinh Hai in Ninh Thuan province.

3. **The basis of Hungarian – Vietnamese cooperation**

The construction of the Paks NPP was a serious challenge for Hungary even with the background mentioned in Section 1. Significant nuclear knowledge was gained from the nuclear plant construction, but it also improved based on the strong technical, scientific and industrial resources of the country. The Training Reactor at BME, the Budapest Research Reactor of the Energy Research Center and the training facilities in Paks NPP represent a very wide range of competences and possibilities to be used in the education and training of nuclear embarking countries.

These opportunities were recognized in 2009, when the Hungarian and Vietnamese governmental representatives and industrial experts started negotiations about a possible cooperation in nuclear education. Beside the well developed Hungarian educational system and infrastructure the traditional good relationship between the two countries represented an important factor. An additional important argument was that Hungary gained lot of experience on how to localize Russian technology.

As the first step of a long-term cooperation, the need of a special training program was recognized. The government of the Asian country selected seven universities which should be prepared for the education of the future nuclear experts, in other words the nuclear expertise at these universities should be developed first. In order to involve as many lecturers as possible, a 6 week training course was introduced, which aims at the overview of nuclear sciences and demonstration of typical educational methodologies applied in Hungary. The participants of these courses are mainly lecturers of the seven selected universities, but representatives of the Vietnamese power industry, ministries and agencies take part, too.
4. Course structure

The two most important locations of Hungarian nuclear education are the Training Reactor at Budapest University of Technology and Economics and the training facilities of Paks NPP. The 6 week long time frame available for the training program was divided into two parts between these two locations: a 3 week program was organized at BME Training Reactor, and the next 3 weeks at Paks NPP. The first 3 weeks at BME were dedicated more to theoretical studies, while the second 3 weeks at Paks gave participants more practical experiences. The course participants had 40 hours of activity every week.

At BME, of the total of 120 hours of time frame 80 hours were spent with lectures, 36 hours with demonstrations of different laboratory exercises in smaller groups and 4 hours for tests.
The fields of study at BME were the followings:

- Nuclear fundamentals
- Reactor physics
- Thermal hydraulics
- Nuclear fuel cycle
- Nuclear power plants
- Nuclear safety
- Operation of nuclear power plants
- Nuclear measuring methods
- Radiochemistry
- Radiation and environmental protection
- Reactor laboratory exercises

The Vietnamese colleagues participated in the following laboratory exercise demonstrations:

- Introduction to laboratory exercise, radiation protection and safety training
- Measurement of scintillation and semiconductor detectors
- Measurement of gas filled and neutron detectors
- Reactor operation exercise
- Determination of spatial distribution of thermal neutron flux in the core of the training reactor
- Experimental demonstration of thermal-hydraulics of PWRs during Loss-of Coolant Accidents on TRATEL plexiglas mock-up
- Radiation protection in practice
- Demonstration of PWR primary circuit behavior on simulator
- VVER-1000 simulator exercise

Fig. 5: Laboratory exercise at BME

At Paks NPP from the 120 hours 64 hours were dedicated to lectures and presentations, 52 hours for practical exercises, plant visits and 4 hours for tests and evaluation.

The key subjects in Paks were the followings:

- International, national requirement of NPP operation
- Introduction of the VVER-440 technology and equipment
- Technology development/upgrade at Paks NPP
- Safety related issues at Paks NPP
- Nuclear fuel management and fuel handling at Paks NPP
- Chemistry issues at Paks NPP
• Maintenance activities at Paks NPP
• Radiation protection at Paks NPP
• Emergency response System at Paks NPP
• Severe accident management
• Technical support activities at Paks NPP
• Human resource management and training system at Paks NPP
• Exercises on the full scope plant simulator
• Practical exercises on real primary circuit equipments

Fig. 6: Demonstration of lifting the reactor internals in Maintenance Performance Improvement Center of Paks NPP

Fig. 7: Hands-on training in Maintenance Training Centre of Paks NPP

All materials presented during the 6 weeks were made available for the course participants. The nuclear related knowledge of all course participants was measured at the beginning of the program in Budapest by different survey test. Other tests were also applied at the end of the first and the second 3 week period in order to determine the improvement of the level of knowledge gained during the program. The participants have shown a very creditable performance improvement. At Paks, the program was continued with practical application of
nuclear knowledge in an operating nuclear facility with the special focus on the importance of nuclear safety. The whole program was closed with a common evaluation session.

5. Experiences and outlook

We are convinced that Hungary has provided a unique environment for learning useful and interesting subjects from well prepared and well organized training content, delivered by experienced and knowledgeable lecturers in an open and constructive atmosphere which – along with the commitment discipline and diligence of the Vietnamese trainees – all helped achieve the overall objectives, thus come to the conclusion that the continuation of the HUVINETT program is considered as highly beneficial for Vietnam to better face its endeavors in nuclear education and training.

Based on the experiences gained during the HUVINETT courses the key stakeholders (the Hungarian Government – Ministry of National Development, Paks NPP and BME Training Reactor) are actually working on the formation of the Hungarian Nuclear Education Network (HUNEN) for further international courses which will be open for other countries, especially for those embarking upon their national nuclear program.

6. References

ABSTRACT

The official report ‘Polish Energy Policy until 2030’, released in 2009, calls for the construction of a new nuclear power plant (NPP) in Poland. One key element of this policy, in addition to the construction of the NPP, is the education of nuclear technology engineers. The Ministry of Economy has released the Polish Nuclear Power Program, which is expected to be approved by the Council of Ministers by the end of the year. The Program stated that the first Polish nuclear power plant will be operational by the end of 2024.

Several universities have launched specialized nuclear technology courses, notably the Faculty of Power and Aeronautical Engineering at the Warsaw University of Technology (WUT), which was in 2006 the first university in Poland to restart its nuclear power specialization. A total of 43 Master students are currently enrolled in this university program. In addition to the education of engineers, WUT received a grant from the National Center for Research and Development to conduct research in the field of safety analysis. The recipient of the results of this grant is National Atomic Energy Agency - the future Polish regulatory body.

The integration of the university in the Polish Nuclear Power Program provides both challenges and opportunities for WUT. The challenges comprise the build up of knowledge and know-how, particularly in the field of safety analyses, and the education of students with a focus on nuclear energy. Cooperation with industry is of great benefit, as it allows students to familiarize themselves with the focus of the nuclear industry. WUT has used this opportunity to develop a cooperation agreement with AREVA, which provides a variety of activities to support the role of WUT in the Polish Nuclear Power Program. AREVA specialists provide lectures at WUT, supplementing the lecture offer of WUT and allowing know-how developed in industry to become part of university education. Also, several students are sent to AREVA laboratories and facilities to work either in internships or on their Master or PhD theses. Groups of students will have the opportunity to visit the unique experimental facilities of AREVA. WUT and AREVA have jointly organized a workshop entitled: Familiarization with calculation codes application and safety analysis workshop.
This paper reviews the tasks and challenges for WUT resulting from current stage of the nuclear new build program in Poland and discusses the opportunities offered by the cooperation with AREVA, as well as its first successes.

1. Introduction

The official document ‘Polish Energy Policy until 2025’, released in 2025, called for diversification of energy sources and for construction of environment friendly power plants in Poland. In view of the possible introduction of nuclear energy in Poland, the report also points out the necessity of providing reliable and accurate information on this kind of electricity generation. The official document ‘Polish Energy Policy until 2030’, released in 2009, calls for the construction of a new nuclear power plant (NPP) in Poland. Key elements of this program, in addition to the construction of the NPP, are creating a research base for the Polish Nuclear Power Program and the education of engineers for nuclear power. The release of the final version of the Polish Nuclear Power Program by the Ministry of Economy is scheduled for October 2013. It is expected that the Program will be approved by the Council of Ministers by the end of this year. The program states that the first NPP in Poland will be operational by the end of 2024.

2. Nuclear Power Engineering at Warsaw University of Technology

Warsaw University of Technology (WUT) realized quickly its mission and capabilities to educate the engineers for Polish nuclear power and as soon as 2006, WUT was the first university in Poland to restart nuclear power specialization. At first the nuclear power specialization was realized in collaboration with the Royal Institute of Technology (KTH, Stockholm, Sweden). Since the academic year of 2009/2010 the specialization was fully taught at WUT.

WUT tries to provide students with the most up-to-date knowledge and the best means to acquire this knowledge and consequently the specialization will be taught exclusively in English starting from the academic year 2013/2014. What is more, by providing the courses in English, WUT sees the opportunity of encouraging international students, especially from Eastern Europe, to choose the nuclear power specialization. Table 1 shows the current curricula of Nuclear Power Engineering at WUT.

<table>
<thead>
<tr>
<th>Subject</th>
<th># of academic hours</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computational Fluid Dynamics</td>
<td>L2Lab1</td>
<td>3</td>
</tr>
<tr>
<td>Energy Transport</td>
<td>L1E1</td>
<td>2</td>
</tr>
<tr>
<td>Finite Element Method</td>
<td>L2Lab1</td>
<td>4</td>
</tr>
<tr>
<td>Math. Mod. and Pr. Identification</td>
<td>L2E1</td>
<td>4</td>
</tr>
<tr>
<td>Numerical Methods in Heat Transfer</td>
<td>L2Lab1</td>
<td>3</td>
</tr>
<tr>
<td>Partial Differential Equations</td>
<td>L2E1</td>
<td>5</td>
</tr>
<tr>
<td>Elements of Nuclear Physics</td>
<td>L2E1Lab1</td>
<td>4</td>
</tr>
<tr>
<td>Energy Law &amp; Legal Frames for Nuclear Power Industry</td>
<td>L1</td>
<td>2</td>
</tr>
<tr>
<td>Elective courses</td>
<td>L4</td>
<td>3</td>
</tr>
<tr>
<td>Sem. I</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Semester II</td>
<td>Sem. II</td>
<td></td>
</tr>
<tr>
<td>Business Law</td>
<td>L2E1</td>
<td>2</td>
</tr>
<tr>
<td>Neural Networks</td>
<td>L2</td>
<td>3</td>
</tr>
<tr>
<td>Physics 2</td>
<td>L2</td>
<td>3</td>
</tr>
<tr>
<td>Course</td>
<td>Credits</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>Stat. and Noneq. Thermodynamics</td>
<td>L2 2</td>
<td></td>
</tr>
<tr>
<td>Elective courses</td>
<td>L2 2</td>
<td></td>
</tr>
<tr>
<td>Nuclear Reactor Physics</td>
<td>L2E1Lab2 6</td>
<td></td>
</tr>
<tr>
<td>Contemp. Nucl. Reactor Syst. (LWR, HWR)</td>
<td>L3 4</td>
<td></td>
</tr>
<tr>
<td>Nuclear Reactor Modeling and Simulation</td>
<td>L2E1Lab2 6</td>
<td></td>
</tr>
<tr>
<td>Nuclear Fuels and Fuel Cycles</td>
<td>L2 2</td>
<td></td>
</tr>
<tr>
<td>Contemp. Nucl. Reactor Syst. (LWR, HWR)</td>
<td>L3 4</td>
<td></td>
</tr>
<tr>
<td>Nuclear Reactor Modeling and Simulation</td>
<td>L2E1Lab2 6</td>
<td></td>
</tr>
<tr>
<td>Nuclear Fuels and Fuel Cycles</td>
<td>L2 2</td>
<td></td>
</tr>
<tr>
<td>Engineering Project</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Intermediate Masters Project</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Information Systems in Management</td>
<td>L2 2</td>
<td></td>
</tr>
<tr>
<td>Project Management</td>
<td>L2 2</td>
<td></td>
</tr>
<tr>
<td>Elective courses</td>
<td>L2 2</td>
<td></td>
</tr>
<tr>
<td>Nuclear Instrumentation and Control</td>
<td>L2L2 4</td>
<td></td>
</tr>
<tr>
<td>NPP Safety</td>
<td>L2E1 3</td>
<td></td>
</tr>
<tr>
<td>NPP Operation and Maintenance</td>
<td>L2 2</td>
<td></td>
</tr>
<tr>
<td>Gen IV Nuclear Reactor Systems (HTR, FBR)</td>
<td>L2 2</td>
<td></td>
</tr>
<tr>
<td>Thermonuclear synthesis</td>
<td>L2 2</td>
<td></td>
</tr>
<tr>
<td>Nuclear Energy and Int'l Security</td>
<td>L1Lab1 2</td>
<td></td>
</tr>
<tr>
<td>Internship at a Nuclear Installation</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Master Diploma Seminar</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Master Diploma Thesis</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Curriculum for the Nuclear Power Engineering at WUT. ‘L’ stands for lectures, ‘E’ for exercises, ‘Lab’ for laboratories. Ex. L2E1Lab2 – 2 academic hours of lectures, 1 academic hour of exercises and 2 academic hours of laboratory classes. Each academic hour is 45 minutes long.

The Nuclear Power specialization is taught at the Faculty of Power and Aeronautical Engineering, at the Institute of Heat Engineering. The Faculty of Power and Aeronautical Engineering was the first in Poland that started a nuclear power engineering education program in 1959. The education in nuclear power engineering was conducted until 1992, educating 170 graduate students and 500 postgraduate students. As one can notice in Table 2, WUT is the leading and most experienced university in Nuclear Power Engineering education in Poland.
Table 2. Number of students of Nuclear Power Engineering at Polish universities.

<table>
<thead>
<tr>
<th>Universities in Poland</th>
<th>Specialization</th>
<th>Level</th>
<th>Startup year</th>
<th>Graduates</th>
<th>Current students</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGH (Cracow)</td>
<td>Nuclear Power Engineering (conducted in Polish)</td>
<td>M.Sc.</td>
<td>2009/10</td>
<td>0</td>
<td>&lt;10 (no formal student group)</td>
</tr>
<tr>
<td>PG (Gdansk)</td>
<td>Nuclear Power Engineering (conducted in Polish)</td>
<td>B.Sc.</td>
<td>2011/12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PP (Poznan)</td>
<td>Nuclear Power Engineering (conducted in Polish)</td>
<td>B.Sc.</td>
<td>2009/10</td>
<td>16 (B.Sc.)</td>
<td>19 (mostly B.Sc)</td>
</tr>
<tr>
<td>PŚ (Gliwice)</td>
<td>Nuclear Power Engineering (conducted in Polish)</td>
<td>M.Sc.</td>
<td>2010/11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PWr (Wroclaw)</td>
<td>Nuclear Power Engineering (conducted in Polish)</td>
<td>M.Sc.</td>
<td>2012/13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PW (WUT – Warsaw)</td>
<td>Nuclear Power Engineering (conducted in English)</td>
<td>M.Sc.</td>
<td>2006/07</td>
<td>15 (M.Sc)</td>
<td>13 (M.Sc.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8 (III s.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22 (I s.)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total: 43</td>
</tr>
</tbody>
</table>

3. WUT international and national cooperation

Since the beginning of the implementation of Nuclear Power Engineering, WUT realized that without the connection to the nuclear industry and institutions that do research in the nuclear field, it would be difficult to develop a research base and educate engineers for the Polish Nuclear Power Program. WUT started the cooperation with:

- KTH-Royal Institute of Technology (Sweden),
- Commissariat à l’Energie Atomique (France),
- Oregon State University (USA),
- Polish Centre for Nuclear Research,
- National Atomic Energy Agency,
- PGE EJ 1 Sp. z o.o. (future owner and operator of the first NPP in Poland), AREVA,
- Westinghouse,
- General Electric – Hitachi.

There is no national detailed strategy of the development of the research base or educating the engineers in Poland. WUT realizes that it can specialize only in those areas where it has capabilities and experience. Therefore WUT started to integrate the Polish scientific institutions that want to be present in the future Polish Nuclear Power Program. The outcome of this integration will be finished potentially next year. The first concept of the integration and scope division is shown in Figure 1.
4. Cooperation between WUT and AREVA

In the following, the cooperation with French nuclear conglomerate, AREVA is presented as one of the most extensive cooperation in the nuclear field that WUT is realizing. Since the AREVA presence (AREVA started its presence in Poland in 2009), both WUT and AREVA were trying to cooperate closely, aiming to formulate an official agreement. After a series of meetings in 2011, the formal cooperation was initiated in 2012 and the formal agreement was signed in late 2012.

The cooperation with AREVA is governed by a so-called Steering Committee that consists of members from both sides. The structure and members are depicted in Figure 2. The Committee meets twice a year, once in Poland and the other time either in France or Germany. The Committee agrees on the means of cooperation on an academic semester basis.
There are mainly two ways of cooperation, on-site AREVA, that requires physical presence of people from WUT at any AREVA facility for a longer time (more than a week) and off-site AREVA in which WUT acquires information from AREVA by hosting AREVA specialists at the WUT or via electronic means. A more detailed scope is shown in Figure 3.

Both ways are very fruitful for WUT. It enables researchers from WUT to obtain knowledge from AREVA's specialists, as well as extensive and detailed information on reactor technology. It enriches the Nuclear Power Program by providing lectures discussing realistic issues and by offering the possibility to students to complete an internship or work on their theses in AREVA facilities, where they can understand the challenges nuclear industry is facing.
4.1. Visits of AREVA Germany and German institutions specialized in nuclear engineering

In July and August 2012, AREVA Germany helped to organize and participated in visits to German institutions that do research in the nuclear field. The meetings were held with Technische Universität Dresden, Helmholtzzentrum Dresden/Rossendorf and Hochschule Zittau/Görlitz. On each meeting, the scope of the research and possible ways of cooperation were presented. As results of the meetings, one student went on Master thesis to Helmholtzzentrum Dresden/Rossendorf.

Furthermore, several research or industrial facilities were visited: the training reactor AKR-2 and laser laboratory at Technische Universität Dresden, TOP FLOW facility at Helmholtzzentrum Dresden/Rossendorf, PKL Loop facility at AREVA Erlangen, INKA facility, Large Valve Test Facility GAP and Multifunction Thermal Hydraulic Test Loop KATHY at AREVA Karlstein.

Each of the visit was very fruitful for WUT representatives. It gave them the true vision how the facilities are being operated and what is needed for successful research. The direct contact with AREVA experts enabled to introduce the student internship program and resulted in first Master theses of WUT students.

4.2. Students internships, visit and AREVA’s lectures at WUT

Since 2012, four WUT students have had Master theses at AREVA facilities, namely in AREVA Erlangen and AREVA Offenbach. Two students are about to start Master theses in November 2013 in Erlangen facility. WUT and AREVA seek to extend the cooperation. One WUT student is expected to start PhD thesis in late 2013 at AREVA Erlangen.

WUT Students had chances to visit the AREVA facilities. It is very valuable for them to see the equipment / installation in operation. It gives students an idea of how powerful and complex the processes in nuclear industry are. Students have visited following AREVA sites:

- MELOX AREVA – MOX fuel Fabrication,
- FBFC Romans AREVA – Fuel Fabrication,
- SAINT-MARCEL PLANT – Heavy components manufacturing,
- CREUSOT FORGE – Heavy forgings and machining capacities,
- AREVA NC Pierrelatte.

AREVA specialists provided lectures at WUT, supplementing the lecture offer of WUT and allowing know-how developed in industry to become part of university education. In 2012/2013 AREVA has provided 4 lectures:

- PWR Nuclear Operation Practice,
- PWR Nuclear Instrumentation,
- PWR Technology illustrated on EPR™,
- Steam Generators – Design and construction.

5. Joint workshop of WUT and AREVA

WUT is realizing the strategy to be the source of nuclear power engineers and expertise for the Polish nuclear industry. To achieve these goals, the WUT is not only focusing on the education of young engineers, but it is pushing to establish a team of experts that will be ready to deal with the issues arising during the construction phase of the first Polish nuclear power plant and later on during plant operation. The National Center for Research and Development (NCBiR) is a state body that provides funding for research and development, especially ones that are focused on industrial applications. The topic of the grant supplied to WUT is: “Elaboration of methods for the safety analysis of PWRs and BWRs in case of
disturbances in coolant system and serious accidents. The safety analysis is to be conducted by the application of the calculation codes RELAP5, TRACE and MELCOR.

Although the American codes were listed in the grant specification, WUT wants to perform the calculations using different codes. WUT got access to CATHARE (French calculation code comparable to the American RELAP5) in December 2012. AREVA greatly facilitated the process of securing the access to CATHARE.

The research work supported by the grant and performed by WUT is important due to the fact that the recipient of the results is the National Atomic Energy Agency (PAA, future regulatory body in Poland). Some parts of the scope of the grant are agreed on with PAA. Even more, the employees of PAA take part in the calculations that are conducted in the framework of the grant. In this sense WUT is convinced that the work is valuable and will be utilized in the future.

To realize the grant funded by NCBiR, WUT managed to build two teams of experts, with members coming from WUT and the Swedish nuclear industry. WUT understands that there is a great need for direct contact with nuclear technology vendors in order to complete the task. The cooperation between WUT and AREVA facilitates the direct contact with the vendor and improves the realization of the grant. A great example of such direct contact was the organization of a common safety analysis workshop. The workshop was titled: Familiarization with calculation codes application and safety analysis workshop. WUT conducted and demonstrated the results of the safety analysis for three pre-selected scenarios pertaining to accidents in nuclear reactors. Prior to the workshop, the three scenarios were developed by AREVA and later jointly agreed. During the workshop WUT presented the approach to modeling and calculations, and specialists from AREVA commented and gave guidance to WUT, discussing whether the models had been prepared in accordance with international standards, and analysis had been duly executed. The agenda of the workshop is shown in Table 3.

The workshop was successful and well received among the participants coming from:

- AREVA,
- Warsaw University of Technology,
- National Atomic Energy Agency (PAA),
- National Center for Nuclear Research (NCBJ),
- Silesian University of Technology,
- Gdańsk University of Technology (PG),
- Polish Nuclear Society (PTN),
- Environmentalists For Nuclear Energy (SEREN Polska),
- Institute of Nuclear Chemistry and Technology (ICHTJ),
- Inspecta AB,
- Baltyn Consulting
- future owner and operator of the first Polish nuclear power plant - PGE EJ 1 Sp. z o.o.

The preparation of the workshop took 4.5 months and was the result of hard work done by WUT and AREVA. There were 35 people directly and indirectly involved in the organization of the workshop (18 – AREVA side, 17 – WUT side or people cooperating with WUT).
**Familiarization with calculation codes application and safety analysis Workshop**

**Agenda**

**September 9, 2013  / Room 105, Institute of Heat Engineering, WUT**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00 – 13:00</td>
<td><strong>Registration and lunch</strong></td>
</tr>
<tr>
<td>13:00 – 13:15</td>
<td><strong>Welcome and Opening Remarks</strong></td>
</tr>
<tr>
<td>13:15 – 13:45</td>
<td><strong>Session 1 – Workshop Purpose</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Status of SARWUT Project</strong></td>
</tr>
<tr>
<td>13:45 – 14:15</td>
<td><strong>Session 2 – AREVA EPR general presentation</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Coffee Break</strong></td>
</tr>
<tr>
<td>14:15 – 14:45</td>
<td><strong>Session 3 – Scenario 1: SBLOCA, 3-loop model, 900 MW. Calculations code: RELAP5, CATHARE</strong></td>
</tr>
<tr>
<td>14:45 – 16:00</td>
<td><strong>Session 4 – Advanced modeling of core in CATHARE</strong></td>
</tr>
<tr>
<td>9:00 – 10:15</td>
<td><strong>Session 5 – Scenario 2: EPR - 20 cm2 Cold Leg Leak. Calculations code: RELAP5, CATHARE</strong></td>
</tr>
<tr>
<td>11:30 – 11:45</td>
<td><strong>Coffee Break</strong></td>
</tr>
<tr>
<td>11:45 – 12:15</td>
<td><strong>Scenarios Summary / Roundtable</strong></td>
</tr>
<tr>
<td>12:15 – 13:00</td>
<td><strong>Session 7 – Safety Analysis for a new plant</strong></td>
</tr>
<tr>
<td>13:00</td>
<td><strong>Lunch and Adjourn</strong></td>
</tr>
</tbody>
</table>

**September 10, 2013 / Room 105, Institute of Heat Engineering, WUT**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00 – 10:15</td>
<td><strong>Session 5 – Scenario 2: EPR - 20 cm2 Cold Leg Leak. Calculations code: RELAP5, CATHARE</strong></td>
</tr>
<tr>
<td>11:30 – 11:45</td>
<td><strong>Coffee Break</strong></td>
</tr>
<tr>
<td>11:45 – 12:15</td>
<td><strong>Scenarios Summary / Roundtable</strong></td>
</tr>
<tr>
<td>12:15 – 13:00</td>
<td><strong>Session 7 – Safety Analysis for a new plant</strong></td>
</tr>
</tbody>
</table>

Table 3. Agenda of Familiarization with calculation codes application and safety analysis Workshop, jointly organized by WUT and AREVA.

6. Summary of cooperation

The cooperation between WUT and AREVA, as one can observe, runs smoothly and is very successful. Both sides are happy with the result of the up-to-date cooperation. WUT, thanks to AREVA, is expanding its research base and having a very attractive nuclear power engineering program. The cooperation with AREVA enriches the work done in the frame of the grant that concerns reactor safety analysis. The summary of cooperation between WUT and AREVA can be found in Table 4.

WUT and AREVA believe that this cooperation poses a good example for universities that want to develop a research base in nuclear engineering and provide education in nuclear power engineering.

<table>
<thead>
<tr>
<th>Cooperation WUT – AREVA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Start of cooperation</strong></td>
</tr>
<tr>
<td><strong>Student Master theses at AREVA facilities</strong></td>
</tr>
<tr>
<td>3 – AREVA Erlangen</td>
</tr>
<tr>
<td>2 – planned for November 2014</td>
</tr>
<tr>
<td>1 – AREVA Offenbach</td>
</tr>
<tr>
<td>1 – Helmholzzentrum Dresden/Rossendorf (with the help of AREVA)</td>
</tr>
<tr>
<td><strong>Student Visit</strong></td>
</tr>
<tr>
<td>1 - MELOX AREVA – MOX fuel Fabrication, FBFC Romance AREVA – Fuel Fabrication, SAINT-MARCEL PLANT - Heavy components</td>
</tr>
</tbody>
</table>
manufacturing, CREUSOT FORGE Heavy forgings and machining capacities, AREVA NC Pierrelatte.

<table>
<thead>
<tr>
<th>PhD Theses</th>
<th>1 (planned for November 2013) – AREVA Erlangen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lectures by AREVA experts, conducted at WUT</td>
<td>4 – 2012/2013, PWR Nuclear Operation Practice, PWR Nuclear Instrumentation, PWR Technology illustrated on EPR, Steam Generators – Design and construction 3 – planned for 2013/2014</td>
</tr>
<tr>
<td>Workshops</td>
<td>1 - Familiarization with calculation codes application and safety analysis Workshop</td>
</tr>
</tbody>
</table>

Table 4. Summary of the cooperation WUT – AREVA.
What are the needs with regard to nuclear education and training?
FROM OPERATION TO DECOMMISSIONING, A TRAINING CHALLENGE IN JOSE CABRERA NPP

J.E. MARTIN, C.A. GOMEZ, R. ESCAMILLA
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J. BORQUE
Dep. Formación y Comunicación, Other ENRESA
C.N. José Cabrera Almonacid de Zorita (Guadalajara) – Spain

ABSTRACT

The Decommissioning Phase (D&D) of nuclear facilities in Spain is currently a responsibility of ENRESA (a national waste management public company), to which ownership of the facility is transferred once it has ceased the operation in accordance with Spanish Nuclear Regulation Jose Cabrera NPP (owner Gas Natural Fenosa) was shut down end of April 2006. In February 2010 the installation has been transferred to ENRESA.

The D&D strategy chosen has been “immediate dismantling”. One of the main advantages of immediate dismantling is to include, in the decommissioning team, people who were involved in the operation of the facility with knowledge of the plant and its operational history. The immediate dismantling strategy has maintained significant number of jobs in the installations (about 70 workers from operation, mainly employees from Gas Natural Fenosa). This ensures a gradual transition and minimizes an uncontrolled loss of resources and knowledge.

Given the novel and diverse nature of D&D, a number of new activities are involved which require training, especially during the transition period, between plant operation and the implementation of a decommissioning, where a number of modifications; both technical and organizational; had needed to adapt the plant to meet new objectives and requirements.

Aspects of qualification of the responsible personnel and other personnel are subject to the regulatory authorization. As compared to operation the requirements have been adapted, according with the progress in dismantling and thus with continuous reduction of the radiological risks. The main objective is to ensure the protection of the workers, the public and the environment against radiation and other hazards.

This paper gives an overview of the experience of José Cabrera NPP in the training and the change of qualification of the workers from operation to decommissioning.

The training plan of each worker or group of them has been designed taking into account the background of the worker and the training needs of the job according to the new objectives and requirements.

1. Introduction
The José Cabrera NPP (hereinafter JCNPP or Zorita) has been a pioneer in the development of the nuclear industry in Spain from its beginnings to its complete D&D. The Spanish nuclear industry has considered Zorita as a training school where technicians have been trained and
have been implemented new developments, requirements and even new regulations. The training in JCNPP has been adapted to the circumstances following the evolution of the life cycle of the plant.

The decommissioning option chosen is “immediate dismantling of the installation” leaving the site free for “industrial use”.

Human resources management, knowledge management and training play an important role to develop the decommissioning process. The main objective is to ensure the protection of the workers, the public and the environment against radiation and other hazards and, also to ensure that the tasks are completed with respect to safety, schedule, quality, and cost considerations.

2. Human resources management & Knowledge management

Knowledge is a dominant feature in our society; knowledge is the basis for all that we do every day. But what is knowledge? Among other definitions we find that “Knowledge is a familiarity with someone or something, which can include facts, information, descriptions, or skills acquired through experience or education. It can refer to the theoretical or practical understanding of a subject.” (Wikipedia). We can define two types:

**Implicit or Tacit Knowledge** is the kind of knowledge that is difficult to transfer to another person by means of writing it down or verbalizing it.

**Explicit knowledge** is knowledge that has been articulated, codified, and stored in certain media. It can be readily transmitted to others. The information contained in encyclopedias are good examples of explicit knowledge.

For example, stating to someone that “dog is a mammal” is a piece of explicit knowledge that can be written down, transmitted, and understood by a recipient. However, the ability to speak a language, use algebra or design and use complex equipment requires all sorts of knowledge that is not always known explicitly, even by expert practitioners, and which is difficult or impossible to explicitly transfer to other users.

The conservation and management of explicit knowledge can be relatively easy as it is related to the maintenance of records in physical or digital, but the conservation and management of tacit knowledge is more difficult because it will be closely related to the Human Resources Management (HRM).

In order to ensure a gradual transition and to minimize an uncontrolled loss of resources and knowledge, the Human Resources Management in JCNPP has maintained significant number of workers from operation with specific skills. In JCNPP has been done reassignment of personnel to new job positions/posts, some of them not previously existing during the operating phase.

3. Decommissioning strategy

Training is one of the essential tools required to achieve a successful transition from the operating phase of a nuclear facility to he decommissioning phase and to implement the decommissioning strategy. The training requirements will, however, depend, among others, of the decommissioning strategy chosen.
The International Atomic Energy Agency IAEA has defined three options for decommissioning:

- **Immediate Dismantling** (Early Site Release/Decon in the US): This option allows for the facility to be removed from regulatory control relatively soon after shutdown or termination of regulated activities. The D&D activities begin within a few years, depending on the facility. Following removal from regulatory control, the site becomes available for re-use (New nuclear installation, Industrial installation or other use).

- **Safe Enclosure** (or Safestor SAFSTOR): This option postpones the final removal of controls for a longer period, usually on the order of 40 to 60 years. The facility is placed into a safe storage configuration until the eventual dismantling and decontamination activities occur.

- **Entombment:** This option entails placing the facility into a condition that will allow the remaining radioactive material to remain on-site indefinitely. This option usually involves reducing the size of the area where the radioactive material is located and then encasing the facility in a long-lived material such as concrete, theoretically preventing radiation release.

UNESA, Unión Española de las Compañías Eléctricas (Spanish Utility Association) is a professional organization which represents the Spanish Utilities interests. Regarding D&D, UNESA has issued Appendix J to the standard contract UNESA-ENRESA to cover the radioactive waste management and D&D of NPP.

The Appendix J of the mentioned contract defines the activities generic program, the way to coordinate those activities and the responsible entity in the process, where the basic milestones are:

- The Cessation of Operation.
- The Ownership Transference to ENRESA.
- The D&D Start Date.
- The Decommissioning Statement.
- The Site Return.

**REFERENCE SCHEDULE**

![Fig 1 Spanish Strategy Schedule.](image-url)
The decommissioning option chosen in José Cabrera NPP was **Immediate Dismantling** that option will be the option follows by other plants in Spain. Figure 1 shows the schedule of Spanish strategy.

Five years before the shutdown, starts the decommissioning on the planning stage. Two drafts of the licensing documentation have been considered. The decommissioning project started 4 years before the shutdown. The first documentation was the Basic Study on Strategies to indicate the best approach; strategies and methods for the D&D Project. Three drafts or proposal of regulatory documentation have been required before obtain the “Dismantling permit”, 46 months after the definitive shutdown.

One of the main advantages of the chosen decommissioning option is that you can keep the knowledge of people who have worked in the previous phase and you can preserve as much as possible the tacit knowledge.

The duration of the transition period, i.e. between the shutdown and the start of the D&D, can be crucial to preserve the knowledge of the people. Excessive time leads to the loss of personnel due to retirement, transfer or abandonment of the company. In the case of José Cabrera this time was relatively short, less than four years, taking into account that at least this stage should be 3 years.

In the world there are several strategies to decommissioning and dismantling a NPP such as:

- The plant operator is responsible for decommissioning of the facility and carries out the decommissioning using his own personnel.
- The responsibility for decommissioning is the plant operator, but the decommissioning is performed with the support of specialist contractors.

Each strategy has its advantages and disadvantages. In Spain the operator transfers the ownership to ENRESA in order to undertake the D&D project. In this case ENRESA is the plant operator contracting part of the staff who is familiarized with the facility systems, configuration, and operating history of the facility. The decommissioning is performed with the support of specialist contractors, being necessary to ensure that the contractor personnel are adequately trained in decommissioning. Also it is needed to provide sufficient information and/or training in relation to the facility systems, configuration and operating history.

### 4. Adaptation of the personnel from the operating phase to the decommissioning phase.

One of the most relevant challenges of the transition period (from the operating phase to the decommissioning) has been the transference of ownership from Gas Natural Fenosa to ENRESA. This transference has been produce on 11 February 2010 and involves a change in the organization of the project.

This change in the organization aims to adapt it to the new activities and objectives. The following two organization charts (Figures 2 and 3) show the organization in force at a plant during the operating (ownership Gas Natural Fenosa) and decommissioning (ownership ENRESA) phases.
The adaptation of the personnel to the organizational changes has required specific training, especially with regard to how to adapt to the new company procedures and culture and new corporate systems (Document Management System, Integrated Improvement System, Regulatory Requirements [IS-19, IS-24, etc.]).
5. Adaptation of the personnel to the new configuration of the plant

After definitive shutdown of the plant and prior to decommissioning, there are several works that can be carried out as preparatory activities. These new activities require specific training, especially during the transition period, where a relevant number of modifications had needed to adapt the plant to meet new objectives and requirements. Some examples about this kind of works are the next:

- Transfer fuel to dry storage system,
- Dry fuel storage,
- Decontamination of the primary system and auxiliary systems
- Radiological characterization of the facility,
- Systems removed from services
- Other activities aimed at facilitating the subsequent D&D process.

Although there has been an important change from operation phase to the decommissioning phase (Table 1), the ultimate objective has always been the same "The workers acquire and maintain the skills necessary to perform their job efficiently and safely".

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>DECOMMISSIONING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliance on permanent structures for the operating life of the plant</td>
<td>Introduction of temporary structures to assist dismantling</td>
</tr>
<tr>
<td>Safety management systems based on an operating nuclear facility</td>
<td>Safety management systems based on decommissioning tasks</td>
</tr>
<tr>
<td>Established and developed operating regulations</td>
<td>Change of regulatory focus</td>
</tr>
<tr>
<td>Predominant nuclear and radiological risk</td>
<td>Reduction of nuclear risk, changed nature of radiological risk, significantly increased industrial risk</td>
</tr>
<tr>
<td>Focus on functioning of systems</td>
<td>Focus on management of material and radioactivity inventory</td>
</tr>
<tr>
<td>Access to high radiation/contamination areas unlikely or for short periods</td>
<td>Access to high radiation/contamination areas for extended periods. Importance of Radioprotection measures</td>
</tr>
<tr>
<td>Low radiation/contamination levels relatively unimportant</td>
<td>Low radiation/contamination levels important for material clearance</td>
</tr>
<tr>
<td>Relatively stable isotopic composition</td>
<td>Isotopic composition changing with time</td>
</tr>
<tr>
<td>Routine amounts of material shipped off-site</td>
<td>Larger amounts of materials shipped off-site</td>
</tr>
<tr>
<td>Well-known working environment</td>
<td>Possibility of unknown working environment</td>
</tr>
<tr>
<td>Routine training and refresher training</td>
<td>Retraining of staff for new activities and skills or use of specialized contractors</td>
</tr>
<tr>
<td>Repetitive activities</td>
<td>One-off activities</td>
</tr>
</tbody>
</table>

Table 1. Operation and decommissioning training requirements.

Many activities and tasks during decommissioning are specifics and only performed one time; for example in José Cabrera NPP the task “Segmentation of internals of reactor vessel”. In such situations it is necessary a specific training program course and training in mockup before the implementation on site.
A new workforce culture (working in a new risk context) focuses on job task has been implemented, as a way to identify hazards before they occur. In D&D Radiological Protection are more relevant than the nuclear safety and conventional risks increase during decommissioning: fire, explosion, electrocution, failure of partially dismantled structures, etc. The Safety culture focuses on the relationship between the worker, the task, the tools, and the work environment. It is necessary to maintain the safety focus of the Staff.

One of the highest radiological risks in D&D is the risk of internal contamination with radioactive material. It has been necessary a extensive monitoring program of workplace and individual contamination.

6. Decommissioning Training courses

One of the pillars of training for decommissioning is the programming of new and recycling courses, which have periodically involved workers of all levels of responsibility.

The decommissioning of a nuclear power plant implies the performance of complex tasks. For this reason ENRESA is implementing a complete training plan, with a view to provide all the workers with the knowledge necessary to guarantee their safety and ensure strict compliance with the requirements imposed by the standards. The Training Plan for the Decommissioning of José Cabrera NPP has applied the directives of the Regulations on Nuclear and Radioactive Facilities, the Regulations on Protection against Ionizing Radiations and the Framework Plan for the Prevention of Occupational Risk.

There is an advantage in using the operators who were engaged during the production phase of the facility, and who are fully familiar with the facility and the operational procedures. These operators and supervisors have a specific license from regulatory body (Consejo de Seguridad Nuclear).

The typical tasks undertaken by the operators include de-fuelling, safety surveillance, waste handling, waste processing, decontamination, and process facility operations. To ensure that all decommissioning work is completed in a safe and efficient manner, the presence of supervisors to oversee the operators is essential.

The training program designed in JCNPP considered two types of workers: personnel with license and personnel without license. During the three first years of decommissioning JCNPP has organized 1,019 courses, attended by some 7,730 people; these courses have included almost 4,000 classroom hours, implying some 19,971 man-hours. (see Tab. 2). Part of those courses has been received by personnel with license (See Tab. 3).

<table>
<thead>
<tr>
<th>Year</th>
<th>Nº Courses</th>
<th>h TOTALES</th>
<th>Nº persons</th>
<th>hxH</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>307</td>
<td>794</td>
<td>2364</td>
<td>5803</td>
</tr>
<tr>
<td>2011</td>
<td>340</td>
<td>1181</td>
<td>2741</td>
<td>7636</td>
</tr>
<tr>
<td>2012</td>
<td>372</td>
<td>1141</td>
<td>2608</td>
<td>6532</td>
</tr>
</tbody>
</table>

Table 2. Training courses of Non-Licensed Staff (Personnel)
<table>
<thead>
<tr>
<th>Year</th>
<th>Training environment</th>
<th>Nº Courses</th>
<th>h</th>
<th>h TOTAL</th>
<th>Nº persons</th>
<th>Manh</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>Face to face teaching sessions</td>
<td>57</td>
<td>54</td>
<td>156</td>
<td>288</td>
<td>640</td>
</tr>
<tr>
<td></td>
<td>Tutored Studies</td>
<td>10</td>
<td>56</td>
<td>56</td>
<td>120</td>
<td>672</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td><strong>67</strong></td>
<td><strong>110</strong></td>
<td><strong>212</strong></td>
<td><strong>408</strong></td>
<td><strong>1312</strong></td>
</tr>
<tr>
<td>2011</td>
<td>Face to face teaching sessions</td>
<td>43</td>
<td>75</td>
<td>142</td>
<td>479</td>
<td>840</td>
</tr>
<tr>
<td></td>
<td>Tutored Studies</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td><strong>44</strong></td>
<td><strong>77</strong></td>
<td><strong>144</strong></td>
<td><strong>490</strong></td>
<td><strong>862</strong></td>
</tr>
<tr>
<td>2012</td>
<td>Face to face teaching sessions</td>
<td>34</td>
<td>77</td>
<td>215</td>
<td>345</td>
<td>733</td>
</tr>
<tr>
<td></td>
<td>Tutored Studies</td>
<td>4</td>
<td>8</td>
<td>8</td>
<td>36</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td><strong>38</strong></td>
<td><strong>85</strong></td>
<td><strong>223</strong></td>
<td><strong>381</strong></td>
<td><strong>811</strong></td>
</tr>
</tbody>
</table>

Table 3. Training courses of Licensed Staff (Personnel)

Table 4 is an outline of the contents of decommissioning training courses that would be applicable to both managers and professional staff. In this table we can see the training similarities with operation phase and specific training courses applied to decommissioning.
## Training: Similarities with Operation Phase

### Basic Initial Training
- Access Course.
  - General Information (Enresa and Decommissioning Project)
  - Emergency Plan
  - Safety Culture
    - Radiological Protection and Industrial Safety
    - Quality Assurance
    - Actions in case of a fire / accident

### Specific Initial Training (depending on job position)
- Radiological Protection
- Emergency Plan
  - Practical exercises (classification of events, communications, radiological impact assessment, etc.)
- Fire Fighting
- Specific Tasks (job position)

### Continuous Training
- Annual Training (Emergency, radiological protection, etc.)
  - Documentation review, lessons learnt, etc.
- Regulator Control
  - Annual Programme is sent to Nuclear Safety Council
  - Training Annual Report
- Specific Programme for Personnel with License
  - Supervisors
  - Operators
- Common Topics (Operation-Decommissioning)
  - Regulatory Documentation
  - Working Procedures
  - International Experience, etc.

### Training Characteristics during Decommissioning Project
- **Enresa «Way of Working»**
  - Information Systems
  - Quality Assurance System
  - Contracting Process
  - Documentation Management and Records Keeping.

### Adaption to Decommissioning Schedule
- **Preparatory Activities (2010-2012)**
  - Modification of Support Systems (ventilation, electrical, fire fighting, etc.) (2010-2011)
  - Modification of Auxiliary facilities (Rad. Waste Stores, etc.)
  - Configuration and Operation of New Installations (2012)
  - Decommissioning Auxiliary Building
  - New Control Room
  - Official Test Plan with Regulator
- **Dismantling Activities**
  - Reactor Internals Segmentation (2011-2012)
  - Radiological Components (2012-2013)
  - Reactor Vessel Segmentation
  - Loading and transfer of Special Waste to Dry Storage Area

### Training According to Organizational Changes
- Key job position incorporation
- Change of job position (dynamic organization)

### Decommissioning Key Processes
- **Material Management**
  - Segregation and in situ Characterization process
  - New equipment (compactor, crane, etc.)
  - Material Release Methodology
  - Surface Release Methodology
- **Safety Culture**
  - Adaptation of Radiological Protection to Decommissioning
  - Industrial Safety (protective equipment, scaffolding, etc.)

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Table 4. Operational versus decommissioning training courses
6. Conclusions

The José Cabrera NPP has been a pioneer in the development of the nuclear industry in Spain and also in the immediate D&D activities.

In order to achieve a successful transition from the operational phase of a nuclear facility to the decommissioning phase and to implement the decommissioning strategy the Human resources management, knowledge management and training play an essential role.

The specific nature of the Spanish case implies the transfer of the ownership from the previous operating to Enresa at the moment of granting of the dismantling permit. The transition period requires time of overlapping between the two organizations.

The adaptation of the personnel from the operational phase to the decommissioning phase requires specific training, especially regarding new organization and company culture, new responsibilities and requirements.
HIGHER LEVEL ACADEMIC NUCLEAR ENGINEERING EDUCATION IN FINLAND – NEED OF POST GRADUATES?

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ABSTRACT

Numerous new experts are needed in Finland to replace retirees and to recruit new ones for the various R&D tasks arising in the nuclear sector. The Finnish nuclear competence review in 2012 showed that of the 3300 professionals over 10% had a postgraduate degree – mostly obtained in the 70’s and 80’s. Even a mature field still needs many high level academics? Postgraduate researchers can be trained in a wide variety of technical and socio-economic R&D tasks of nuclear energy. Strict scientific approach partly assures the quality and enables to create a broader perspective. Besides innovativeness, problem solving skills, and specific personal competence, an expert has to understand nuclear safety and safety culture. In a small country, special and general knowledge may have to be compromised. Postgraduate E&T requires resources to pursue relevant R&D. In Finland long-term funding has been based on national research programs like SAFIR2014 (nuclear safety) and KYT2014 (nuclear waste management). Fusion energy research is fully coordinated by the Euratom-Tekes Association. For Generation IV activities an informal GEN4FIN network has been established. Academy of Finland has financed a research consortium called NETNUC 2008-2011 and the Ministry of Education and Culture is sponsoring the doctoral school on nuclear engineering and radiochemistry, YTERA 2012-2015. The future strategy of R&D and its role in postgraduate education is briefly discussed. We have utilized many European E&T schemes under EFTS (e.g. ENEN, PETRUS, CINCH) and the EU projects containing educational components. The role of European research facilities (JRC, JET, etc.) has been instrumental in researcher training. ENEN and its activities are connected to Finnish postgraduate activities. Fusion researchers have participated in two goal oriented training programs (GOT). The time span in achieving expertise is long: the steps M.Sc. $\rightarrow$ D.Sc./Ph.D. $\rightarrow$ “tenured position” takes a minimum of 5+5+5 years. Besides competent researchers, teachers and instructors are needed, too. Finnish universities have supported nuclear engineering education by creating new tenure track positions. Post graduate studies can follow three routes: 1) full-time (fast) researcher training at academic doctoral schools, 2) part-time graduate studies with university supervision, external instructors/mentors, and participation in R&D programs, or 3) completion of the degree by continuous education during the job.

1. Introduction

The electricity consumption in Finland was 85.2 TWh in 2012 and 25.9% of that was supplied by nuclear power. Imported electricity from Scandinavia and Russia amounted to 20.5%. We have four running units, Loviisa 1&2 and Olkiluoto 1&2, licensed to operate until 2027-2030 and 2018, respectively. The Olkiluoto 3 unit is under construction and for two more units, Olkiluoto 4 and Hanhikivi 1, decisions-in-principle have been ratified. Spent nuclear fuel is to be buried in a deep-rock repository. The underground rock characterization facility ONKALO for geological disposal in Olkiluoto has been excavated and POSIVA is waiting the construction license for the encapsulation plan and for the geological disposal facility. Spent fuel disposal operations are expected to take place in early 2020. The main building blocks to ensure nuclear safety and spent fuel management have been politically solved and the work continues with technical
assessments together with R&D support. A critical condition to use nuclear energy is that
enough competence exists to insure that all operations are safe. License holders are
responsible to have the relevant know-how, but in addition independent expertise of regulators
and researchers must be sufficiently available.

The nuclear competence level in Finland has been regularly assessed against the prevailing
nuclear scenarios. A most hectic period started when the presently operating reactors were
constructed around the 70’es. Then also the main nuclear research infrastructure was created.
Later on, TMI-2, Chernobyl, and Fukushima and less severe incidents have made large impacts
to nuclear research. Plant modernization projects managed to counteract the nuclear stagnation
of the 90’es, but still in 2000 the worst nuclear competence scenario assumed “no new build
and only replacement of retirees”. Even that scenario predicted a considerable E&T need for the
new generation of professionals. The actual situation changed dramatically in 2002 when
Olkiluoto 3 was decided. A large number of professionals have been replaced inside the nuclear
sector and new ones recruited and trained. Academic research has not fully managed this
situation: research positions are economically non-competitive, hard to create and fill. Part time
postgraduate studies have been dispersed by the unavoidable project work.

This paper addresses the question whether we need research minded postgraduates with
higher academic degrees or are experienced engineers sufficient to run safely our nuclear
program. Clearly both are essential. Teachers, supervisors and instructors are indispensable in
all nuclear E&T. Nuclear fission technology may be regarded a mature field in view of current
science frontiers, but still numerous R&D problems have to be solved. Lately September 11 and
Fukushima challenged the safety of present nuclear power plants. Demonstration of safety is
multidisciplinary and involves cross-boundary issues which provide excellent ground for new
innovations and insights. Widening the research to more exotic regions, like Gen IV, P&T of
nuclear waste, thorium fuel and fusion, provides a huge number of postgraduate topics and
enables to find new views and to further validate contemporary procedures.

Today, many factors, however, hamper nuclear energy research: degradation of present
research infrastructure, political reluctance, large resource requirements, and cumbersome
licensing of new facilities. No wonder, only a few countries can afford large scale nuclear
research beyond industrial R&D. Academic studies in Finland have to be based on a few
spearheads and full exploitation of domestic and international collaboration in wider areas.
Nuclear engineering R&D tasks range from basic studies to continuous improvement projects,
and to operation of all facilities in safe, economic and sustainable manner throughout all the
phases from new build till decommissioning and waste management.

The entire nuclear sector needs postgraduates with fundamental researcher skills and proper
attitudes. Besides innovativeness and an ability to tackle new problem areas, they are assumed
to have basics of nuclear safety and safety culture. In a small country like Finland, one has to
compromise between special and general knowledge. A large fraction of Finnish R&D in the
public domain is being done by graduate and post graduate students – of course, senior experts
are essential to supervise this work. Formally, the academic theses as research deliverables
provide quality assurance of the projects; academic degrees can be included into an individual’s learning portfolio with ready accreditation. This paper deals with post graduate studies in Finland. In Section 2 the Finnish nuclear competence survey and the main universities involved are discussed. Section 3 describes the Finnish nuclear R&D networks and their role in postgraduate education. The doctoral school on nuclear engineering and radiochemistry is presented in Sec. 4. Section 5 concludes the paper.

2. Academic E&T activities of nuclear engineering in Finland

2.1 Nuclear competence in Finland - a survey

The intense nuclear activity in Finland has created a large need for new professionals understanding the special features of nuclear energy. The know-how situation has regularly been followed and recently an extensive human resource survey was published in 2012 by the so-called Competence Committee [1]. The statistics of this report notes that in 2010 the total number of nuclear energy personnel was 3285, and from them 1298 had a higher polytechnic degree or a university M.Sc. degree, and 387 a licentiate or doctor degree. Many of the 232 doctoral degrees were obtained in the 70’es and 80’es at the time when the present nuclear power plants and the related infrastructure were established. A large number of academically educated senior experts have in recent years retired or are close to do that.

The Nuclear competence in Finland report displays extensive statistics of personnel according to their specialist duties, competences, degrees, age distribution and work experiences, working sectors, and many other factors. As a conclusion, in the Finnish nuclear energy sector about 1200 new persons has to be educated and trained within twelve years to satisfy the estimated personnel of 4500 in 2025. Persons with higher university or polytechnic degree will increase about 35% from the level of 2010. The number of postgraduates is somewhat hard to predict due to the uncertain evolution of academic positions and the appeal in researcher tracks. The present situation is, however, not expected to change drastically except that licentiate degrees will most probably be gradually abolished.

The premises of Finnish universities to provide postgraduate education in nuclear sector are discussed in the next section. Some experts have in the past obtained their doctoral education in universities other than those specializing on nuclear sector education. Their nuclear qualifications come from on-the-job learning and supplementary education and training. Probably this route of “nuclearization” will continue and should be even enhanced.

As a continuation of the Nuclear competence in Finland survey, a new working group has recently been established to make a strategic roadmap up to 2030 involving R&D focus areas, its resource needs, and ways to enhance international collaboration. This project has an acronym YES, coming from “Nuclear Energy Strategy” in Finnish. YES-discussions deal also fusion research, EC Fusion Roadmap 2050, and its goal-oriented training tasks. An important work package in YES is to explore the need of researcher education. Postgraduate studies are fundamentally related to R&D and plans of its E&T can exploit experiences from our national research programs SAFIR2014 (nuclear safety) [2] and KYT2014 (nuclear waste management) [3], and their predecessors. All these programs have emphasized the importance of researcher
training, and have used the number of M.Sc. and D.Sc./Ph.D. theses as performance indicators. Postgraduate studies require relevant research infrastructure which due to its expenses must more and more be based on international collaboration. A decision to decommission the Triga research reactor of VTT has been made and replacement of its activities should be found. Alternatives exist but how to make the selections. The strategy planning project YES attempts to respond these questions.

2.2 Universities involved in the nuclear energy sector education

Aalto University (Aalto) and Lappeenranta University of Technology (LUT) are the main academic institutions where nuclear engineering (NE) education has been widely covered. The Laboratory of Radiochemistry of University of Helsinki is unique in its own field in Finland. Several other universities are active in the nuclear sector within limited areas. University of Jyväskylä has expertise in nuclear physics, nuclear waste management, and in socio-economic topics. The Physics Department in University of Helsinki is e.g. studying nuclear materials. These are just examples of universities involved; a fuller description can be found in the competence report [1]. A characteristic feature in Finland is that the academic community is rather well networked and collaborative in many disciplinary areas. A wish of improvement is to further the dialogue and understanding between physicists, chemists, social scientists, etc. National research programs can have a great impact in satisfying this goal.

Aalto University started in 2010 when three former academic institutions, Helsinki University of Technology, Helsinki School of Economics, and the University of Art and Design of Helsinki merged. Nowadays Aalto consists of six schools where nuclear engineering is present in the Schools of Science, Engineering, Chemistry and Electronics. Aalto University is very multidisciplinary providing comprehensive coverage of the nuclear field from human behavior to dedicated technologies: fission and fusion reactor physics, thermal hydraulics, nuclear materials, structural safety, power systems, PSA, systems studies, organization management, automation and control, ICT and safety critical IT, and nuclear waste. These activities are scattered into many smaller units which necessitates efficient intra-university networking.

Aalto University has great expectations on multidisciplinarity and the catalytic effects research boundaries can create. On the top level strategy of Aalto sustainable energy has large priority and consortia like Multidisciplinary Institute of Digitalization and Energy (MIDE) have received considerable funding. In the School of Science the Aalto Energy Science Initiative (ESCI) encourages also nuclear projects. AaltoSafe is a platform planned for education and networking within nuclear safety. A master’s degree of Nuclear Engineering is not at the moment anticipated in Aalto. No doubt, such a degree would have an imago value, but to satisfy a comprehensive curriculum of nuclear engineering and, on the other hand, be flexible enough for academic ambitions may be incommensurable. The Otaniemi campus in Espoo is a huge technology concentration in Finland. In particular the vicinity of VTT technical research centre is crucial. Just to mention a few other examples of other R&D institutes: Geological survey, paper and pulp laboratory KCL, IT centre for science CSC, Centre for Metrology and Accreditation Mikes, etc. All these units collaborate with Aalto and recruit many of its postgraduates.
LUT Energy of Lappeenranta University of Technology (LUT) is the largest academic research and education organisation in Finland’s energy sector. It works in close cooperation with VTT and all universities associated within the field. The main application areas of energy technology research include energy production and conversion processes, and energy-efficient equipment and processes in accordance with sustainable development principles. The research operations within these areas are built primarily upon robust basic competencies in thermal dynamics, fluid dynamics and heat transfer.

The primary research area of the Nuclear Engineering Laboratory has been the experimental and computational research of nuclear safety. Several extensive test facilities have been constructed at the university research laboratory for simulation of light water reactor safety systems: PACTEL, PWR PACTEL, PPOOLEX. Unique test data has been produced using these facilities, primarily for the purposes of software validation. This data is utilised every year by various organisations in several SAFIR2014 research programme projects. Using its own test results, LUT has developed calculation codes for thermal-hydraulic and fluid dynamic safety analyses of transient and accident phenomena codes as part of several international projects, such as the ongoing EU projects and within OECD/NEA.

The COUPE project investigates phenomena related to new types of nuclear reactors and is funded by the Academy of Finland. LUT focuses particularly on coupled modelling of gas-cooled Pebble Bed Modular Reactors (PBMR), taking advantage of the institute’s competence in combustion modelling. Reactor physical modelling has been carried out using VTT’s SERPENT software. LUT is a member of the Sustainable Nuclear Energy Technology Platform SNE-TP.

The Laboratory of Radiochemistry of University of Helsinki is the single general university unit in Finland in its field, and is a very large one even on an international scale. Its largest area of research is final disposal of nuclear fuel. The laboratory plays a central national role especially in the study of the behaviour, retention and migration of radionuclides dissolving from nuclear fuel in bedrock and soil. The laboratory has developed an internationally unique method for determining rock porosity, and this is applied, for instance, to in-situ diffusion testing of radionuclides in Olkiluoto. The Laboratory of Radiochemistry also studies the effects of radiation on dissolving of uranium fuel.

Another important area of research related to the nuclear sector is development of inorganic ion exchangers for selective separation of radionuclides from nuclear waste effluents. Fortum Oy produces three types of exchangers developed at the laboratory in industrial scale and these have been used in a large number of nuclear facilities in several countries, the latest and so far largest utilization being the waste effluent treatment at the Fukushima plant in Japan. The Laboratory of Radiochemistry is the leading research unit in the world in this area. The third nuclear-related research field is environmental radioactivity. The most important current research focuses on dissolving and migration of radionuclides from mining mill tailings in the ground and waterways. The laboratory also develops methods for determination of radionuclide contents in nuclear waste.
Aalto University and Lappeenranta University of Technology have expressed a clear policy to support nuclear engineering education and several related tenure track slots have been filled. However, due to retirement the actual increase in personnel is modest. The new positions have involved reactor physics, nuclear safety, waste management, and materials. In addition ICT, risk and system studies, safety critical organizations, are under consideration. Tenure track recruiting with a narrow profile of expertise is uncommon, and professors’ interests usually cover both nuclear and non-nuclear applications.

Postgraduate education in all universities has the general goal of educating proper research minded students, but thereafter real expertise must be reached by "nuclearization" and further on-the-job learning. Stringent measures are being adopted to keep the graduation time short for full time doctoral students. The tenure track system enables researchers' career development, but the number of available slots is limited, salary benefits unattractive, and in particular in technical disciplines there may be too strong weight on science impact factors. Besides full-time research students paid by the university and selected by a general competition, part-time post graduate studies can also be carried out, but then external funding is needed and usually the student has to carry out project work outside his/her thesis to supplement the salary. The third path is the long one where occasional participation in academic courses, continuing education and life-long learning provide the necessary background to write the thesis. In case the accreditation of the studies, learning portfolios, mentoring and tutoring play an important role.

3. Research networks and their role in E&T
3.1. National research programs
Strong domestic collaboration within the nuclear R&D has traditionally alleviated our limited resources available and provided dissemination of results. Nowadays, the role of international collaboration is becoming more important. Nuclear safety research has been coordinated by several national programs: the present one is SAFIR2014 covering 2011-2014 [2]. The predecessors of SAFIR2014 have been assessed and the program format with active steering and reference groups appears to be most cost-effective. Posiva Oy carries the largest part of research on nuclear waste management, but the publicly funded KYT2014 [3] is also an important contributor. The two research programs above involve our current NPPs and waste facilities. Future nuclear energy alternatives are partly sponsored from grants and other separate funding sources. The GEN4FIN network is an example of a live collaboration forum. Fusion energy research has been extensive and efficiently coordinated by the Association Euratom-Tekes.

The mission of the SAFIR2014 research programme, derives from the stipulations of the Finnish Nuclear Energy Act: “The objective of the SAFIR2014 research programme is to develop and maintain experimental research capability, as well as the safety assessment methods and nuclear safety expertise of Finnish nuclear power plants, in order that, should new matters related to nuclear safety arise, their significance can be assessed without delay.” Cooperation and networking are established in order for the Finnish research on nuclear safety to reach the following standard: “The SAFIR2014 research community is an internationally respected and
strongly networked competence hub that has extensive expertise, equipment and methods for conducting internationally outstanding research on nuclear safety issues important to Finnish nuclear power plants."

The SAFIR-programmes have played a significant role in educating a new generation of experts and in knowledge transfer. They have greatly contributed to the R&D resources and provided essential guidance by senior researchers. Networking between academic supervisors and instructors support the career development of part-time doctoral students and also facilitate their future employment. High-level research, international cooperation and contacts between different scientific and technical fields created in research projects contribute to deepening and broadening the know-how among senior researchers. Learning portfolios of E&T during life-long or continuous education tasks, could formally be accredited by a review committee consisting of supervising professor(s) and recommended by reference group professionals. Postgraduate education can also be used to enhance the scientific standard, the number of publications and the span of the research programmes. Doctoral studies may take several years and, therefore, full-time funding of it from research programmes has required additional funding or carrying out projects not directly involved in the completion of the thesis.

The public nuclear waste management program KYT2014 has analogous goals as SAFIR2014 but includes smaller amount of funding and while its spectrum of disciplines is very wide individual projects are relatively small. The goal of KYT2014 is "to ensure that the authorities have such sufficient and comprehensive nuclear engineering expertise and other facilities at their disposal that are needed for comparisons of the various ways and methods of carrying out nuclear waste management". In particular the law stipulates that the research projects "shall be of a high scientific standard and their results shall be publishable". In the project assessment the educational merits are one criterion. Due to the financial limitations KYT2014 has a catalytic effect but can only provide partial funding for thesis work. KYT2014 can also cover topics in life and social sciences.

The third domestic research network is called GEN4FIN. Although, it involves only money for coordination, it serves as a discussion forum for research units and other Finnish stakeholders, and disseminates information on international activities like GIF, ESNII, SNE-TP, NOMAGE4 etc. Generation 4 plans involve very long time goals and it is well suited to university driven projects. A good case is the NETNUC consortium between Aalto, LUT and VTT which was part of the SusEn sustainable energy research program in 2008-2011. NETNUC project was practically the first one of its kind funded by the Academy of Finland. Except fusion research, systematic R&D and E&T of researchers by the Academy of Finland and the Ministry of Culture and Education (MCE) is a reasonably new feature.

Fusion research in Finland has been very successful, in particular, concerning graduate education. One of the benefits has been the coordination by Euratom and of course the continuous, large enough funding. Just to mention a few significant features:

- Instead of an own plasma physics device, we have concentrated on a few large scale tokamaks in Europe, JET and Asdex UG
- The flexible mobility schemes and remote participation have facilitated efficient use of European fusion research campaigns, besides a few long-term researcher secondments.
- Basic knowledge on fusion research has been updated to know-how created.
- Our research areas have evolved to focus into computational plasma engineering, wall-materials and remote handling, and some other technology areas.
- Goal oriented training (GOT) has taken place in both computational areas GOTiT and in remote handling.

GOT provides an interesting comparison between the need of E&T of experts for ITER and DEMO and, on the other hand, similar Generation 4 facilities (cf. ENEN-III). In both regions, the number of people remains for a long time limited and very special expertise is needed.

### 3.2 YK nuclear safety course – a case of nuclearization
The nuclear energy sector requires a lot of various kinds of professionals, but usually their acquaintance in nuclear energy problems is limited. These people need supplementary education in nuclear safety and safety culture – the nuclearization process. The nuclear safety course, YK, is an excellent case put into practice to nuclearization of professional. The first six week long course YK1 took place in 22.9.2003 - 6.2.2004. Today, YK11 has just started and, of course, has evolved and improved during the ten years. Altogether more than six hundred people have been trained. A more detailed description of the YK courses can be found for instance in this conference's Poster sessions. It is worth mentioning that successful passing of the YK-courses has entitled the students 8 ECTS as a part of their post graduate curriculum. The YK courses providing for students a broad view on the nuclear field, is deep enough and insures excellent integration into the nuclear field. YK is also an important possibility for professionals who have done their researcher education in other fields.

### 3.3 National Waste Management course
In 2010 a course covering nuclear waste management (Kansallinen YJH) was launched in 2010. The course curriculum was designed based on the earlier Finnish experiences in teaching the subjects. The full six-day course has been run now since 2011 for around 20-25 students at a time. YJH credits are 1-2 ECTS. The course set-up is similar to the YK-course where the content is produced jointly by the participating organizations. To fully understand the wide range of problems in NWM the course has been favorably received.

### 3.4 International collaboration in education networks
The European and other international E&T schemes under EFTS and the numerous R&D fission projects strongly related to education, have been noticed and exploited in Finland. Aalto and LUT are ENEN [5] members and e.g. YTERA makes use of this network. Similarly there is YTERA connection between University of Helsinki and radiochemistry projects like CINCH, and JRC. The new PETRUS III EFTS also involves a postgraduate component and Aalto University is involved in this project together with other ENEN member universities.

Major European cooperation forums related to Education and Training and maintaining the nuclear competence include also the EHRO-N (European Human Resources Observatory in Nuclear) initiative under the Joint Research Centre in Petten, and the working groups in this
field under the two technology platforms i.e. the Education, Training and Knowledge Management (ETKM) of the Sustainable Nuclear Energy Technology Platform SNE-TP and the Competence Maintenance, Education and Training Working Group (CMET) of the Implementing Geological Disposal of Radioactive Waste Technology Platform IDG-TP.

Today, most of the Euratom R&D projects are supporting participation of young scientists and training of doctoral students. This is an opportunity that could be benefitted more in the Finnish doctoral programme in the future. Also the Jules Horowitz materials testing reactor (JHR MTR) that is participated by the Finnish JHR MTR pool in realising the testing facility, is an important example of the future possibilities to make experimental research in an European facility when it is started around year 2016.

We have compared the activities of the Finnish doctoral E&T programs with analogous European programs. A case study is offered by the characterization and implementation of the education of GEN4 engineers within ENEN-III work packages. In European Fission Training Schemes harmonization and mutual recognition and accreditation of studies is an important topic that has been taken into account also in our education plans.

4. Doctoral program YTERA

Safe utilization of nuclear energy demands thorough knowledge, skills and competence regarding construction, use, decommissioning, and nuclear waste management during the long lifetime of a nuclear power plant. Finland has committed itself to nuclear power for over a hundred years due to its existing NPPs and new builds. After the recent decisions-in-principle the Parliament commitment is strengthened implying also that additional resources are needed to cover all nuclear-specific fields. Research and resources in nuclear have traditionally been scarce in Finland as compared to European standards. The public stakeholder, the Ministry for Employment and the Economy has launched initiatives like the nuclear Competence Committee and the YES strategy group to strengthen E&T and R&D in the nuclear energy sector.

As an essential part of these efforts, Aalto University, University of Helsinki and Lappeenranta University of Technology proposed long-term collaboration of postgraduate education within nuclear engineering and radiochemistry (YTERA). This collaboration originated from NETNUC consortium and GEN4FIN activities. YTERA Doctoral School of Nuclear Engineering and Radiochemistry [4] has its present funding for 2012-2015. YTERA contributes to implementing the statement of the Finnish Parliament, attached to the decisions in principle on new nuclear plants on 1.7.2010: “The Parliament provides that the Government creates such conditions that Finnish labor, competence and enterprises can be utilized in the new nuclear projects.”

Public funding of YTERA is from the Ministry of Culture and Education, the participating universities, and Academy of Finland. In addition, all the nuclear power companies, Fortum Oyj, TVO Oyj and Fennovoima Oy, and Posiva Oy, provide considerable private sector sponsoring for YTERA. All our Finnish stakeholders are members in the YTERA steering committee and can influence the programme. Each student is enrolled in their own university and obey the
respective study regulations. The effective collaboration between the participating universities facilitates acceptance of individual studies between various partners.

YTERA employs seven full time graduate students and 27 associated students with other external funding. YTERA provides courses, seminars and other educational actions and is an important network for nuclear engineering postgraduate students. The enrolled students have actively taken part into conferences, courses and student exchange to abroad which has been secured through the possibility to receive travel grants. YTERA activities are regularly evaluated by students, supervisors and instructors, teachers, and the stakeholders. YTERA seminars enhance social and scientific networking, and the programs are planned and leveled to truly satisfy multidisciplinarity. The stakeholders have all emphasized the need to provide, besides the thesis topic issues, also sufficient breadth of the studies. About half a dozen doctoral degrees are expected to be completed within YTERA by this year.

The goal of YTERA doctoral program is to educate high-quality researchers and experts for the needs of universities, industry, authorities and other society. The program is supported by all relevant interest groups in Finland in the fields of research, education, industry and public authority. The YTERA program also utilizes international education networks for nuclear engineering and radiochemistry where the partners are already members. An essential part of the program is a 6-12 months visit at a cooperating foreign university or research center.

The principal research areas of the graduate program are related with safe utilization of nuclear installations and their development:
- Nuclear engineering, reactors of the next generation
- Geological Disposal of nuclear waste and Partitioning and Transmutation
- Sustainable fuel cycle
- Nuclear safety
- Socio-economic questions and environmental impact of nuclear energy.

Themes for research are long-term applications of nuclear energy and demanding development projects for current plants. This kind of challenging work creates both future teachers and researchers and broad minded top experts that are indispensable for assuring safety and competitiveness of nuclear energy.

5. Discussion
Many more issues should be considered:
- How to enhance R&D in areas where acute demand is high but only a few critical persons are available (ICT, several areas in materials, …)
- Practical realities: personnel cannot be obtained as JOT (just on time) and stakeholders cannot keep reserve personnel.
- How to integrate science in socio-economic areas
- Head-hunting of most promising students?
- The market prospects for narrow-band experts for very long time prototypes (ITER etc.).
- The nuclear taxonomy: a comprehensive, detailed curriculum versus general and flexible course lists?
- How to encourage cross-disciplinary attitudes?
- General ideas of Bloom’s taxonomy are very useful (emphasized e.g. in ENEN-III)
- How to assure long-term funding for full-time research.
- Etc.

To repeat: Nuclear postgraduates with fundamental researcher skills and proper attitudes are needed for R&D tasks involving a wide range from basic studies in the field to the continuous improvement of our running nuclear facilities. Besides innovativeness and an ability to tackle new problem areas the expert is assumed to have particular competences concerning safety and safety culture. In a small country one must to some extent make compromises between special expertness and on the other hand the profound knowledge real generalists’ have to possess.

The time span in achieving reasonable expertise is long – to reach a M.Sc. is typically five years, a D.Sc./Ph.D.-level adds five years and a further five years is needed to obtain a tenured position at a university. In practice, doctoral level research careers in Finland have been pursued during on-the-job training in nuclear industry, universities, and/or research institutes together with a ‘light’ university level supervision and tutoring. Presently, the general trend is to have a stricter formal control on post-graduate studies and thus shorten the graduation times, but at the risk of less-mature skills and knowledge. The economic competitiveness of various R&D paths is an important issue in which also the added value of a formal graduation has to be assessed. Several means, e.g. an “inverse sabbatical”, are worth trying to improve completion of doctoral studies at the research institutes or industry.

6. References
REVISITING THE SLOVENIAN PH. D. THESES IN NUCLEAR ENGINEERING: IS USE-INSPIRED BASIC RESEARCH AN APPROPRIATE GOAL?

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ABSTRACT

Slovenia is the smallest nuclear country in the world. The scarce resources available for the national research activities are additionally affected by the somewhat contradictory but well established concepts of basic and applied research, stipulated by the public research funding agencies and industry, respectively.

To progress strategically towards the use-inspired basic research may be therefore perceived as an adequate option for a sustainable development of a nuclear engineering and safety research group.

An analysis of Ph.D. theses proposed and defended during the 25 years of the Nuclear Engineering Programme jointly operated by the University of Ljubljana and Josef Stefan Institute has been performed to evaluate the main drivers directing the research in the past. More than 20 Ph.D. theses in the fields of thermal hydraulics, integrity and ageing, probabilistic safety assessment and severe accidents were included in the analysis. The evaluation has been performed by the supervisors and authors by answering a set of questions related to the input data, research methods and results.

The results indicate that both students and supervisors largely agree that the use-inspired basic research is the dominant form of the research in the analyzed nuclear engineering Ph. D. theses.

1 Introduction
Slovenia is the smallest nuclear country in the world. The single unit nuclear power plant located at Krško, Slovenia, is jointly owned by the utilities from Slovenia and Croatia. The electricity produced is shared in the 50%-50% fashion by both owners.

Such arrangement brings a full national responsibility towards the nuclear safety to Slovenia and at the same time poses rather strict limits to the resources available for the Slovenian national research. The scarcity of the research resources is furthermore affected by the traditional but somewhat contradictory concepts of basic and applied research, stipulated by the public research funding agencies and industry, respectively.
The dichotomy of the basic and applied science has recently received a wide attention in the literature. Mavko in Kljenak [1] reviewed the doctoral theses in the fields of nuclear reactor thermal hydraulics and severe accidents, from the point of view of “basic” vs. “applied-oriented” They limited the review to the theses completed at the Reactor Engineering Division of the Jožef Stefan Institute within the graduate studies of nuclear engineering at the University of Ljubljana, Slovenia. They showed a preponderance of the basic theses over applied-oriented ones and concluded by survey of the later positions of the holders of doctoral degrees, that the work on basic thesis may still be an adequate basis for future careers in the nuclear or other industries.

Other interesting examples include Tijssen [2], who derived a comprehensive system for the classification of the scholarly journals according to their “application orientation” and Evans [3], who noted that the “industry partnerships draw high-status academics away from confirming theories and toward speculation”. It has to be noted however that it is far beyond the scope of this paper to make a thorough review of such studies.

Stokes [4] on the contrary argued that the basic and applied research may coexists. Louis Pasteur was identified as typical example, since he made a purely basic discovery of the microorganisms while on the mission to improve the brewing process. Stokes’ further examples included Niels Bohr, who pursued basic research without any considerations of use. On the other hand, Thomas Edison was known for his passion for application in the absence of a need for deeper understanding of the causes.

Stokes proposed to visualize the coexistence of the basic and applied research in a two dimensional space with the “Quest for fundamental” understanding” spanning the abscissa and the “considerations of use” the ordinate (see Fig 1). Three quadrants appeared in this visualization scheme: the top left quadrant is dedicated to the pure basic research and is named after Bohr. The bottom right quadrant is dedicated to applied research and is named after Edison. The upper right quadrant accounts for the use-inspired basic research and is named after Pasteur. It is the Pasteur’s quadrant, which was used by Stokes also as the title of his book [4].

Fig 1: Pasteur’s Quadrant [4]
The concept of the Pasteur’s quadrant has not yet been widely accepted by the funding agencies worldwide. It has however already been reported as a successful framework to analyze scientists who have committed themselves to the collaboration between academia and industry [5]. Furthermore, a Brazilian research group active in nuclear energy has already implemented the Pasteur’s quadrant to assess the basic and applied dimensions of a set of Ph. D. theses [6].

The Ph. D. theses produced within the 25 years of the Nuclear Engineering programme jointly operated by the University of Ljubljana, Faculty of Mathematics and Physics, and the Jožef Stefan Institute, were re-evaluated in the view of the use-inspired basic research. The methods and results of this re-evaluation are outlined in this paper.

The re-evaluated theses address the topics of thermal hydraulics, ageing and integrity, severe accidents, probabilistic safety assessment and radiation protection. Part of those theses have been evaluated as basic or applied-oriented by Kljenak and Mavko [1].

<table>
<thead>
<tr>
<th>Input: Nature of the problem</th>
<th>Process: Nature of the performed research</th>
<th>Output: Perspective of immediate use</th>
</tr>
</thead>
</table>
| Which of the answers below most closely describes the nature of the problem investigated in the Ph. D. Thesis)?  
1 Totally theoretical  
2 More theoretical than practical  
3 Balanced between theoretical and practical  
4 More practical than theoretical  
5 Totally practical | Which of the answers below most closely describes the nature of the research performed to complete the Ph.D. Thesis?  
1 Pure basic research without aiming for immediate economic and/or social benefits or for solutions to the practical problems  
2 Basic research aiming at knowledge construction for use in an undefined future  
3 Basic research aiming at knowledge construction for use in the near future  
4 Applied research to solve problems defined in the present  
5 Development to obtain new products, processes etc. or their improvement in the present | Which of the answers below most closely describes the perspectives of immediate use of results of the Ph.D. Thesis?  
1 Theoretical foundations for other theoretical studies  
2 Theoretical foundations for other theoretical and experimental studies  
3 Incorporation in technologies on the laboratory scale  
4 Incorporation in technologies on a pilot scale  
5 Incorporation in technologies for commercial use |

Tab 1: Variables and questions for the »Consideration of use«.  
All three variables are weighted equally.
2 The Method

The method implemented in this paper is based on the paper by Hoppe de Sousa et al [6], which has been derived while putting in practice the Pasteur’s quadrant assessment of the Brazilian Ph. D. theses in nuclear energy. The method is for the sake of completeness briefly outlined below. Please note that some minor adaptations, mainly in the wording of questions and predefined answers, have been developed for the purpose of this analysis.

Hoppe de Sousa et al [6] broke down each of the axes in Fig 1 in three separate variables, describing the three stages of the creative research process: input, processing and output, respectively. These variables were then evaluated through questionnaires with predefined answers. Each of the answers assumed an integer value, as outlined in Tab 1 for the Consideration of use and Tab 2 for the Fundamental understanding.

<table>
<thead>
<tr>
<th>Input: Knowledge requisites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which of the answers below most closely describes the knowledge requisites required to initiate the research in the Ph. D. Thesis?</td>
</tr>
<tr>
<td>1 No theoretical and in-depth knowledge in many knowledge areas</td>
</tr>
<tr>
<td>2 Limited theoretical and good practical knowledge in few areas</td>
</tr>
<tr>
<td>3 Limited theoretical and practical knowledge in some specific knowledge areas</td>
</tr>
<tr>
<td>4 Good theoretical and practical knowledge in some specific knowledge areas</td>
</tr>
<tr>
<td>5 Profound theoretical-practical knowledge in a specific area</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process: Knowledge generation process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which of the answers below most closely describes the knowledge generation process utilized to complete the Ph.D. Thesis?</td>
</tr>
<tr>
<td>1 Experimentation and aggregation of new knowledge to a broader knowledge base as the initial research problem</td>
</tr>
<tr>
<td>2 Experimentation and aggregation of existing knowledge to the same knowledge base as the initial research problem</td>
</tr>
<tr>
<td>3 Integration and/or classification and/or systemization of existing knowledge</td>
</tr>
<tr>
<td>4 Deepening the existing understanding and knowledge on the wider knowledge base than the initial research problem</td>
</tr>
<tr>
<td>5 Deepening the existing understanding and knowledge on the same knowledge base as the initial research problem</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Output: Knowledge progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which of the answers below most closely describes the contribution(s) of the Ph.D. Thesis?</td>
</tr>
<tr>
<td>1 Extraordinary technological advancement (e.g., change in the quality of life)</td>
</tr>
<tr>
<td>2 Significant technological advancement (e.g., publications in the upper half of the SCI journals, international patents)</td>
</tr>
<tr>
<td>3 Moderate scientific and/or technological advancement (e.g., publications in the lower half of the SCI journals, national patents)</td>
</tr>
<tr>
<td>4 Significant scientific advancement (e.g., publication in the upper half of the SCI journals)</td>
</tr>
<tr>
<td>5 Extraordinary scientific advancement (e.g., publications in top journals, for example Nature)</td>
</tr>
</tbody>
</table>

Tab 2: Variables and questions for the »Fundamental understanding«. All three variables are weighted equally.
The values of the two sets of three variables are therefore defined by the person answering the questionnaire. The final values are summed (with equal weights) resulting in a point in the two dimensional space limited by the points (0, 0) and (0, 15). Equal spacing has been chosen for the quadrants: the Pasteur’s quadrant is therefore limited by the points (7.5, 7.5) and (15, 15).

Both students and supervisors have been asked to evaluate each of the dissertations independently.

3 The Data
Thirty tree (33) Ph. D. theses have been completed in the 25 years being supervised by 11 supervisors.

For 21 theses, both the student and the supervisor answered the questionnaire independently of each other. These 21 theses have been further analyzed in this paper.

Nine (9) supervisors answered the questionnaire. Four (4) of them supervised 1 thesis, 4 supervised 2 theses and 1 of them supervised 9 theses.


4 Discussion of Results
The results (answers) obtained from the students and supervisors are summarized in Fig 2.

The top row of figures depicts the answers obtained by the students. The three leftmost figures depict the positioning of the individual dissertations in the Pasteur’s quadrant by each of the creative phases, input, process and output, respectively. The rightmost figure places the whole dissertations (non-weighted sums of input, process and output) in the Pasteur’s quadrant.

The middle row of figures depicts the answers obtained by the supervisors. The three leftmost figures depict the positioning of the individual dissertations in the Pasteur’s quadrant by each of the creative phases, input, process and output, respectively. The rightmost figure places the whole dissertations (non-weighted sums of input, process and output) in the Pasteur’s quadrant.

The bottom row relates the assessments of the students and supervisors. The arrows point from the estimate provided by the student to the estimate proved by the supervisor. The structure of the figures is the same as in the upper rows: depiction of individual creative phases on the left and total placement on the right.

The following observations are noted in Fig 2:
- The vast majority of the points in the combined (rightmost column) figures fall into the Pasteur’s (use-inspired) quadrant. This goes for both students and supervisors.
- A few points can be found in the Bohr’s (pure basic research). This goes for both students and supervisors.
The Edison’s quadrant seems to be the very least populated: only one among the students felt that there is more applied than basic research added value in his or her thesis. Supervisor and student disagree in this particular case.

The generation of the new knowledge (basic science) was seen among the main incentives for the Ph. D. research by both students and supervisors. This probably explains the fact that virtually all of the analyzed theses lie in the upper half of the figure indicating contributions to the basic science.

Supervisors generally tend to assess the contributions of the theses more in the basic and less in the applied science than students do.

Estimates by students:

<table>
<thead>
<tr>
<th></th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
<th>All three combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental understanding</td>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
<td><img src="image3.png" alt="Graph" /></td>
<td><img src="image4.png" alt="Graph" /></td>
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Considerations of use

Estimates by supervisors:

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<tr>
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<th>Input</th>
<th>Process</th>
<th>Output</th>
<th>All three combined</th>
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<tr>
<td>Fundamental understanding</td>
<td><img src="image5.png" alt="Graph" /></td>
<td><img src="image6.png" alt="Graph" /></td>
<td><img src="image7.png" alt="Graph" /></td>
<td><img src="image8.png" alt="Graph" /></td>
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</tbody>
</table>

Considerations of use

Compare students and supervisors. For each dissertation, the arrows point from the estimate provided by student to the estimate proved by supervisor.

Fig 2: Summary of results
The quest for fundamental understanding is therefore not to be seen as an obstacle to the considerations of use or vice versa. On the contrary, there seems to be a tacit agreement between the students and supervisors that the use-inspired basic research is the dominant form of the research in the analyzed nuclear engineering Ph. D. theses.

No data clustering by supervisor or by the year of Ph. D. dissertation has been noted in the analysis.

5 Conclusions
The results indicate that both students and supervisors largely agree that the use-inspired basic research is the dominant form of the research in the analyzed nuclear engineering Ph. D. theses. The quest for fundamental understanding is therefore not to be seen as an obstacle to the considerations of use or vice versa.

To progress strategically towards the use-inspired basic research may be therefore perceived as an adequate option for a sustainable development of a nuclear engineering and safety research group.

6 Acknowledgement
The authors would like to express the gratitude to the European commission, Slovenian Ministry for Science, Research Agency and the Nuclear power plant Krško, who funded the Ph. D. research analyzed in this paper. The authors are also greatly indebted to all students and supervisors who took time and evaluate the questionnaires.

7 References
COLLABORATIVE TRAINING DEVELOPMENT IN NUCLEAR WASTE MANAGEMENT IN FINLAND

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ABSTRACT

In 2010 a course covering nuclear waste management ("Kansallinen YJH course" or National YJH course as used in the following) was launched. The impetus for the course development resulted from an evaluation of the KYT2010 programme (Finnish Research Programme on Nuclear Waste Management) pointing out the need to address competence maintenance also by the means of training not only in research projects. The National YJH course curriculum was designed based on earlier Finnish experiences in teaching the nuclear waste management subjects. The current course with a six day curriculum has been running since 2011 for around 20-25 students at a time and equalling 2 ECTS. The course set up is similar to the Finnish YK-course in nuclear safety, where the content is produced also jointly by the participating organizations. The practical course coordination has been carried out by Aalto University, first with the KYT2010 assistance and later based on a cost sharing principle by the participating organizations. The course has been favourably received both by the participating new staff members and by their employers since the course provides a basis for the new professionals to fully understand the wide range of multidisciplinary issues that need to be addressed in nuclear waste management.

1. Introduction

Nuclear Waste Management is a multidisciplinary field. Traditionally the professionals in the field have a basic education in some technical or scientific discipline prior entering the field of nuclear waste management. In Finland, the personnel working in this field are employed by the nuclear waste management company Posiva Oy, the authorities (MEE and STUK), the utilities, universities and research organisations, and by consulting companies.

In the nuclear energy sector it has been customary to invest to the development of personnel by internal training that is complemented with on the job training /1, p. 65 /. In the nuclear safety field the YK course on Nuclear Safety was set up in collaboration in 2003 with the various stakeholders in the field (1, pp. 67-68) and (2). In the field of waste management, the critical mass of participants was smaller. Training was carried out mainly by the main organisations themselves or in limited cooperation. No general curricula models either existed for such training. However, cooperation had existed for several years since the 1980s between STUK and the Geological Survey of Finland and VTT, and between Posiva Oy and
VTT (1, p. 68) since 2003. These have formed the first basis for the course curriculum development, too.

A new staff member independent of whether he or she is a recent graduate or a more experienced specialist in his or her field is often very dependent on one’s superior and on one’s colleagues in the discovery process of the core new knowledge about nuclear waste management and all of the activities that have been carried out during the last 30-40 years in Finland. A new entrant does not necessarily possess such a large network of contacts in the nuclear waste management community, or the wider picture of this multidisciplinary field of research and technology has not yet dawned on the newcomer. Often the other organizations and stakeholders working in the field are also unknown.

In 2006, a Finnish Research Programme on Nuclear Waste Management KYT2010 was established. In the independent review report of this first programme phase (3, pp. 17-18) attention was paid to the lack of a national training initiative in the field of nuclear waste management. Resulting from these review findings a preliminary planning group and the writers of this paper consisting of a representative from the Ministry (MEE), STUK and Posiva Oy started talks in 2008 on how to address this training needs issue. Further organisations were engaged into the process and a pilot course was organized with Aalto University as the course coordinator with KYT2010 support.

2. A National YJH Course Kicked-off

The pilot course run in 2010 was two and half days long. In 2011, the National YJH course curriculum was extended and repeated in 2012 and 2013. The third full length 6-day course took place in October 2013. The main extensions to the content included an overview of the legal and regulatory framework applicable in Finland and a more in-depth look at the different components of Posiva’s Safety Case as a part of the construction license application for a deep geological repository.

The underlying idea of the course is to provide an overview of the nuclear waste management as a whole. The course is complementary to the YK course that has run since 2003. In its current form the National YJH course replaces Posiva’s specific induction course for new staff that run until 2011. A new National YJH course is under planning for 2014 with new participant organisations desiring to join the consortium producing the course.

Almost 100 professionals have now participated in the course and the feedback has been favourable from all stakeholders. Feedback has been collected both from the participants and from the organisations providing the course content (lectures, excursions and exercises) and sending participants to the course. National YJH course has now been run successfully for four years and this paper and a poster discuss the course organization, curriculum development and its implementation (4, pp.14-16).

The course planning group has extended and in 2013 Ms. Jaana Avolahti from TEM continued to chair the group. The other group members are Marjatta Palmu from Posiva, Kari Rasilainen from VTT; Jari Tuunanen from Fortum; Anssu Ranta-aho from TVO; Mia Ylä-Mella from Fennovoima; Kaisa-Leena Hutri from STUK; Risto Harjula from Helsinki University, Laboratory of Radiochemistry; Timo Saanio from Saanio & Riekkola Engineering Consultants; and Jussi Leveinen from Aalto University, who have contributed to the course development and its content. These organisations are also the ones who can in exchange to their input to the delivery of the course send their staff members to the course as students. The coordinators have come from the Aalto University. An approval was made by the planning group to include the University of Jyväskylä and Pöyry consulting company to the consortium and discussion on their role in the consortium has been initiated.
3. Curriculum and Delivery of the Course

The course content covers topics from the legal and regulatory framework internationally and in Finland. The nuclear fuel cycle is covered from the origin of the uranium to the geological disposal of all types of nuclear waste. Radioactivity and waste classification and international developments in both LILW and HLW and spent fuel are covered. Decommissioning and interim storage solutions and the contents of Posiva’s Safety Case are addressed. Advanced reactors and alternative concepts for final disposal are presented as shown in Tab 1.

<table>
<thead>
<tr>
<th>Day 1</th>
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<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course objectives (Group exercise)</td>
<td>Nuclear Fuel cycle</td>
<td>Low and intermediate level waste: Operating waste and decommissioning; Safety case for operating waste</td>
<td>EBS: Buffer and Backfill</td>
<td>VTT waste laboratories and FIR1 research reactor</td>
<td>Special topics:</td>
</tr>
<tr>
<td>Regulatory requirements</td>
<td>Nuclear safety principles</td>
<td>Geological disposal:</td>
<td>Safety case for spent fuel (TURVA 2012)</td>
<td>Repository evolution and scenarios</td>
<td>Group exercise on argumentation for safety</td>
</tr>
<tr>
<td></td>
<td>Waste classification</td>
<td>KBS-3 disposal system. Engineered barriers (EBS): Canister</td>
<td>VTT and Aalto underground research laboratory facilities</td>
<td></td>
<td>Feedback discussion</td>
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<td></td>
<td>Nuclear waste management outside Finland</td>
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</table>

Tab 1: National YJH course curriculum in 2013.

Besides lectures provided by thirty different experts and tutors, the students are engaged in group work around their own objectives for the course and in preparing arguments for safety (Fig 1). The timing of the activities is depending also on the constraints posed by the length of each day and earlier also on the possible access times to the research reactor, which was used for medical radiotherapy.
Within the 6 days also excursions are included: to the Triga research reactor FIR1 in Otaniemi and to the laboratories of VTT’s nuclear waste management team studying various long-term safety related phenomenon and processes. A further set of excursions take the students underground to the geosciences excavation test tunnel of Aalto University (Fig. 2) and to the underground research hall of VTT.

Fig 1: Getting acquainted and sharing learning objectives (Photos: Marjatta Palmu 2012)

Fig 2: Excursion to Otaniemi Underground (Photo: Lauri Uotinen, Aalto University 2012)
4. Experiences from the Course

Even though the course length in days is 6 days, the course days range from 8:30 am to 5 p.m. The course includes a total of 40 hrs of learning activities for the participants and responds to around 2 ECTS at the Aalto University depending on the final exercise input by the students desiring academic course credits.

The students are also encouraged to maintain their newly created network of radioactive waste management professionals. Several networking opportunities are covered both nationally and internationally starting from the ENS Young Generation networking events to the ENEN association, and the IGD-TP opportunities. A LinkedIn group has been set up for the students, course alumni, and lecturers.

From each course a feedback is collected from the participants both orally in a feedback discussion and by a feedback questionnaire. The feedback is then compiled and discussed in a feedback meeting right after the last course days by the planning group. The lecturers and organisers of the course are also asked for their oral feedback during the planning meeting. The feedback is included into the content and to the delivery methods of the course when the next course is carried out. At the moment, it is not possible to extend the scope of the course beyond the six days. Thus the students are encouraged to network and to participate in other events that complement the knowledge and skills received during the course.

The National YJH course is also one of the arrangements for education and training of staff on the national level in waste management as required by the new Waste Directive 2011/70 (5, p. 54).

In the 2012 evaluation of the on-going Finnish Research Programme on Nuclear Waste Management KYT2014 the review team regarded the National YJH course as successful. It offers opportunities for many to become familiar with the subject and it also clearly promotes networking among its participants with different backgrounds (6, p. 17).

5. References:

DEVELOPMENT AND ACTIVITIES OF THE PROJECT
“ENGINEERING RESEARCH AND EDUCATION ON SAFETY AND SECURITY UNDER LOW-LEVEL RADIATION ENVIRONMENT”

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ABSTRACT

For the future generations, it is needed to cultivate a steady and sustainable culture of safety in the field of nuclear engineering. It is imperative to introduce a structured knowledge in the field of nuclear education and research. Okayama University is one of the leading universities in Japan, and we have run an education and research program related to nuclear engineering and radiation health problems since October 2008. The major object of this programme is to supply human resources who possess not only high level skill and knowledge on nuclear problems but also ethics as a professional engineer. It has been made much effort to establish a graduate program in this field. In addition, we have keenly joined an engineering project for closing a uranium mine, which has been managed by the Ningyo-toge Environmental Engineering Center of the Japan Atomic Energy Agency (JAEA), and these experiences strictly help to develop our research and education programme. Cultivating human resources in the field of safety and security management is of a prime concern in nuclear engineering. Okayama University is the only one institution that provides a higher educational and research programme, especially on a low-level radiation environment. We have exchanged information for research and education with domestic institutes and international organizations. Above all, the universities joined to the Japan Nuclear Education Network have been cooperating. An open seminar and international joint workshop were arranged under this program. We provided an atmosphere to the participants with open-minded discussions and then established deeper cooperation beyond organizations. Eventually students started to think critically and logically. The new environment after the Great Eastern Japan Earthquake and Tsunami should be taken into consideration for our future educational activities. Indeed, the lack of experienced engineers in the field of nuclear waste management becomes obvious because of the severe accident of the Fukushima-Daiich nuclear power plants. The Ningyo-toge area which is located in Okayama prefecture is now important related to nuclear waste treatment and disposal. The Ningyo-toge project contributes to the progress of research and education on the safety and security management of radioactive wastes (henceforth, radwastes). Now we aim to extend our program to cover mitigation of natural disasters and human behavior when committing a severe natural disaster. It will help the international nuclear community which requires a new challenge after the Fukushima accident.

1. Introduction

After the severe accident of the Fukushima nuclear power plants due to the Great East Japan Earthquake and Tsunami, the safety management must be reconsidered. Obviously we have not the sufficient number of experts in the field of nuclear waste management. In the site a massive amount of radioactive wastes are daily produced, and the wastes must be treated and disposed. It should be noted that the radwastes are a negative heritage of nuclear use. In this paper we show research and education project “Engineering Research and Education on Safety and Security under Low-level Radiation Environment” in Okayama University. Now the aim of this project is to enhance the tolerance ability of our human society against severe natural disasters. We understand that one of the important roles of the university is to challenge the keen social issues. Without question the radwaste management
due to the Fukushima accident is such the keen problem. The cleanup work will last more than 30 years, and we are obliged to supply well-educated professional engineers and technicians continuously.

2. The project “Engineering Research and Education on Safety and Security under Low-level Radiation Environment”

Its main aim is to give a solution to the urgent requirement of human resources with high level skill and knowledge on low-level radiation environment. Master and Doctoral education course programme on this topic was already established. The development of human resources is of prime importance for safety and security management of worldwide nuclear environment. Okayama University is the only one that provides a higher educational and research programme on low-level radiation environment in Japan. The duration of the project is 4.5 years (Oct. 2008 – March 2013). This project was granted by Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan and Okayama University. 1.5 years (Oct. 2008 through March 2010) was for preparing Master Course and 3 years (April 2010 through March 2013) for Doctoral Course. These courses were in 3 graduate schools of Okayama University, i.e. Graduate School of Health Sciences, Graduate School of Environmental and Life Sciences and Graduate School of Natural Science and Technology. Teaching staffs were not only from Okayama University but also from other Japanese Universities (TITEIC, Osaka Univ. and Fukui Univ.), Chugoku Electric Power Company and JAEA. Also foreign professors and researchers were invited for this education programme. Lectures prepared by JNEN (Japan Nuclear Energy Network supported by JAEA) are offered to students by use of private network education system.[1]

The research plans have been started to find solutions for the Ningyo-toge former uranium mining site problem. Ningyo-toge is in a north region of Okayama prefecture of Japan, the JAEA developed a uranium mine, which was already closed. We have discussed the tailing problem of that mine. Note that the tailing is a Naturally-Occurring Radioactive Materials/Technologically-Enhanced ones, called as NORM/TENORM. Because of world-wide increasing demands of nuclear energy, the radwastes become more serious problem including these NORM/ TENORM and the radwastes produced by nuclear accidents. Fig.1 shows an outline of this project.

![Fig.1 Outline of the project “Engineering Research and Education for Safety and Security under Low-level Radiation Environment”](image-url)
2.1 Steering Committee
To manage this project Okayama University prepared Steering Committee, chaired by Vice President (in charge of Education). This committee was organized and started its function to check curriculum for the improvement for Master and Doctor Courses and to verify progress of research plan. This project is approved by MEXT, Japan and offered financial support with Okayama University. The enrolment in the masters program has increased, starting with 7 students in 2008 to 22 students in 2012. The enrolment in the doctoral graduate program was 2 in 2010 and 6 in 2012. The largest participation at the master’s level was in the Natural Sciences and Technology area, which had the highest potential for employment both within the Nuclear Energy production sector and the Regulatory Sector. The educational background of the students tended to vary from the pure sciences to engineering and both governmental and private sector businesses could benefit from the graduates.

2.2 Education
We prepared these education courses for Master and Doctor as to reflect new knowledge and technology obtained through wide-range researches on 1) risk communication with local community neighboring nuclear and its relating facilities, 2) accident prevention based on risk management, 3) safe and secure management of nuclear facilities and development of destruction technology after its closure. The graduate courses consist from the cooperation of four existing graduate schools (Graduate Schools of Natural science, Environmental and Life Science, Human Health Science and Humanities and Social Science) of Okayama University. By suggestions from supervisor students can select lectures from these four graduate schools and also from lectures offered by JNEN, which are sent to 6 universities as Tokyo Institute of Technology, Ibaraki University, Kanazawa University, Fukui University, Osaka University and Okayama University via network. The universities of JNEN have cooperated with related organizations to educate students as professionals with a higher sense of ethics.

2.3 Cooperation with JNEN
JNEN has been initiated in 2007, lectures are provided through the system at real time to the students at various universities. JNEN is a real-time and interactive remote education system using internet (Virtual Private Network) [1], as illustrated in Fig. 2.

![Fig.2 Japan Nuclear Education Network (JNEN)](image)

The students and the professors of 6 universities can make Q&A and discussions through wide monitors multi-directionally on the real time. The students can also review by the e-
learning system after the lectures.[2] Since 2010, Okayama University have provided for New Lecture “Environments and Human Activities”. This lecture is a summer session gathering students and teachers from the universities of JNEN to Okayama University in Fig. 3. It is organized as a 5-day intensive course including lectures, group discussion, presentation and debate. Active learning is important for students to develop a broad vision and to think for themselves.

Fig. 3 The Lecture “Environments and Human Activities”

3. COOPERATION WITH STAKEHOLDERS

Safety culture [3] is essentially important in nuclear engineering because the use of nuclear energy is inevitable for our future generations. After the Fukushima accident, most Japanese people feel anxiety not only to nuclear engineering but also to science and technology. In order to build up a believable safety culture into all persons concerned with the nuclear engineering, the followings are particularly important.

1. Involvement of individual/organization responsibility into safety culture
2. Mutual understanding and sharing of safety information between organizations
3. Inheritance of technology and safety knowledge

Safety culture is the whole of the attitude and characteristics of organizations and individuals. When committed to a crisis, a quick decision is required. The information including risk must be shared by all stakeholders. An accident of a nuclear power plant causes profound effects on the broad region. As stated previously we live in the era after the Fukushima accident. It is our essential purpose to cultivate the safety culture in each engineer and stakeholders through our education programme.

3.1 International Symposium, Seminar and Workshop

We have already started to cooperate with domestic and international organizations. It is also our scope to contribute to local social and economic bodies such as local governments, NPOs, Okayama-based corporations and Ningyotoge Environmental Center of JAEA. Since 2008 Okayama University held a series of international and domestic symposia on nuclear safety and radwaste management. The symposia were open for citizens. We also organized international seminars to educate young scientists and engineers. In 2012, The 5th Environmental and Energy Symposium & International Workshop (Co-sponsors; Tokyo Institute of Technology) were held at Okayama and Tokyo. The graduate program has benefited from international events such as the International Joint Workshop on Nuclear Energy and Radioactive Waste Management Activities. Efforts could be made to include other International Meetings and Special Sessions organized by the Japanese and international scientists involved in management of nuclear wastes, with special emphasis on aspects of the Fukushima event. Younger faculty and graduate students should be encouraged to participate at these events as shown in Fig. 4.

A Special Seminar of scientists and engineers working to develop waste management
strategies could be a useful activity.

Fig.4 Workshop “What happened in Fukushima?” and The 5th Environmental and Energy Symposium & International Workshop

3.2 Networking
The project has successfully contributed to the progress of cooperate with domestic and international organizations. The exchange of students and researchers related the present effort have lead to positive result of interactions and networking. This should be strengthened through scientific exchanges of both students and younger faculty. It has been shown that multidisciplinary discussions on the issues to nuclear power are very fruitful and promote common understanding.

4. For the Future
Nuclear power is utilized in many countries, and the safe use of nuclear energy is our common interest. The final and most difficult problem is the radwaste disposal. This project was inaugurated before the Fukushima accident. The primary social concern at that time was how to reduce the emission of carbon dioxide. It was the era of ‘nuclear Renaissance’.
We now inhabit the post-Fukushima era. Under this altered circumstance, we focus on the following four fields of nuclear engineering.

Field 1; Environmental security and management after the accident
Field 2; Radiation safety and healthcare
Field 3; Safe decommissioning of the power plant
Field 4; Risk assessment/management and risk communication

In order to contribute to the radwaste problem, we have initiated a new Project for Disaster-Resistant Nuclear Facilities and Radwaste Management, called as DiRaM, in FY2013 under the support of MEXT. We will establish a R&E center in Okayama University under support of IAEA and JAEA.

References
The National Institute for Nuclear Science and Technology (INSTN) stands out as a specifically nuclear-oriented higher education institution in France. Under the joint supervision of the Ministries in charge of Education and Industry, the INSTN offers advanced courses to engineers, university graduates, technicians and professionals in the applications of nuclear physics, from power generation to the use of radionuclides in biology and medicine. High quality and up-to-date knowledge and know-how is provided by cutting-edge scientists from CEA but also university staff as well as experts from the industrial sector, from the medical area and from regulatory authorities. In all, over 1400 specialists participate in the education and training programs offered by the INSTN. National and European academic and vocational courses cover the full spectrum of nuclear education ranging from nuclear engineering, science and economics, nuclear medicine and radiopharmacy, molecular imaging and instruction for nuclear technicians. The courses are delivered in a modern setting and make use of specific infrastructures and tools such as a training reactor, reactor simulators for normal and accidental operating conditions, research and industry codes, radiation protection facilities, electronic microscopes and a Van de Graaff accelerator. Presently, online courses on a research reactor are also being developed.

At the international level, the INSTN is involved in several European projects aimed at the implementation of nuclear education and training on nuclear engineering (ENEN III), radiation protection (ENETRAP II) as well as, in the new Framework Program 7, on radioactive waste (PETRUS III) and sharing and growing nuclear safety competences (NUSHARE). The INSTN is also the founding member of the European Nuclear Education Network (ENEN), a nonprofit association with 64 members, including academia, research centers and industry, from 18 EU countries plus South Africa, Ukraine, Japan and Russian Federation. With a wealth of experience in international collaboration for many years, the INSTN is committed to the development and harmonization of the European higher educational area in all domains of nuclear science.

Introduction
The Institut National des Sciences et Techniques Nucléaires (INSTN) has been created in 1956 within the French Alternative Energies and Atomic Energy Commission (CEA) when France decided to launch the civil nuclear program. Originally designed to train mainly EDF professionals and engineers to acquire a high level of scientific and technological qualification in nuclear energy, the INSTN has now set up a broad range of further education in cutting-edge disciplines (nuclear engineering, material science, health science, nanoscience) relying on the skills available at the CEA and in other institutions and companies such as, for the nuclear power sector, EDF, AREVA, and IRSN the French TSO. The institute has also invested in the development of innovative pedagogy with the implementation of new distance learning courses on nuclear reactor operation as well as radiation protection courses and serious games. Experimental facilities such as training reactor, ICT facilities including new generation PWR simulators, field school for decontamination and radiation protection, laboratories for the practical training in radiochemistry, radiation protection, detection and measurement of β, γ, neutron and X rays are available for trainees. In addition, its location allows an easy access for students and professionals to the extensive facilities of CEA laboratories.
With a permanent academic and administrative staff of about 110, plus the backing of some 1400 experts from national and foreign academic and scientific institutions as well as industries (EDF, AREVA, Siemens…), regulatory bodies and hospitals, the INSTN hosted in 2012 about 8000 trainees for continuous education and 800 students for academic degree programs.

Over the past years the involvement of the INSTN in education and training at the international level has strongly increased with the development of both academic and vocational programs. Presently up to 30% of our students are foreigners. A large panel of international courses lasting one to two weeks has also been implemented on a yearly base and covers neutronics, thermo-hydraulics, nuclear materials, principles and operation of nuclear reactors as well as fuel cycle and reactor dismantling topics. In addition, international tailored made trainings have been developed on demand and delivered at the INSTN for the specific need of the nuclear sector. INSTN experts have also been providing training and support in various fields, including radiation protection and radiopharmacy, at customer’s location. At the European level the INSTN has strengthened its cooperation’s with universities and companies of the nuclear sector from the European Union by participating at several European projects of the Framework Program 7 aimed at developing nuclear education and training in nuclear engineering (ENEN III), radiation protection (ENETRAPII) as well as on radioactive waste (PETRUS III) and the enhancement of safety culture (NUSHARE).

To tackle the growing need for a high level education and training in the nuclear field, the INSTN developed different training modalities, including widening the initial and continuous training offer. The following sections will present each training mode and illustrate some of the most fruitful examples of actions undertaken at the national and international level.

1. Initial training

Over 40 academic degrees, including Higher Technician Diplomas, Bachelors, Masters and engineering degrees are issued by the INSTN.

**Higher Technician Diploma (BTS) in radiation protection**

This course teaches students all about the requirements for working in an irradiated environment. They learn to implement all the techniques for radiation control and to apply radiation and contamination protection rules in compliance with applicable legislation. Students are selected on the results of a knowledge test in mathematics and physics. A B2 level in French is required for attendance.

**Masters and engineering degrees**

More than 30 Master degrees, delivered in cooperation with Universities and Engineering Schools, are mainly addressed to M2 students and cover a wide range of topics developed within CEA research laboratories such as nuclear energy (fission and fusion), functional and structural engineering of proteins, radiobiology, materials for structures and energy, nanophysics, nanobiology and nanobiotechnologies, innovation and technology management, astrophysics, radiation protection…

Most of those Masters are taught in French but a few of them are in English. They are all open to foreign students who represented in 2011 more than 23 % of the INSTN student population (Figure 1), coming from 58 countries, mainly non-EU (Figure 2).
INSTN main pedagogical efforts are focused on the design and implementation of specifically nuclear-oriented educational programs as required for the maintenance and development of the nuclear sector, some of them being accredited exclusively by the INSTN (Figure 3). They include a medical physicist degree (DQPRM) as well as specialities for medical doctors and radiopharmacists, in accordance with the French directives on health, and two specialised educational programs on nuclear engineering: the Master in nuclear energy and the “Génie Atomique” course.

The Master in nuclear energy is a two-year program fully taught in English by a large consortium of universities, engineering schools and key industrial partners such as AREVA, EDF, GDF SUEZ. It aims to teach both French and international students the principles and knowledge required for the nuclear industry. The M1 is aimed at acquiring compulsory “Core Syllabus” of a general basic knowledge in almost all the domains in nuclear energy. The five Majors offered at the M2 level cover a wide variety of careers in the nuclear industry as either experts or managers in fields such as:
- Design and construction
- Operation and Maintenance
- Nuclear plant decommissioning and waste management
- Fuel cycle
The programme also aims to prepare students for a career in research and education for those continuing with a doctoral scheme.

The Génie Atomique is a specialized engineering degree (Master after master degree in nuclear engineering) delivered by the INSTN and aimed at educating talented engineers in the nuclear engineering field. Students learn basic sciences and technology and its application to research, design, operation, and optimization of nuclear power plants. The curriculum last one calendar year and is organized in 2 phases:
- A 7 months academic part of courses, conferences, exercises and laboratory sessions to acquire a systemic view in the nuclear engineering field
- Followed by a 5 months internship in research centres, universities, industry in France or abroad to apply the knowledge and concepts acquired during the first phase to concrete research or industrial situations.

This educational scheme is unique in France in terms of number and volume of the courses (more than 500 hours) and facilities involved in the training. Since its inauguration in 1955, INSTN has graduated more than 5000 nuclear engineers, some are active today in all the major organizations of the French and International nuclear sector. As illustrated in Figure 4, the higher student enrolment occurred at the creation of the curriculum, between 1958 and 1970, when France decided to launch the nuclear civil program. The following years about 60 to 100 students per year enrolled in the programme, depending on the French and world perspective of the nuclear sector. In the past few years an increasing number of foreign students attended the “Génie Atomique” course, mainly from China and North-Africa (Figure 5).
2. Continuous professional training offer on catalogue

Continuous education constitutes another important panel of the INSTN activity aimed at updating knowledge of those who already have a strong background in the applied field (professionalization program) or initiation into new techniques for those specialized in other fields (retraining program). Training sessions, lasting a few days to a few weeks, are organized all year around for professionals, researcher or qualified technicians. The courses available cover nuclear engineering, all the stages in the nuclear fuel cycle, radiation protection, imaging in nuclear medicine, micro and nanotechnologies, new energy technologies as well as soft skills such as patenting and intellectual property rights. All the vocational training is under quality assurance procedures, the INSTN being certified ISO 9001 since 2001. The INSTN course catalogue presently includes an offer of more than 200 trainings that take place at the INSTN and are mainly run in French. Over the past 10 years the INSTN has developed an international offer in nuclear engineering taught in English, which cover the following topics:

- Principles and operation of nuclear reactors
- Neutronics for Light Water Reactors
- Thermal hydraulics for Light Water Reactors
- Operation and safety of pressurised water reactors
- Criticality-Safety
- Nuclear fuel cycle
- Nuclear materials for pressurised water reactors
- Metallurgy and properties of Zirconium alloys for nuclear applications
- Introduction to the use of plutonium
Overall in 2012 the INSTN delivered 644 training session for a total of 3371 training days to more than 7000 trainees. Despite the economic crisis, the difficult post-Fukushima context and the debate on the energetic transition the number of training days delivered in the nuclear field remain constant. Over 85% of the training delivered was in the nuclear field, with 7% being international (Figure 6). The need of training in radiation protection and nuclear for health is noticeable with more than 50% of the total training delivered in this field (Figure 7).

For PhD students and young researchers a dedicated international offer of six advanced courses has been also developed. Each course, lasting one week, is dedicated to a specific aspect of nuclear reactor design and operation: (i) Thermal Hydraulics and Safety, (ii) Nuclear Fuels for Light Water Reactors and Fast Reactors, (iii) Reactor Core Physics and Monte Carlo Methods, (iv) Materials for Nuclear Reactors, Fuel and Structures, (v) Nuclear Fuel Cycle and Reprocessing, (vi) Nuclear Waste Management.

Recently, under the auspices of the IAEA, an Internet Reactor Laboratory (IRL) project will be developed. A virtual research reactor will be made available to access to countries that have no installed facilities, but need to train students & professionals in experimental nuclear physics and reactor operation. The IRL works by creating a virtual reactor in a remote location via an internet link. Using hardware and software installed in the research reactor, signals are sent over the internet to the training institution, where a real-time display of the reactor’s control room is visible to trainees. Then, using videoconference equipment, trainees can interact to “conduct experiments” by asking the reactor operators to change reactor settings and seeing the real-time displays change accordingly. The IRL distance learning course will be launched by end of 2014.

3. Training on demand
The INSTN is also keen in designing, implementing and organizing basic to advanced flexible, tailored training on its field of expertise on demand. Those customized national or international trainings can be delivered either at the INSTN or at clients’ location. Examples of training on demand delivered at the INSTN includes Safety Culture for Rolls Roys (FR), Energetic Transition and Sustainable Development for Renault (FR), Operation of Pressurized Water Nuclear Plant for EDF (FR), as well as Principle and Operation of Nuclear Reactors for ENEL (IT) or Practical training on ISIS reactor addressed to university master students from Sweden and Finland. Those training, lasting from 2.5 days to 2 weeks, are mainly dedicated to provide new or up-dated skills and knowledge to trainees. More interestingly, the INSTN has also been active in serving new comers in the field to develop their own nuclear engineering educational program. A 12 weeks “Train the Trainers” program, to train future trainers in science and technologies, has been thus conceived in 2010 for university professors and researchers on the demand of Polish Universities. The objective of this training session was to provide the trainees the necessary knowledge to
build up an educational program to ensure a proper implementation of the nuclear power program that Poland is willing to develop by 2020. In addition to conferences and lectures, technical visits of CEA as well as industrial facilities have been organized including the visit of the EPR construction site in Flamanville, a fuel reprocessing unit in La Hague and a nuclear power plant in Doel (BE). Shorter effective sessions for tutoring decision-makers to address energy-related issues, are also offered. A course of this type have been developed for the Electricity of Vietnam (EVN) Company to train future project managers for Vietnam’s first nuclear power plant.

Finally, INSTN experts have been supporting the creation of several programs at customer’s locations such as the development and implementation of the Master on radiation protection (University of Kenitra) as well as a vocational training offer on radiation protection in Morocco or the development of radiopharmacy initial training in Tunisia. An introductory course on nuclear energy has also been provided to students of the National school of engineers of Tunis (ENIT) as well as assistance for the development of human resources to the Tunisian electrical supplier STEG.

Traditionally INSTN organizes also courses exclusively intended for specialist from foreign countries under the International Atomic Energy Agency (IAEA) umbrella.

4. Involvement in EU projects
The INSTN is strongly committed to the development, share and harmonization of educational skills in nuclear science and technology, in particular at the EU level. It has been awarded the extended ERASMUS University Charter and, as declared in its ERASMUS Policy Statement (EPS), it promotes mobility of students and teaching staff to favor scientific exchanges, cooperation and dissemination of best practices and is open for multilateral cooperation with higher education institutions and enterprises. Indeed the INSTN is involved in several European projects aimed at implementing nuclear education and training on different topics ranging from nuclear engineering (ENEN-III), radiation protection (ENETRAP) and waste management (PETRUS III) to the enhancement of the nuclear safety culture (NUSHARE). It has also be a leading member of the European Nuclear Education Network (ENEN) since its creation in 2003.

5. Conclusions
The INSTN is the French key player in education and training on nuclear engineering and radiation protection since 1956. Sensitive to the growing educational and training needs of the nuclear sector, the INSTN has been diversifying its training offer to better respond to this national and international challenge. Presently, beside offering a large spectrum of high level educational programs, mainly at the Master level, as well as vocational training open to French and foreign students, it is also able to tackle specific training needs expressed by countries freshly acquainted to the nuclear field for civil applications and health.

References:


*Course catalogue -French:* [http://www-instn.cea.fr/Stages-de-formation-2013_theme375.html](http://www-instn.cea.fr/Stages-de-formation-2013_theme375.html)


ABSTRACT

The AP1000 Nuclear Power Plant (NPP) includes in its design passive safety systems and combines in its Main Control Room (MCR) software controls with hardware controls. Training is a fundamental tool to merge the new advanced control features with a safe plant operation. The special features of workstation soft controls represent a challenge that Tecnatom, in a partnership with Westinghouse Electric Company, is facing to teach the AP1000 plant Reactor Operators (ROs) and Senior Reactor Operators (SROs) in China and the United States.

Human performance enhancement techniques have been used in the nuclear industry for decades. However, software based control rooms strengthen even more the need for error prevention techniques due to the fact that almost all plant components can be operated through the very same computer screen.

Additionally, traditional assessment schemes in simulators take advantage of the physical location of each component controller. Software based control rooms do not allow the instructor to identify the system or even the component the operator is handling without taking a close look at the computer screen.

This paper describes the main differences between traditional and software based control rooms from a training and performance assessment point of view. It incorporates the recent experience of Tecnatom in delivering initial training to ROs and SROs for Sanmen and Haiyang NPPs and proves that conduct of operations must evolve and adapt to the new environment provided by all software based control rooms.

1. Introduction

Besides the evolution in the nuclear industry that AP1000 NPP materializes in its design by using passive safety systems, the new all software based MCR is another step ahead in the control of a NPP.

Vintage plants usually have all hardware controls (Fig. 1). This was the first type of MCR and due to the well known layout of the systems, components and alarms throughout the panels, the plant operation manoeuvres were hardly missed by the crew or the instructors. Also, all the information available and the plant parameters were collected by walking down the panels and the alarms.

In the last decade a new element for plant operation has taken its place in the MCR: software control displays. Hybrid MCR resulted from merging hardware and software controls (Fig. 2). In this new type of layout, effective communication tools were confirmed to be essential to not miss
any manoeuvre from the software controls and also to verbalize the new set of parameters and information contained in the different displays.

By taking to a minimum the hardware controls, as it has been done in the AP1000 plant MCR, where they are only related to a few components and signals, the newest way of operation and control of a NPP has been established.

![Fig. 1 Traditional MCR: Asco NPP simulator (Spain)](image1)

![Fig. 2 Hybrid MCR: Fangjiashan NPP simulator (China)](image2)

2. Materials and Methods: AP1000 NPP Main Control Room

The AP1000 plant MCR is designed to enhance the operator control capabilities and to provide all the needed parameters of the systems' operation and equipments' performance from a single computer screen.

The MCR is laid out in two horseshoe desks, which include the operation stations, three hardware control panels and 14 Wall Panel Information System (WPIS) Displays in 65” flat screens. The WPIS provides dynamic display of plant parameters and alarm information so that a high level understanding of current plant status can be readily ascertained (Fig. 3).

![Fig. 3 AP1000 Plant MCR layout](image3)

2 Courtesy of Westinghouse Electric Company, LLC

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Each of the operation stations includes two workstation computers, each with two flat computer screens, one keyboard and one mouse. All of them are connected to the Ovation™ expert distributed control system software, which provides the control capability of plant equipment through multiple displays.

The SRO position is at the smallest horseshoe desk and is provided with two workstation computers. The supervisor workstation is identical to the RO workstations, except that its controls are locked-out and are used only for information and to follow and check the manoeuvres of the crew. This modified configuration maintains independent, redundant workstations. The supervisor workstation contains both internal and external plant communications systems.

The RO and Balance of Plant (BOP) Operator are located at the largest desk closer to the WPIS. They have two stations each to control the plant, facing 12 WPIS displays which contain the most useful plant information. There is a spare station facing the side wall in front of another two WPIS displays which is used for convenience by an extra operator, Shift Technical Advisor (STA) or when one of the main stations is not available.

Besides the control stations, each position is provided with a local area network (LAN) computer not connected to the Ovation™ expert distributed control system software network but with access to all the plant and operation documents.

The instrumentation and control architecture uses both discrete control switches and soft control units. The soft control units are used to provide a compact alternative to the traditional control board switches by substituting virtual switches in the place of the discrete switches. The hardware operation in this MCR is only reserved for the safety signals, systems and components. The Protection and Safety Monitoring System (PMS) and the Diverse Actuation System (DAS) are the systems which signals are actuated from the hand switches.

The switches panels for PMS are located in between the RO and BOP, at the Primary Dedicated Safety Panel (PDSP), which includes four safety screens, each for one PMS division, and at the end of the biggest horseshoe desk at the Secondary Dedicated Safety Panel (SDSP). The manual actuations for DAS are performed from a separate cabinet at the side wall.

This new all software control MCR has different software programs to support the plant operation:

- **Ovation**: The Ovation™ expert distributed control system software is the one controlling all the non-safety plant systems and components, providing the parameters for the plant control and the indications of the equipments status. Ovation provides useful information with a glance to one screen since it has multiple displays, not only for systems and components, but also related to actuation signals, core conditions and parameters, maintenance activities, etc. (Fig. 4 and Fig. 5). The displays provided by the plant information system are non-safety related displays, but provide information on both safety-related and non-safety related systems. Those displays can be opened at the same time from all the operation stations, which facilitate the concurrent verification of the tasks. The human system interface is designed to reduce the likelihood of operator error and provide for error detection and recovery capability for the identified critical human actions and risk important tasks (1).

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3 Ovation is a trademark or registered trademark of Emerson Process Management Power & Water Solutions, Inc. Other names may be trademarks of their respective owners.
Fig. 4 Example of main menu display in Ovation

Fig. 5 Example display and indications in Ovation

4 Courtesy of Westinghouse Electric Company, LLC
5 Courtesy of Westinghouse Electric Company, LLC

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- **Computerized Procedures System (CPS):** This program includes the general, abnormal and emergency operation procedures. It receives information from the plant and has its own logic to open the appropriate procedure when one entry condition is met and to provide the input with a green check when a step is met, which helps the operator with the decision making process. By using CPS the operator can follow the procedure and apply human performance tools of place keeping and three-way communication. These error prevention techniques are different when using procedures in CPS or in paper copy. Another helpful feature of this program is that, when the critical safety functions are applicable, it displays the colour code for the critical safety functions' priority and directs the entry into the appropriate critical safety function procedure when they are orange or red.

- **Alarm Presentation System (APS):** APS is a software application that reads alarm information from the distributed control and information system and presents it to the operators via workstation displays and wall-mounted panel displays. The system is designed to alert the plant operators to an alarm condition and to provide fast access to alarm-related information that will guide the operator in managing abnormal plant conditions. The system also provides suppression features to assist the operator in identifying and managing alarms. The wall-mounted panel displays are visible to the operators from anywhere in the MCR and are readable from the RO's console and the SRO's console. The system presents alarm information on two of the wall panel displays. The use of spatially dedicated, continuously visible graphical alarm tiles promotes early detection and fast cognitive processing by the operators. The workstation displays present alarm information using a mix of graphical alarm tiles and alarm lists. The workstation graphical alarm tiles duplicate the graphical alarm tiles on the wall panels and provide a navigational aid to viewing the alarms driving each tile. The workstation alarm lists organizes alarms into several lists that the operator can use to support the current activities. The alarm lists can be sorted by time, priority, plant area, system, point name, point description, alarm type and alarm status. One helpful feature to rapidly respond to an alarm is that all of them are linked to their associated Alarm Response Procedure.

- **Reactor Operator Peer Check System (ROPCS):** The new MCR configuration gives the operators the opportunity to operate and control the plant without the need of moving around, just from their own screens. This could be an advantage for the crew, but also implies a lack of supervisory oversight from the SRO. This has been a new feature from a training point of view as well, since it is not easy to follow the trainee manoeuvres unless there is an instructor looking at the very same screen. To help with this potential lack of supervision during normal plant operation and training sessions a new software tool has been developed. It duplicates at one SRO workstation the current screen in use by one operator. Thus, it allows the SRO to follow the crew manoeuvres from the SRO station.

On the one side, the benefits of these new environment and tools are compelling and should result in more efficient operations and maintenance. On the other side, it is also important to recognize that, if those new tools are poorly implemented or used, there is a potential challenge to negatively impact performance resulting in a detrimental effect on safety (2).

Therefore, training needs to be oriented to take advantage of all these new features and to apply and adapt the Human Performance Tools as well as the Conduct of Operations to comply with a safe and efficient plant operation.

3. **Results**

Tecnatom has participated in this training evolution and has adapted to these advanced features. The first operations training course in the AP1000 plant simulator was successfully delivered to 48 instructors from VC Summer and Vogtle NPPs (USA) in 2011. After that, continuing with the training program for the new plants under construction, 72 operators and plant technical staff from Sanmen NPP (China) in 2012 and 72 from Haiyang NPP (China) in 2013 received the operations training as well.
Tecnatom’s consolidated experience delivering initial operations training of AP1000 plant to future operators and instructors, has confirmed the special care that needs to be taken when implementing human performance enhancement tools. Industry events support this statement and strengthen the need for an even stricter implementation of such tools.

Due to the new MCR characteristics previously described, one of the singularities found during the training was the different way of implementing some of the human performance tools compared to the traditional MCRs:

- Peer-checking: The operator performing the peer-check to an action from a display has to accomplish this task by looking at the very same control station that is being used, which implies leaving his own station since there is no shadow tool in the operators’ workstations. Peer-checking is therefore done as in vintage MCRs and verifier still has to interrupt any task in progress at that moment. The ROPCS is the new capability in the AP1000 plant MCR because of the software available at those control stations. Thus, the SRO can follow the operator’s display and precisely oversee the computer mouse and peer-check the task that is being performed without leaving the command and control position.
- Decision making: Because of the MCR configuration and its full capability from all the operation stations, the SRO has more supervision capability over all the plant evolutions making the decision process easier and the communication between all the crew members more fluent. Besides that, the software operation tools also facilitate the operator’s decision process thanks to the useful information provided in multiple displays, the priority of the alarms given by APS and the input for each procedure step from the logic schemes in CPS.
- Concurrent verification: The capability of opening the same displays and controllers from each of the workstations facilitates this process, being easier to create a freedom of thought between the operators and act independently.
- Three-way communication: This useful tool for an effective communication is implemented differently when using procedures in CPS. This program allows all the crew members to read and follow the same procedure, giving feedback of the step in progress and its condition (met or not met). The SRO doesn’t have to read each of the procedure steps, reducing the number of three-way communications, most of them becoming two-way communications and making the process easier, shorter and more effective.
- Place keeping: The CPS is a useful tool that automatically helps the operators to keep track of the procedure step in progress in each moment.
- Signature: The capability of the operators to individually log into each of the workstations implies a change in the signature process. Furthermore, the CPS automates log keeping and the Ovation™ expert distributed control system software will keep track of every action taken by the operators and automatically record the manoeuvres in the plant historian database. The personal accountability that is necessary for creating and maintaining an effective safety culture (3) is thus fostered by the MCR design itself.

From a training point of view there are also some significant changes. Even though the basics and fundamental principles of training remain the same, adaptation of the instructors to the new learning environment is mandatory. Also, the aforementioned human performance tools and their application must be modified for software based control rooms.

Instructors have to get used to new tools when training in this simulator. For example the ROPCS, that, on top of being a useful tool for supervisory oversight during plant operations, has also revealed itself to be a valuable resource for simulator instructors. In the AP1000 plant simulator the booth instructor uses the ROPCS to follow the crew performance and identify the components that are being operated in each moment. This information retrieved by the booth instructor is a very helpful input to the floor instructor. Sometimes it is even fundamental when several actions are taking place during a plant transient and a closer analysis of the operators’ performance is needed.
However, there are also some difficulties that arise for consistently conducting a performance evaluation in software based control rooms. During traditional simulator assessments, the instructor takes into account how the operators move inside the control room. The floor or even the booth instructor can penalize operators’ performance if they approach the wrong panel. In contrast, software based control rooms do not allow the instructor to identify the system or even the component the operator is handling without taking a close look at the computer screen. The need for having as many evaluators as positions are in the MCR is thus reinforced. Moreover, guidelines must be issued to standardise the assessment whenever the operators select a wrong controller or display but do not carry out any action, since this situation did not exist in vintage simulators.

Additionally, Conduct of Operations as described by the International Atomic Energy Agency (IAEA) (4) needs to evolve and incorporate the special features of the AP1000 plant MCR design. Though this decision depends on each utility, specific paragraphs should be added to specifically address the use of error prevention techniques. These sections could include directions for using traditional performance enhancement tools in the new MCRs. Furthermore, extra clauses could be included to take into account the uniqueness of trainee’s On-the-Job Training (OJT) in that type of environment. Thus, incorrect equipment operation could be prevented, likely to happen with all components being operable through a single component screen.

The plant specific Conduct of Operations is also a suitable administrative procedure to include guidelines promoting communication between the different operation team members. Due to the challenges that software control rooms poses to the situation awareness of the operators (5) there can be situations where it is beneficial to set standards for crew briefs or updates in order to keep up to date the information shared among the different crew members.

4. Conclusions

The evolution of the design and control in the AP1000 NPP is not only a step ahead in the safety and reliability of nuclear industry; it also implies an evolution in the plant operators and instructors to keep the safety culture principles applicable in the new all software based MCR.

Human performance enhancement tools and administrative procedures, as the Conduct of Operations, must evolve and adapt to the new environment, not only for normal plant operation but also to initial and continuation training in the simulator.

However, pursuing excellence obliges to continuously monitor and improve simulator training in order to verify the effectiveness of the aforementioned measures.
5. References


Options for an International Nuclear Training Standards Accreditation Model

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1 Introduction

With the development of new nuclear build programmes across the world and the demographic challenge facing existing nuclear operators it is essential that the industry has the capability to maintain a qualified and capable workforce. This paper proposes an international nuclear training standards accreditation model based on international best practice as a means of ensuring high quality and sustainable training and development programmes are in place for the future.

2 Description

Operators around the world are seeking to develop a sustainable training model for the current and future generations or workers. The current training models are broadly based on international nuclear curriculums (IAEA, INPO, WANO). These provide the foundations for the initial training models with some refresher and continuing training subjects.

Diagram 1: Typical Nuclear Training Model

<table>
<thead>
<tr>
<th>Operations</th>
<th>Engineering</th>
<th>Maintenance</th>
<th>Technical Support</th>
<th>Topic and Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Role Specific (1 year to 6 years)</td>
<td>Plant Systems and Processes (2-8 weeks)</td>
<td>Nuclear Fundamentals (2-6 weeks)</td>
<td>Induction (4 weeks)</td>
<td></td>
</tr>
</tbody>
</table>

The development of the Peer Evaluation programmes within WANO now seeks to identify opportunities for improving safety and performance for both the plant and personnel. This is recognition of the personnel development requirements in the nuclear industry of the 21st century. The peer evaluation models provide specific guidance with regard to the standards and quality of the training and qualification requirements expected to meet best practice. With the maturity of
these processes the opportunity now exists to further strengthen the self-governing models with the use of an international nuclear training standards accreditation process.

The proposed structure of an international model would be based on voluntary participation, using the INPO and/or WANO peer evaluation methodology with a specific and dedicated focus on meeting the training and qualification performance objectives and criteria. The use of an international board and assessment teams based on a standardised approach to reviewing criteria requirements would be followed similar to the current arrangements experienced in the US and the UK. This would involve direct involvement and feedback to Senior Plant Management throughout the process.

The challenges of the impact or positioning with national regulatory models, the plant diversity and the language and cultural differences would need to be carefully considered in establishing the model, and it would need to be designed to complement other peer review processes including WANO Peer Reviews and OSART Missions.

EDF Energy in the UK have developed a nuclear standards accreditation model, Designed to meet UK needs with a ‘European’ flavor. The model is not regulatory driven but follows the UKs ‘goal-setting’ approach dependant on self-regulation. This includes a Training Standards Accreditation Board (TSAB) made up of 8 international members from Germany, Switzerland, France, UK, RSA, USA, Spain, covering a diverse expertise such as training in the nuclear industry and civil aviation. The process is very similar to the WANO Peer Evaluation but focuses on Training.
Where are efforts on harmonisation needed?
10-YEAR EXPERIENCE
OF EUROPEAN NUCLEAR EDUCATION NETWORK

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ABSTRACT

The European Nuclear Education Network (ENEN) Association, a non-profit organization established in 2003 under the French law, has as its main objective the preservation and further development of expertise in the nuclear fields by higher education and training. In the last September, the Association celebrated its 10th Birthday, coming at the end of a very active decade in which major achievements were reached and ENEN grew from the initial number of 22 Members to the present 64.

The paper summarises these achievements, obtained by efforts spent in order to harmonise and promote mutual recognition of MSc courses, PhD activities and training in nuclear matters throughout Europe. The establishment of the European Master of Science in Nuclear Engineering certification, the yearly PhD Events, the promotion of courses in nuclear matters at different levels, the extension of the range of action of the Association beyond the European borders represent some of the relevant results achieved so far, in the frame of the several EU Projects in which ENEN participated and as autonomous developments. General conclusions about the present status of the Association and its future perspectives are finally drawn.

1 INTRODUCTION

The European Nuclear Education Network (ENEN) [1] was founded in 2003 at the end of an effort focused on education in nuclear engineering which was the subject of an Euratom FP5 Project having the name of European Nuclear Engineering Network. Among the objectives of the project, establishing the basis for preserving nuclear knowledge and expertise, creating a European Higher Education Area for nuclear disciplines and facilitating the implementation of the Bologna declaration [2] in the nuclear disciplines can be mentioned.

A the root of these efforts there was the awareness of the difficult situation of nuclear education in Europe at the time, when many high level courses were at risk of extinction for discontinuity in the preparation of the necessary human resources and when the attractiveness of careers in the nuclear fields was starting declining. The effort spent in
In this regard was then justified by the attempts to put repair to this situation, trying to restore conditions that could assure the necessary workforce in the nuclear field.

A decade later, in the aftermath of the Fukushima accident, the motivations for the existence of ENEN are quite similar. Notwithstanding the short period of nuclear renaissance experienced in the last years, again the volatility in energy policies and the lack of popularity of nuclear energy are threatening the capability to maintain and develop knowledge in the nuclear field as required by the future needs for plant operation, maintenance, decommissioning and for new builds. Research in the nuclear fields, related to power and non-power applications, also needs qualified manpower, to be obtained by a well-designed education process, enabling the new developments needed for the design of new generations of nuclear power plants, for waste management and geological disposal and for radiation protection and the new emerging medical applications of ionising radiations.

In this situation, ENEN is continuing to pay its service to European citizens in contributing to maintain high level education and training schemes in the nuclear field. Recently, in the frame of a new effort [3], the Association also undertook activities in ETI (i.e., Education, Training and Information), responding to a precise call by two European Commissioners for establishing training schemes specifically related to “nuclear safety culture”, as the necessary ingredient to assure the high levels of safety of the European nuclear plants.

This paper summarises the relevant achievements that ENEN obtained in the last decade and shortly discusses the present and future challenges in front of the Association.

2 MISSION AND STRUCTURE OF ENEN

The Statutes of the ENEN Association [4] establish that:

“The main objective of the ENEN Association is the preservation and the further development of expertise in the nuclear fields by higher education and training. This objective should be realized through the co-operation between universities, research organisations, regulatory bodies, the industry and any other organisations involved in the application of nuclear science and ionising radiation.”

Indeed, the Association presently includes 64 Members or institutions connected to it by MoUs, including Universities, Industries, Research and Training Centers (Table 1). Though a more extended presence of non-academic members in ENEN is an objective to be further pursued in the future, the cooperation achieved up to now is satisfactory enough and allowed to perform common actions in the field of training, as it was recently in the ENEN-III Project [5] (see below).

The structure of the Association is represented in Figure 1, showing that the General Assembly and the Board of Governors are the major bodies charged of deciding the lines of general policy of the Association, while the Secretary General has the role to implement these decisions in the day-to-day life of ENEN. Working groups, stimulated and coordinated by the Secretary General, provide the necessary elaboration at the basis of the actions of the Association, acting within the Teaching and Academic Affairs Area, the Advanced Courses and Research Area, the Training and Industrial Projects Area, with Knowledge Management and Quality Assurance being cross-cutting areas of activity.
Table 1. List of ENEN Members

Figure 1. Functional structure of the ENEN Association
3 OBJECTIVES REACHED IN THE PAST DECADE

3.1 The European Master of Science in Nuclear Engineering

ENEN developed the European Master of Science in Nuclear Engineering as a “quality label” (or certification) released by the Association to those engineers whose studies satisfy the following requirements:

- “the total load of the study programme of the applicant leading to the degree of Master in Nuclear Engineering, or equivalent, is at least 300 ECTS credits at university level (...);
- of which at least 60 ECTS credits (which may include the master thesis project) are in nuclear sciences and technology, preferably engineering, at master level;
- of which at least 20 ECTS credits (which may include the master thesis project) are taken at one or more academic institutions or clusters of such academic institutions, that are effective members of the ENEN-A, other than the home institution and in a different country than the home institution;
- the applicant has successfully defended a nuclear engineering master thesis project” [6].

The mentioned 60 ECTS in nuclear sciences and technology must cover at least the following areas: Nuclear Power Plant Technology & Reactor Engineering; Reactor Physics; Nuclear Thermal Hydraulics; Safety and Reliability of Nuclear Facilities; Reactor Engineering Materials; Radiology and Radiation Protection; Nuclear Fuel Cycle and applied radiochemistry. Laboratory work on some of the above fields of study should be also included, to provide a minimum of additional practical skills. Every year a Ceremony is held for assigning the certifications to EMSNE students.

3.2 International Exchange and Advanced E&T Courses

The equivalence of nuclear engineering curricula relies on the mutual recognition of courses among the ENEN member universities. ENEN therefore also has the task of promoting student and faculty exchanges by encouraging and supporting the organization of international exchange courses at Master level, advanced courses at PhD level as well as training courses for young professionals.

A typical example is the Eugene Wigner course, a three-week course on nuclear reactor physics including lectures and practical exercises at three different reactors, which has been organized five times since 2003 by a group of universities and research centres in central Europe, addressing nuclear engineers and young professionals. Joint courses have also been organised on Neutronics for LWRs, Principles of Operation of Nuclear Reactors, and Dismantling Experience of Nuclear Facilities. Advanced courses at PhD level have been organized by ENEN in the framework of the Integrated Project EUROTRANS (http://www.enen-assoc.org/en/activities/for-universities/eurotrans.html). Many international training seminars addressing students and professionals have been organised on a regular basis since 2003 in France, Germany, Romania, Finland, etc..

3.3 PhD EVENTS

At PhD level, starting with 2007 a “PhD event” is being organised yearly for stimulating young researchers to discuss and share their ideas in a public occasion. Its objectives are:

- to provide a forum for PhD students to present their research work to their fellows and colleagues in a friendly but competitive spirit;
• to promote the research work of PhD students in the nuclear filed;
• to set up a bridge between PhD students and professionals in the nuclear field.

The event generally consists of 8-12 PhD presentations nominated by ENEN Members and selected by the ENEN PhD Event Jury. The participants are requested to make a presentation of their research work in a reasonable time span, with allowance for questions and comments. The presentations are finally judged by the Jury members, considering the submitted paper as well as the quality of the presentation and the clarity in the discussion while answering the questions and discussions. The best presentations are awarded by the ENEN Prize in a specific ceremony at the end of the event.

At present, the ENEN PhD Events are co-sponsored by the European Nuclear Education Network Association (ENEN), the European Commission Joint Research Centre (JRC) and the organizer of the international conference hosting the event.

3.4 FP6 ENEN II and NEPTUNO Projects

The implementation of the EMSNE concept was achieved under NEPTUNO FP6 project. The project developed ENEN activities related to education in Nuclear Engineering and its extension to include training courses for professionals and knowledge management by the establishment of the “ENEN Database”, as a valuable resource for disseminating information on available courses at any level and on job opportunities. In addition, textbooks and multimedia resources with the brand name of ENEN were also developed.

The ENEN-II Coordination Action consolidated and expanded the achievements of the ENEN and the NEPTUNO projects attained by the European Nuclear Education Network Association in the 5th and 6th Framework Programme of the European Commission. The objective of the ENEN-II project was to develop the ENEN Association in the areas of nuclear engineering, radiation protection and radwaste management, including underground disposal. The interaction between the different communities, engineering, radiation protection and waste management, has been considerably strengthened. Although the training projects ENEN-III, PETRUS-II and ENETRAP-II, run under the 7th Framework Program, were distinct activities, they have been prepared in mutual consultation by the three communities.

3.5 Nuclear European Fission Training Schemes (EFTS)

In the seventh framework programme of Euratom, ENEN took part in or coordinated projects aimed at setting up training schemes for different target groups of learners. In particular, the following projects were (or are still) addressed (see the ENEN website [1]):

**ENETRAP II on Radiation Protection (2009-2012)**

The overall objective of ENETRAP-II, coordinated by SCK-CEN, has been to develop European high-quality "reference standards" and good practices for education and training (E&T) in radiation protection (RP). The introduction of a radiation protection training passport as a means to facilitate efficient and transparent European mutual recognition was an objective of this project. ENEN took part in it cooperating in some actions of the project.

**PETRUS II on Waste Management and Disposal (2009-2012)**

The aim of the PETRUS II project, coordinated by the Institut National Polytechnique de Lorraine, has been to enable present and future professionals on radioactive waste
management in Europe, whatever their initial disciplinary background, to follow a training programme on geological disposal which would be widely recognized across Europe. Also in this case ENEN participated in project actions, together with some of its Members. The continuation of the project, named PETRUS-III, is presently starting with the participation of ENEN.

TRASNUSAFE on Nuclear Safety Culture (2011-)

This project, coordinated by the Université Catholique de Louvain, aims at designing, developing and validating two training schemes on nuclear safety culture for professionals operating at a high level of managerial responsibilities in nuclear installations. One of the training schemes is related to the nuclear industry, while the other is related to the other installations making use of ionizing radiation based technology, mainly in the medical sector. ENEN cooperates in this project, also acting as an umbrella for some of its members, working as third parties.

ENEN III on Nuclear Engineering (2009-2013)

The ENEN Association directly coordinated this project, aimed at setting up training schemes for four different profiles of engineers, having different needs in terms of Education and Training:

Type A: Basic training in selected nuclear topics of non-nuclear engineers and personnel of nuclear facilities contractors and subcontractors;
Type B: Technical training for the design challenges of GEN III plants;
Type C: Technical training for the construction challenges of GEN III plants;
Type D: Technical training for the design of GEN IV plants.

The Project involved 19 Partners from 12 countries: ENEN, SCKCEN, UCL, AALTO, LUT, INSTN, AREVA, ISAR, BME, CIRIEN, DUT, UPB, UL, JSI, TECNATOM, UPM, UPC.

4 RECENT EFFORTS

4.1 NUSHARE EFTS on Nuclear Safety Culture (2013 - 2016)

The NUSHARE project (Project for Sharing & Growing Nuclear Safety) [3] originated as a Euratom education and training (E&T) initiative proposed by Commissioner Ms. Máire Geoghegan Quinn after the Great East Japan Earthquake on 11 March 2011. The objective of NUSHARE is to develop and implement training and information activities with the aim to share and grow, across EU Member States, the safety culture in nuclear installations.

This project, presently running, represents a very challenging effort, characterised by a high visibility for the Association, which is called to pay a service to the European Union in taking the lead in a process of education, training and also information at very high level, including three target groups:

- TG1: Policy and decision makers at the level of governments, emergency management teams, including international organizations;
- TG2: Staff of Nuclear Regulatory Authorities and Technical Safety Organisations;
• TG3: Managers and operators in the nuclear industry, system suppliers and energy providers.

4.2 Other Projects

In some projects, ENEN is presently involved in different coordination or advisory roles. A list of these projects is reported hereafter, referring the reader to the ENEN website [1] for further information.

• FP7 CORONA Establishment of Regional Center of Competence for VVER Technology and Nuclear Applications (2011 – 2014)
• FP7 CINCH-II - Cooperation in education and training In Nuclear Chemistry: focus on the European master's degree in nuclear and radiochemistry (June 2013 – May 2016)
• FP7 EUTEMPE-RX - EUropean Training and Education for Medical Physics Experts in Radiology: (September 2013 – August 2016)
• FP7 GENTLE - Graduate and Executive Nuclear Training and Lifelong Education (January 2013 – December 2017)

5 INTERNATIONAL COOPERATION

In the framework of the Sustainable Nuclear Energy Technology Platform (SNE-TP) launched in 2007 with the aim of coordinating Research, Development, Demonstration and Deployment (RDD&D) activities in the field of nuclear fission energy, ENEN co-chaired with the industry the Working Group on Education, Training and Knowledge Management (ETKM).

The Association was also engaged in projects aiming at broadening the cooperation in education and training to other areas of the world in which nuclear energy is being developed. The projects run in this frame were ENEN-RU, with Russian Federation, and ECNET, with China.

The EUJEP project, instead, involved the mobility of students at the Master level of Nuclear Engineering and other nuclear disciplines related to the application of nuclear technologies and radiation sciences. The project included exchanges of students and faculty members between the participating European and Japanese institutions.

In 2009 and in 2013 the ENEN Association signed Practical Arrangements with International Atomic Energy Agency (IAEA) for cooperating with the regional networks operating in Asia (ANENT), Latin America (LANENT) and Africa (AFRA-NEST).
6 CONCLUSION

The European Nuclear Education Network Association has recently celebrated its 10th Birthday, being strongly engaged in pursuing its mission. The past decade has seen several important achievements and made the Association to grow and to become a reference institution in the field of nuclear education and training.

The momentum acquired by ENEN in performing education and training actions in Europe and abroad is now directed also towards the field of information, through the NUSHARE Project, aimed at performing the service to set up training schemes focused on nuclear safety culture. This represents a new challenge that requires making full use of ENEN’s potential by deploying the resources available through its many members.

Indeed, the recent growth in the number of members and of links that the Association was able to establish within Europe and abroad gives to ENEN a key role in nuclear education and training. In this respect, the existence of ENEN now represents a resource that may be deployed in support to different efforts aiming at the construction of the European educational system in the nuclear sector.

REFERENCES

ABSTRACT

The major objective of the CORONA project is to facilitate the transfer of higher-level knowledge and technology between disciplines, sectors and countries. The ultimate goal is to develop a European passport for Continuous Professional Development, which relies on the principles of common qualification criteria, a common mutual recognition system, and the facilitation of teacher, student and worker mobility across the EU.

The aim of this paper is to describe the characteristics of the process of development of the following training schemes:

- Basic training on VVER technology specifics for non-nuclear professionals and subcontractors;
- Specialized technical training on VVER technology for students studying of nuclear professions;
- Specialized training on specific VVER technology aspects for nuclear professionals and researchers.

The safety culture and soft skill training are incorporated as an integral part of training schemes of all the above groups. The objectives of the safety culture training for the personnel are to understand better the involvement of each one in nuclear safety; to identify areas for improvement in nuclear safety when carrying out the activities; to exchange experience based on real-life situations (operation and engineering). Practical aspects like development of questioning attitude, elaboration and use of procedures, providing and use of feedback, development of efficient communication shall be achieved through investigation of real situations (incidents in operation, design errors) occurred in their company.

The training schemes are developed according to the SAT (systematic approach to training) and include the following five phases: Analysis, Design, Development, Implementation and Evaluation.

The paper considers the specifics during the implementation of SAT methodology regarding the defined groups including various specialists. The paper presents results from the activities during the analysis, design and development phases, as the results from pilot training delivered to selected specialists.

It is planned to be performed a verification of the technical content and pedagogical value of the components of the training scheme and the logical sequence of the different modules, as an assessing the qualifications acquired and the skills developed during the training.

1. Introduction

CORONA project (Seventh Euratom Framework Programme for Nuclear Research and Training Activities) promotes a special purpose structure for training and qualification of personnel for serving VVER technology (VVER - Russian specification of pressurized light water reactor) as one of nuclear power options used in the European Union (EU). Such approach should allow unifying existing VVER related training schemes according to International atomic energy agency (IAEA) standards and commonly accepted criteria recognized in the EU.

The major objective of the schemes is to facilitate the transfer of higher-level knowledge and technology between disciplines, sectors and countries. The ultimate goal is to develop a European passport for continuous professional development, which relies on the principles of
common qualification criteria, a common mutual recognition system, and the facilitation of teacher, student and worker mobility across the EU. CORONA training schemes are dedicated to nuclear engineering and are focused to specifics of VVER technology implementation and operation. The schemes cover complete range of subject related specialists from students to experienced nuclear professionals.

2. Description of general framework for the training schemes

The training scheme presents training programmes, set of courses, training materials, training aids and various forms of training activities designed to meet the requirements regarding necessary professional knowledge and skills. The training schemes cover the necessity of certain knowledge, the methods and forms to be presented that provide its good understanding, the approaches to attract the trainees in nuclear activities.

2.1. Target groups’ description

The training schemes included in the CORONA project concept are aimed at three target groups:

- Group A - Nuclear professionals and researchers;
- Group B - Non-nuclear professionals and subcontractors;
- Group C - Students on power and non-power nuclear study.

Specialists of the following categories are included within the scope of group A: nuclear power plant (NPP) personnel employed in the management, maintenance, operations, technical support and safety control; nuclear professionals from research and engineering organizations, surveillance and regulatory bodies performing activities in the areas of design, technical support and decommissioning of nuclear facilities, radioactive wastes and spent nuclear fuel management, nuclear safety and radiation protection surveillance/control; specialists involved in nuclear training related activities.

Group B covers: personnel of nuclear facility serving systems and facilities outside the nuclear island; research, engineering, design and civil construction organizations performing NPP lifetime related activities – construction, start-up, operation, decommissioning; employees involved in nuclear technology matters (government, municipality, branch, ecological, public, trade union, etc.); all suppliers and contractors involved in design, engineering, manufacturing, construction, operation, maintenance or other safety related activities.

Group C covers students who have acquired higher education at the level at least of Bachelor of Science (BS) degree in engineering and techniques in designing, manufacturing, operation and maintenance of nuclear plant facilities (NPF), as well as students who are only indirectly connected with NPF operation but NPF cannot exist as a nuclear object without their activities.

Safety culture is a significant topic of importance and requires continuous consideration. The training programmes shall emphasize the necessity of understanding the safety issues, shall include consideration of the possible safety consequences caused by errors and shall deal with the ways to avoid or correct these errors. For this reason the group D is defined and named “Safety culture and soft skills training for nuclear professionals and personnel of nuclear facilities suppliers and contractors”. [1]

The graphical presentation of the CORONA components (work packages) and their interdependencies are shown in Figure 1.
Identification of the training needs for all target groups

Training scheme on advanced VVER technology specifics for nuclear professionals and researchers

Basic VVER technology specifics for non-nuclear professionals and subcontractors

Specialized training on VVER technology and non-power nuclear applications for students

Safety culture and soft skills training

Assessment and recommendations for Regional centre of competence sustainable development

Creation of knowledge management portal for VVER technology

Figure 1 Graphical presentation of the CORONA components and their interdependencies

2.2. Application of European qualifications framework
European Qualifications Framework (EQF) is an EU initiative to create a translating facility for referencing academic degrees and other learning qualifications among EU member states. The EQF is a common European reference framework which links countries’ qualifications systems together, acting as a translation device to make qualifications more readable and understandable across different countries and systems in Europe. This European reference framework consists of eight levels that are defined according to so-called “learning outcomes” – that is to say with reference to the knowledge, skills and competences acquired. [2]

2.3. Lifelong learning – initial and continuous training
Lifelong learning is defined as “All learning activity undertaken throughout life with the aim of improving knowledge, skills and competence, within a personal, civic, social and/or employment-related perspective”.

Lifelong learning is therefore about acquiring and updating all kinds of abilities, interests, knowledge and qualifications from the pre-school years to postretirement. It promotes the development of knowledge and competences that will enable each citizen to adapt to the knowledge-based society and actively participate in all spheres of social and economic life, taking more control of his or her future.

Comprehensive training comprises initial training and continuing training or retraining.

Initial training is provided to persons before they are assigned to a job or a position within the operating organization.

Continuing training is provided to all persons throughout their working life, as it is necessary to ensure that their knowledge, skills and attitudes are maintained current in both theory and practice. Continuing training is also directed to the permanent improvement of skills and attitudes which is necessary for safety related activities.
3. Methodology used for development of the training schemes

3.1. Systematic approach to training

The training schemes were developed according to the systematic approach to training (SAT).

The SAT provides a logical progression from identification of the competences required for performing a job to the development and implementation of training towards achieving these competences, and to the subsequent evaluation of this training. The use of a systematic approach to training offers significant advantages over more conventional, curricula driven training in terms of consistency, efficiency and management control, leading to greater reliability of training results and enhanced safety and efficiency of the plant.

A systematic approach to training includes the following phases (see Figure 2):

- Analysis – The phase comprises the identification of training needs and the competences required to perform a particular job;
- Design - In this phase competences are converted into training objectives and the objectives are organized into training plans;
- Development - In this phase training materials are prepared so that the training objectives can be achieved;
- Implementation - In this phase training is conducted by using the training materials developed;
- Evaluation - In this phase all aspects of the training programmes are evaluated on the basis of data collected in each of the other phases. This is followed by feedback leading to improvements in the training programmes and to plant improvements.

This approach is in compliance with the European strategy for vocational training. The activities for implementation of each of the phases within this approach are described below. [3][4][5]

3.2. Analysis

The activities during the analysis phase are carried out for definition of the required qualification of the specialists included in the defined groups of personnel.

The analysis performed was based on past experience, lessons learned and recommendations of the stakeholders, e.g. regulatory bodies, utilities, and international organisations. The main sources of information were experience of experts involved in the analysis; outcomes of the analysis of other projects (both national and international); documentation describing functions or possible areas of work, etc.

The method JCA (job competency analysis) was applied [6]. The method includes definition of the required competences, presented as combination of knowledge, skills and attitudes.
(KSA). The typical JCA method involves identification of generally stated tasks. Job competency statements are then determined and analyzed to identify the related knowledge, skills, and attitudes that support the competency. These knowledge, skills, and attitudes are then generally grouped together and sequenced.

According to JCA method lists of topics/training units can be used which are already available and applied in the personnel training. The results of the analysis phase include description of the groups, brief description of the job areas or/and functions of job positions related to respective groups and list of competencies. To facilitate the analysis process the personnel of different target groups were divided in the sub-groups in accordance with their responsibilities and functions. As a result the personnel of Group A were distributed to eight sub-groups – Management, Operation, Maintenance, Engineering and technical support, Radiation protection, Design, Research & development and Training/Instructors. Group B was divided into four sub-groups (Non-nuclear professionals for works at NPP, Non-nuclear professionals for works related to NPP and nuclear applications, Non-professional technical staff, Contractor’s personnel) and Group C – into three sub-groups (Nuclear students, Non-power nuclear students and Non-nuclear students).

In the analysis process the available information concerning competencies was collected in areas, for example, safety principles of nuclear facility, nuclear facility theory/technology, nuclear facility components/equipment, nuclear facility systems, safety culture and soft skills etc.

The competencies for each of the above defined target groups were selected from lists of the competencies defined as topics/training units. EQF was used for definition of expected level of competencies. The respective lists of competencies for each target group include competencies selected from available lists, as well as new competencies defined during the analysis phase.

For the development of training schemes in the case of safety culture and soft skills, the SAT method of “Expert panel” was used to define the units and competences of each course. This is because many of the tasks are introspective to the people and it is not possible to observe them.

3.3. Design

The purpose of the analysis phase is particularly to produce sufficient data to allow measurable training objectives to be derived from this data and developed in the design phase of SAT. The same personnel were used to develop the training objectives as to analyse the tasks or competencies. By combining these steps better assurance is provided that the training objectives adequately reflect the analysis data. Combining the steps also ensures that there is a direct and logical link between the tasks or competencies, the training objectives, and job performance.

Based on the competencies defined for each of the groups of personnel the respective training programmes were elaborated during the design phase. Each programme includes a couple of elements including learning outcomes and list of courses and training units. The lists of training courses were prepared based on the list of competencies defined during the previous phase of the approach and the defined entry level of the trainees. Duration of the training, training objectives/learning outcomes, types of training used (theoretical, practical/on-the-job training, simulator), evaluation methods and forms, and training aids were determined for each topic.

All training programmes for specific plant activities make reference to safety culture. The knowledge and skills referring to safety culture and soft skills are common for all participants. Although safety culture and soft skill training topics are covered by a specific training programme, the training programmes for different groups contain references on safety culture and soft skills courses.

For integration of safety culture in the training schemes were used the following:
- Integration in the beginning of each course of a safety culture baseline as an introduction;
- Development of several business cases based on real situations regarding how safety culture is affected by each process of VVER technology as a part of personnel practical training;
- Inclusion of tools and methodologies such as “power questions” (what, how, when, who, where, which) at the end of each training course in order to evaluate and enhance the safety culture awareness of the participants.

To describe the training scheme on safety culture and soft skills training, and to develop a list of competencies on the “soft” skills for all target groups, a re-grouping has been made of all the categories, defined above. Group D1 includes personnel of management, operation and training/instructors “A” sub-groups. The required EQF level is above level 3, up to level 6, depending on the job position. Group D2 includes the rest “A” sub-groups, as well as contractors and non-nuclear professionals for works at NPP. The required EQF level is up to 4. The third group D3 covers the rest sub-groups and required EQF level is up to level 3. [7] According to EQF the entry level requirement to reach any competence regarding safety culture and soft skills is the level 1 (basic general knowledge) to each target group. This is justified because to improve in those competences is not necessary to have a previous knowledge about the issues. In fact, in many cases it is better not to have such because the participants have less assumptions and expectations about those issues and is easier for them to enter in deeper levels of knowledge. The aim of the training is that the target groups build their new knowledge on the assumptions that enhance a strong safety culture. Further, lists of training courses, training units and their duration in training hours (max hours) including different forms of training for sub-groups D1, D2 and D3 were developed. [7] The overall purpose of the training is to ensure enough competences to develop a strong safety culture and to improve the awareness about the impact that each employee has on safety with his work and to acquire the necessary skills and correct attitudes to develop the organizational culture which improve the safety culture.

3.4. Development
This phase consists of elaboration of training materials to cover the training programme. The tasks within the phase were:
- Select and collect training courses, training sessions and training events to obtain the competencies;
- Develop additional training materials for selected courses (if necessary);
- Develop new courses.

The developed materials include:
- For theoretical training – lesson plan, trainee’ handbook, PowerPoint presentation, test questions bank, supporting material (if necessary);
- For practical training - instructor guide, check lists or job performance measures (JPM), exercise description for defined task (if applicable);
- For simulator training - simulator scenario.

3.5. Implementation
During the phase, implementation of theoretical, practical, and simulator training forms, as well as visits to introduce the experience and participation while performing specific tasks and activities are arranged. Pilot training is delivered for specialists selected. It is decided that during the pilot training each training scheme will offer 4 different courses. After the completion of the specialized training under a programme, the trainees undergo examinations to review the compliance of the knowledge and skills acquired with the requirements established. The expected method of assessment is a test. The overall objective is to check that the information provided during the development of the courses is understood and internalized, while the participants can see that use of these new tools is something useful to their performance and help to enhance safety. After the course completion the participants have to complete a test (one of each course). The test is conformed by a questions bank regarding the key concepts of the different units of the course. The trainees have to choose between several answers.
In addition to the test, it is possible that the facilitator uses business cases, role playing or group games. This practical methodology could be a part of the examination used after the training course completion.

The criterion for success in a test is 80% correct answers. During the practical training the facilitator must observe an appropriate predisposition to participate to the developed dynamics and put in practice the new concepts during the exercises by the participants.

In the frame of the project two pilot trainings were organised and conducted:

- In Sofia and Kozloduy NPP, Bulgaria during the period 27-31 May 2013 with a goal to evaluate the training programme of Group B [7]. The training was addressed to non-nuclear specialists that have to be trained in nuclear field. Interest in the training course was demonstrated by 19 specialists from physical protection employees, government employees, secondary school teachers, journalists etc. Nine observers attended the presentations of lectures and visited the Kozloduy NPP. The trainers selected for the pilot training were experienced in the corresponding field of knowledge;

- Second pilot course was organised in the period July 1 – 5 2013 in Moscow, Russia to evaluate the training programme of Group C - Nuclear and non-nuclear students. The course included lectures and practical sessions (training on simulator and technical tour to special laboratories) (see Figure 3).

![Figure 3 Participants in the pilot courses](image)

### 3.6. Evaluation

The evaluation phase has two components. The first evaluation is carried out by project management bodies. The purpose is to verify the technical content and pedagogical value of the components of the training scheme and the logical sequence of the different modules. The second evaluation is carried out after running the training schemes/pilot course and assessing the qualifications acquired and the skills developed during the training. This evaluation includes recommendations for optimising and improving the training scheme. The evaluation is performed through special evaluation forms.

The results from the performed pilot trainings assessed the training programmes ability to provide specialized knowledge, skills and attitudes. The recommendations are considered as initial recommendations. Further feedback from employers could give additional information on the area of knowledge and skills needed as well as on the matter to increase the effectiveness of the training programme.

The feedback from the pilot training showed that the activities to be carried out within the CORONA project are necessary, beneficial and efficiently implemented.

### 4. References


[7] Documents developed during CORONA project
ABSTRACT

The Implementing Geological Disposal of Radioactive Waste Technology Platform (IGD-TP) community according to its vision (Vision 2025) aims to proceed to obtaining licenses to construct and to operate deep geological repositories for spent fuel, high-level waste, and other long-lived radioactive waste in their respective Member States. Their commitment to the Vision 2025 includes developing joint means to facilitate access to expertise and technology and maintain competences in the field of geological disposal for the benefit of the European Member States. In the Strategic Research Agenda (SRA 2011) a need for the Cross-cutting Activity Competence Maintenance, Education and Training (CMET) was identified. Preliminary work towards setting up a permanent Organisational Working Group to address this area has begun. In 2013, the CMET Working Group convened for its first meeting with the support of the IGD-TP Secretariat (FP7 project: SecIGD2). The CMET group has several objectives and one of their objectives is to carry out a feasibility study about the use of the ECVET instrument in voluntary accreditation of learning outcomes within the field of geological disposal.


1.1 Implementing Geological Disposal of Radioactive Waste (IGD-TP)

In 2009 a technological platform was launched in Europe to promote the sharing and pooling of resources to carry out jointly research, development and demonstration activities that are needed to address the remaining scientific, technological and societal challenges in deep geological disposal. This European wide cooperation was established by producing a common shared vision for the technology platform stating that the IGD-TP’s vision (Vision 2025) is that by 2025, the first geological disposal facilities for spent fuel, high-level waste, and other long-lived radioactive waste will be operating safely in Europe (1). The vision was supported by three commitments. This vision led to the formulation of a Strategic Research
Agenda (2) and its Deployment Plan (3). In alignment with the platform's commitment to facilitate access to expertise and technology and maintain competences in the field of geological disposal for the benefit of European Member States a Joint Activity was started and a permanent IGD-TP Working Group on "Competence Maintenance, Education and Training" was set up.

1.2 Competence Maintenance, Education and Training Working Group (CMET)
The CMET Working Group provides a forum for discussing the education and training matters in nuclear waste management and especially in geological disposal. Interaction within the CMET group is seen as a source for innovation beyond the current activities, too. The group has four main objectives as defined in its Terms of Reference (4):

1. To carry out transfer of the state of the art of strategies and activities for Competence Maintenance, Education and Training related to the implementation of Vision 2025. This requires identifying what the specific CMET needs are for implementing the SRA 2011 and the IGD-TP's first Deployment Plan until 2016 (DP 2012 in ref. 3).

2. To develop quality assurance of training aimed at new and experienced professionals in the field of geological disposal. This is done by developing quality assurance procedures and criteria for the voluntary accreditation of training (and education) for the sector. The work starts with carrying out a feasibility study for an accreditation scheme for informal learning that will be undertaken and that can also be applied to the formal setting. The background of the scheme is derived from the European Credit system for Vocational Education and Training (ECVET) approach (5)&(6) initiated by the Copenhagen process.

3. To compile the content of training i.e. a type of "curriculum or curricula" for professionals in geological disposal for pooling joint training efforts or alternatively engaging educators and trainers to address the IGD-TP's RD&D work's education and training (E&T) needs. Identifying the current state of curricula that have already been developed for geological disposal is required. Mapping their content in relation to the generic stages of repository development identified in the SRA 2011 (2) is a starting point of the CMET work towards this objective.

4. To ensure indirectly the sustainability of providers and the necessary infrastructures/facilities for CMET, and the new personnel and their development in the future. The first three objectives and the voluntary pooling of resources for the development and implementation of CMET action plan are also foreseen to strengthen the sustainability of supply of expertise.

The CMET Strategy and Action plan ("StrAP") are in the formulation process by the CMET Working Group volunteers from 13 European countries. The CMET working group aims to promote new type of approaches to meet the future human resources needs and to maintain the knowledge, skills and competence already achieved in the geological disposal community with the help of the new instruments. And this is done in cooperation with various stakeholders and in interaction with other complementary initiatives in the European Union.

1.3 Complementary European Initiatives to CMET
The aim of this paper is to discuss the prerequisites related to the feasibility of a voluntary accreditation scheme for geological disposal using the ECVET approach. This task is related to the second main objective of the CMET working group. During the past years, several European policy efforts within education and training carried out include e.g. the Bologna process (http://ec.europa.eu/education/higher-education/bologna_en.htm), Copenhagen process (http://ec.europa.eu/education/vocational-education/copenhagen_en.htm) and European law governing the recognition of professional qualifications (http://ec.europa.eu/internal_market/qualifications/index_en.htm)
European initiatives have addressed the different issues in quality assurance and mutual recognition of the professional competence.

ECVET instrument was introduced as a voluntary approach in the European Vocational Training context as part of the Copenhagen process. One emphasis in ECVET is that a person is able to reached defined learning outcomes independent of the means one has acquired the learning. Drivers to ECVET have not only been the mutual recognitions of vocational knowledge, skills and competence (KSC), but also to promote life-long learning of individuals in accumulating and recognising the learning that has been acquired either by education, training, on the job learning, at free-time activities or as in the context of geological disposal in research and project activities. During the recent years, the ECVET has also provided a good basis for piloting its use also on higher levels of qualifications in the European Qualification Framework (EQF) and especially on the EQF levels starting from level 5 to even to level 8 (Doctoral level) of KSC.

Pilot activities that provide input also to the CMET work towards the voluntary accreditation are the European Fission Training Schemes (EFTS) like PETRUS II and its continuation PETRUS III (9), ENEN III and several training schemes in radiation protection and radiochemistry. The European Human Resources Observatory for the Nuclear Energy Sector has initiated ECVET workshops (6) that have produced complete sets of Learning Outcomes for various nuclear new build job profiles and EHRO-N has also worked together with the ECVET team in DG-Education and Culture to train various stakeholders in the implementation of the ECVET principles (8, pp. 10-12). The on-going work in EHRO-N is also expected to provide further generic approaches and tools for the implementation of the ECVET approach in the sector.

The 2013 study by OECD on adult skills (16-64 years of age), the PIAAC study , also indicates that the skills and competences levels (in literacy, numeracy and problem-solving in technology-rich environments) have a positive correlation with the overall educational level but also participation in both formal and non-formal training activities independent of their context (job related or extra curriculum activities) has a favourable impact on the studied skills and competences (see ref. 9 for PIAAC, pp. 37-39 & 45-46). ECVET as an instrument can thus also contribute to making such non-formal and even informal learning activities more attractive to the European labour force and especially to the professionals already having a high basic education.

The main impetus for the CMET feasibility study are the foreseen benefits for the geological disposal community and also for the wider nuclear and other industry sectors from having individual's learning outcomes recognised by the use of such a voluntary system. The main ambition in the use of ECVET is to help in the development of a common understanding on standard job requirements to promote the mutual recognition of qualifications (6). Such benefits were identified in terms of the labour market, mobility and for flexible career pathways also in the 2012 ECVET Seminar for the Nuclear Energy Sector, see Tab 1 (8 & 10) that was initiated by EHRO-N, too:

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1 http://www.enen-assoc.org for more information on the different EFTS
2 http://ehron.jrc.ec.europa.eu/
4 Programme for the International Assessment of Adult Competencies (PIAAC)
http://www.oecd.org/site/piaac/
### Benefits of ECVET

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<td>Competence gap analysis</td>
<td>Training including on-the-job learning and mobility</td>
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<td></td>
<td>Mobility - higher safety culture</td>
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<td>Planning for the future needs</td>
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<th>For the employer:</th>
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<tbody>
<tr>
<td>Enlargement of the recruitment area</td>
<td>Broadening the Human Resources Management (internal flexibility)</td>
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<td></td>
<td>Mixed careers for young professionals (combining training and job)</td>
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<th>For the individuals:</th>
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<tr>
<td>Enhanced career opportunities</td>
<td>Intersectoral mobility</td>
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<td>Upward mobility and job rotation</td>
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<tr>
<th>For the education and training providers:</th>
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<tbody>
<tr>
<td>Fostering faster and improved employability of graduates and trainees</td>
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<th>For mobility</th>
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<tr>
<td>Mobility of personnel at all levels</td>
<td>Streamlining of human resources allocation to where needed</td>
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<tr>
<td>Knowledge preservation about the needed KSC</td>
<td>Tool for transparency, quality improvement and excellence</td>
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<tr>
<td>Mutual recognition of KSC and qualifications</td>
<td>Common assessment standards</td>
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<tr>
<th>For flexible pathways</th>
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<tr>
<td>Flexible pathways to qualifications</td>
<td>Less overlapping training</td>
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<tr>
<td>Faster way to qualification</td>
<td>NIFL(^5) can be assessed</td>
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<tr>
<td>Harmonized terminology in use</td>
<td>New perspectives on how to increase competence</td>
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<tr>
<td>Recognition of learning (outcomes) acquired in various schemes</td>
<td>Opportunity to be exposed to different cultures</td>
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<tr>
<td>Access to different technical approaches</td>
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Tab 1: Identified benefits from the adoption of the ECVET instrument (10).

The group sees that these benefits can also help the geological disposal community to overcome some of the main challenges (the Euradwaste2013 paper by the authors (11) outlines a more detailed discussion on the challenges) related to the competence maintenance over the long timeframes inherent in the management of radioactive wastes. The role of the IGD-TP as a forum with authority on expertise can have also a significant role in the quality assurance of learning outcomes and their mutual recognition when provided with a developed implementation framework for such validation. This is a challenge for the CMET Working Group to address in its work that is supported by the EURATOM FP7 project grant no 323260 SecIGD2\(^6\).

\(^5\) NIFL = Non-formal and Informal Learning
\(^6\) Secretariat of the Implementing Geological Disposal of Radioactive Waste, phase 2, e.g. www.igdtp.eu
1.4 Units of Learning and KSC and their development for geological disposal

The ECVET objectives (Fig 1) are both about transnational mobility and lifelong learning for all labour force in Europe independent of their status on the labour market or of their sector of work. In the core of ECVET is the recognition of learning outcomes in view of achieving qualifications. The ECVET contributes to these objectives by making the qualifications transparent, enabling the accumulation of learning outcomes and providing for a transfer and communication mechanism for the learning outcomes from one organisation to another and further from one context to another (12, p. 7).

![ECVET Objectives and technical components](image)

Fig 1: The ECVET Objectives and technical components (12, p. 7). Copied from original source as produced and published by ECVET User's Group.

The CMET feasibility study on a voluntary accreditation aims at addressing also this gap with regards the validation and mutual recognition of the professional's learning outcomes using the ECVET as an approach. Since the implementation of ECVET instrument is still voluntary within the European Union, the main piloting of the system has been carried out within the educational system and apprenticeships and student exchange related to these. This is partly influenced also by the subsidiarity of the Member States regarding professional qualification. Any bodies, national, sector specific or professional that could validate the learning outcomes of an individual that is not attached to a training or education provider does not exist. The approach and prerequisites of defining Units of Learning and the Knowledge, Skills and Competence in geological disposal following from the ECVET are discussed in the following and in Fig 2.

Under the ECVET, a Unit of Learning Outcomes (or unit) is defined as a component of a qualification, consisting of a coherent set of knowledge, skills and competence, which can be assessed and validated. Before any knowledge, skills and competence (KSC) related to the unit can be defined, one needs to define the qualification level aimed at as an outcome. Under the European Qualification Framework, qualifications are divided into 8 different levels. EQF levels 5-6 related to higher education qualifications like engineers at Bachelor level, the EQF level 7 relates to Masters and EQF level 8 relates to Doctoral Degrees. This is a simplified explanation of the levels and one should note that the levels are defined in terms of levels of learning mastered, not by a given degree even though in the national qualification framework context a specific level is often linked with a specific formal degree. The recent developments have also harmonised the EQF and the new ISCED 2011 (International Standard Classification of Education) levels used in the education statistics collection to correspond to each other (13).
After the qualification level for the units are defined, then the knowledge, skills and competences related to this specific learning outcome is broken down using a suitable taxonomy. Within the nuclear sector ECVET pilots, first a specific job profile is described, which is an accumulation of the units of learning outcomes. The definition for the Knowledge is: Cognitive competence (occupational-conceptual), for Skill: Functional competence (occupational-operational) and for Competence: Personal competence (conceptual and operational), for more detailed definitions see e.g. ref (6).

Fig 2: Schematic process of defining the content of an ECVET based curriculum ultimately leading to e.g. to a certificate or portfolio of KSC like the EuroPass.

In geological disposal, the number of job profiles is more challenging as at least prior the deep repositories are in operation, the personnel's job profiles consist of many different functions, which include often also knowledge and skills from different technical or scientific or cross-cutting disciplines. This makes a focus on the units of learning more attractive in the geological disposal compared with the wider requirements of a specific job profile. The needed job profiles can then be put together by each organisation needing them by accumulating the units into a full profile.

2. Definition of the required qualifications and expertise and their development

The development of the required qualifications in geological disposal starts by defining a basic educational level of a job. These qualifications are based on the degrees defined by the national legislation regarding education and degrees (by the national qualification framework). Depending on the maturity of the programme and national requirements further competence requirements are set either due to regulatory guides that in general state that
according to the graded approach stricter requirements for competence are set for personnel dealing with tasks having a more significant impact on the nuclear safety than on tasks that do not influence nuclear safety. Meeting such requirements may also include taking training and passing the authorities exams. In addition, specific professions have requirements based on other national legislation than nuclear acts. For such positions, there are legal qualification requirements that need to be met by the job holder. Further professional associations and groupings qualify professionals according to certain criteria and state them competent within the national setting or among their peers. This is the type of voluntary accreditation of individuals and curricula that are based on the ECVET principles that is aimed at as an important action of the CMET. Taking the competence requirement definition even further down the line, each nuclear energy organisation is able and often obliged by the authorities to set their own requirements for competence and training. Often it is easier to set the training requirements (14), as the methods of assessing the learning outcomes require more development work. Finally each individual staff member should address one’s own development needs merely just from the point of view of the safety culture and to be able to contribute to the continuous improvement of safety and security. ECVET brings now a new perspective also to the Human Resource Management practices related to competence management.

3. Addressing changing and evolving KSC needs during the different stages of a geological repository development

The CMET group is in the process of preparing its Strategy and Action Plan (StrAP). In the first discussion about the content of this plan, it was clear to the group that as the repository development from the initial concept development to the full operating repository have various stages (Fig 3), the units of learning defined for geological disposal also need to take the different needs of the stages into account. One can also consider the different stages of repository development to correspond also to the different technological readiness levels (TRLs) towards implementing geological disposal.

![Stages of repository development](image-url)

Fig 3: Different generic stages of repository development and examples of actions and related functional and task needs at the different stages from IGD-TP SRA 2011 (2, p. 16).
For example, conducting the work for a safety case has the same elements at all of the stages of the development, but the level of knowledge, skills and even competences changes from a more general/generic view to specialist work related to a specific technical or scientific discipline. And at the same time as the waste management programme advances, the need for interaction and the understanding of the complex couplings between the different components of the safety case increases.

Other functions or jobs are, on the contrary, specifically related to one stage of the geological repository development, such as "component design and layout design" in the technology development and repository design. In this case, the units of learning should provide the individual knowledge, skills and competences that are relevant to different projects and organisations and can be transferred cross border, contributing in this way to the mobility of skilled professionals. The two examples show as the units of learning need to be thoroughly defined in the broad perspective of the repository life cycle and to respond to the needs and work practices of different organisations.

As a starting point for any pilot under the CMET in using the ECVET principles, the most feasible target would be to focus on units of learning that have been used already extensively in some Member States who wish to preserve the KSC and at the same time these units of learning could be applied in a Member State, which is taking its first steps towards the same stage of development. The process of formulating the KSC would provide for an ideal knowledge transfer, too.

The feasibility study for the voluntary accreditation looks at two points related to the ECVET objectives. First, how to provide for a voluntary accreditation of an individual's learning outcomes resulting in recognised and certified learning outcomes. Second, how to provide, following the ECVET principles, a quality enhancing voluntary accreditation system addressing the non-formal learning outcomes of education and training providers. In order to advance in developing a voluntary accreditation scheme within the IGD-TP, the several issues related to the ECVET technical components as listed in Tab 2 need to be addressed with practical solutions by the CMET.

In addition to the ECVET technical components, several other solutions are needed like the actual accreditation body, the width of such a body's authority within the geological disposal community (starting with the IGD-TP) and the funding structure for the accreditation and the related certificates especially when the learning outcomes are acquired through informal learning and assessment of the learning outcomes against the set criteria need to be carried out by an accreditation body.
<table>
<thead>
<tr>
<th>ECVET Technical Components need for:</th>
<th>Voluntary Accreditation of an individual’s LOs</th>
<th>Voluntary Accreditation of an ECVET training provider</th>
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</table>
| Qualification                    | Yes. Recognition of mastery, but not a formal qualification. No requirement to have a home institution. | Not applicable. [Formal qualification of a legally recognized provider is outside the scope of voluntary accreditation.]
| Units of learning outcomes (LO)  | Yes, need to define tasks or functions in terms of EQF-level and KSC for the LO, for which the accreditation is sought. These definitions need to be approved by the geological disposal community. | Yes, production of units of learning corresponding to predefined KSC. Definitions should be universal for a unit of learning corresponding to an EQF-Level. [Formal: For a degree full range of units of LOs is required for the desired EQF level.] |
| Size of qualifications           | No                                          | Yes. Weight of units or credit points for transfer between different provider parties are needed if included into the training provider’s scope. |
| Assessment of LOs                | Yes. Assessment criteria and demonstration of LOs needed See also validation. | Yes. Assessment criteria and demonstration of LOs needed. |
| Validation of LOs                | Yes. An accreditation body needs to be set up or approved by the partners. | Yes. Done by an internal process, by MoU partners, or by an accreditation body. |
| Recognition of LOs               | Yes. By the industry and institutions in the community and/or by training providers by signing an MoU. | Yes (see MoU). |
| Partnerships (MoU)               | Yes. Wide coverage of partners to engage themselves in a MoU for voluntary approval of the recognised LOs. | Yes. Basis for transfer of the recognized LOs between various providers (a criteria for voluntary accreditation, too). |
| Learning Agreement               | No                                          | Yes, needed for exchange in the formal exchange between training providers or between a provider and a workplace. |
| Learner’s transcript of record   | Yes. A certificate needs to be provided of recognition of LO’s resulting from assessment => e.g. inclusion into Europass. | Yes, provided by the training provider to the home institute and later into the Learner’s transcript (achievements). One example, the ENEN supplement to a diploma. |

Legend: LO = Learning outcome, MoU = Memorandum of Understanding, KSC = Knowledge, Skills and Competence

Tab 2: ECVET technical components to be addressed in developing voluntary accreditation adopted from (12, p. 7)
4. Conclusions

The work is in its initial stage. The expected benefits encourage tackling this ambitious task. Fortunately, there are several complementary initiatives on-going, so all the challenges need not to be faced alone. The commitment of all stakeholders to the application of the ECVET is needed and more communication is needed about the different initiatives around it and the practitioners themselves need more training and piloting of different approaches and interaction to meet the ambitious goal.

Other sectors in Europe are more advanced in such voluntary accreditation approaches. The CMET group also intends to learn from these experiences, so that a feasible scheme can be developed for acknowledging knowledge, skills and competence in geological disposal irrespective of the means by which an individual has acquired them. At the same time support will be provided to acknowledge training schemes that use similar principles for producing the needed learning outcomes.

5. Acknowledgments

The writers wish to thank for the support through the co-funding by the European Commission as a part of the seventh EURATOM Framework Programme for nuclear research and training activities (2007-2013) under Grant Agreement no 323260 SecIGD2, the contributions made to the CMET Working Group's work by the CMET members and the work carried out by the various individuals and organisations working in implementing the ECVET pilots in Europe.

6. References


What are the answers that help to close the gap?
ABSTRACT

The European Nuclear Safety Training and Tutoring Institute (ENSTTI), an initiative of the European Technical Safety Organizations Network-ETSON, provides a high quality training and tutoring programme addressed to professionals at Technical Safety Organizations (TSOs) and nuclear regulatory authorities (NRAs). Through this programme ENSTTI shares, inter alia, the operational experience gained by TSOs in dealing with the interfaces between nuclear security, nuclear safety, and radiation protection with international experts. At present, ENSTTI is in the process of broadening its services by developing a modular training programme designed to meet the training needs of junior and senior professionals at NRAs and TSOs. This effort aims at building-up mutually recognized technical and regulatory competencies, foster global nuclear safety culture, increase workforce mobility and contribute to the lifelong learning efforts of the European Union. In order to give value to learning achieved in the training programme, ENSTTI will apply the European Credit System for Vocational Education and Training (ECVET) that is characterized by flexible procedures for validation, transfer and recognition of learning outcomes. This approach should also be of great value for learners from other regions in the world.

1. Introduction

Human resources development is recognized as the cornerstone of capacity building and sustainability of nuclear skills by the European Commission and the International Atomic Energy Agency (IAEA). This is set out in several legally binding instructions agreed by the European Council of Ministers such as Nuclear Safety Directive adopted on 25 June 2009¹, the Waste Directive adopted on 19 July 2011² or the Proposal for a Council Directive laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation (Brussels, 29.9.2011)³ as well as in a number of IAEA documents, such as the Action Plan on Nuclear Safety⁴, the Nuclear Security Plan 2014-2017⁵ or in the IAEA Safety Standards and Security Guidelines. These documents explicitly emphasize the importance of education and training, and require the maintenance and further development of knowledge, skills and competences of experts working, inter alia, at competent authorities responsible for nuclear safety, nuclear security and radiation protection.

The rapid expansion of nuclear and radiation related activities in many countries has highlighted the limited number of skilled and experienced experts available. Therefore, a number of nuclear regulatory authorities (NRAs) have generally identified a need to use a range of providers of external expert support or designated Technical Safety Organizations (TSOs) such as the Institute for Radiation Protection and Nuclear Safety (IRSN) in France, or Gesellschaft für Anlagen und Reaktorsicherheit (GRS) in Germany. It is essential that professionals working at NRAs and their TSOs maintain adequate technical competence in order to assure the fulfilment of regulatory responsibilities.

The European Nuclear Safety Training and Tutoring Institute (ENSTTI), an initiative of the European Technical Safety Organizations Network-ETSON, was created in 2011 to put in place a high quality training mechanism to tackle the training needs of experts at NRAs and TSOs, to ensure the continuous development of qualified experts in this area and, to foster harmonization of technical practices in nuclear safety, nuclear security and radiation protection. This is achieved through the regular provision of vocational training and tutoring exclusively delivered by senior professionals of European TSOs that take into consideration latest technical developments and is continuously up-dated and improved by applying a systematic approach to training. It is ENSTTI’s ultimate goal to provide initial training and continuous qualification programmes that will ensure that personnel at NRAs and TSOs are able to maintain competencies in their current positions and that they have the opportunity to get prepared in time to take on emerging tasks or advancements.

The paper provides insight in the design of a basic training programme within a qualification system for experts interested in starting a career at NRAs and TSOs that is developed based on regulatory functions and responsibilities and follows the systematic approach to training. This effort is supported by the European Commission through the NUSHARE project. The specialized and expert training modules and the individual development programmes offered by ENSTTI are not covered in this document since this would go beyond the scope of this paper.

2. The NUSHARE Project

The NUSHARE project for ‘Sharing & Growing Nuclear Safety Competences’ originated as an EURATOM Education & Training initiative proposed by Commissioner Máire Geoghegan Quinn (Research and Innovation) and Commissioner Günther Oettinger (Energy) after the Fukushima Daiichi accident in Japan 11 March 2011.

This project is interdisciplinary (e.g. requiring ‘hard’ and ‘soft’ sciences) and multi-sectorial (e.g. addressing policy makers and opinion leaders on the one hand and nuclear technology and radiation protection experts on the other). It is an EU-wide initiative, requiring firm commitment from many public and private stakeholders in the fields of reactor safety, waste management, radioactive waste and spent fuel management, accident management, radiation protection, nuclear fuel cycle, decommissioning, environmental safety, nuclear and radiation protection.

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6 For the purpose of this paper the following definition set out in the IAEA GSG-4 is used: A ‘provider of external expert support’ or a ‘provider of external expert advice’ is an individual or organization that is not part of the regulatory body but that is recognized for its expertise and competence in safety and can provide support and/or advice to the regulatory body [1].

7 For the purpose of this paper the definition of the European Technical Safety Organisation Network (ETSON) is used: ‘A Technical Safety Organization (TSO) is a nuclear assessment body that realizes the technical evaluation of safety files in support of their national authorities.’

8 IRSN http://www.irsn.fr/EN/Presentation/about_us/Pages/who_are_we.aspx

9 GRS http://www.grs.de/en/content/research-and-development-activities

10 http://www.enstti.eu/

11 http://www.etson.eu/Pages/Homepage.aspx

12 Information about the current ENSTTI training and tutoring programmes can be obtained from the following website: www.enstti.eu
management and radiation protection, who contribute to the ambitious EU-wide objectives mentioned above by providing, whenever necessary, their own human and/or financial resources. This project also requires the collaboration of DG RTD with other DGs. For example, DG ENER, DG JRC and DG DEVCO are involved and will share their experience in this field. The conclusions of the ‘stress tests’\textsuperscript{13} are particularly important in this context and the recent EC-driven ‘2012 Interdisciplinary Study’\textsuperscript{14} also provides some useful background. The Collaboration with organizations in non-EU countries would be highly welcomed.

NUSHARE is a Euratom FP7 ‘support action’ of four years, launched under the work programme 2012 through a ‘grant to named beneficiary’. The named beneficiary of NUSHARE is the ‘European Nuclear Education Network (ENEN) association’\textsuperscript{15}.

The main objective of this project is to develop and implement education, training and information (ETI) activities aimed at sharing and growing nuclear safety culture across the EU in all nuclear installations and in all applications of ionizing radiation, including security aspects.

The main tasks of the NUSHARE project are carried out by the following institutions:

- Coordinator: ‘European Nuclear Education Network (ENEN)
- Four partners responsible for Working Package (WP) 2 - 4:
  - ‘Institut National des Sciences et Techniques Nucléaires’ (INSTN)/‘Commissariat à l'Energie Atomique et aux Energies Alternatives’ (CEA)\textsuperscript{16}, France – WP 2
  - ‘European Nuclear Safety Training and Tutoring Institute’ (ENSTTI) – WP3
  - ‘Universidad Politecnica de Madrid’ (UPM)\textsuperscript{17}, Spain – WP 4
  - ‘Tecnatom’\textsuperscript{18}, Spain – WP 4

Three groups of ‘learners’ (preferably at higher education level) are targeted in the NUSHARE project:

- Policy and decision makers (responsible = INSTN / CEA) => at the level of communities and governments (including EC and international organizations), emergency and crisis management teams (including the medical community);
- Nuclear Regulatory Authorities and Technical Safety Organisations (responsible = ENSTTI) => professional staff members of those organizations and others interested in the regulatory aspects of nuclear safety and security culture;
- Industry (responsible = Tecnatom in collaboration with AREVA) => managers and operators in the nuclear industry, in particular, systems suppliers (vendors, engineering companies, etc) and energy providers (electric utilities, etc).

Within the project, it is planned to establish a ‘NUSHARE ETI catalogue’, containing the ETI schemes that will pass the required quality and performance tests. It will be a living document, and will be posted on the ENEN website and other dedicated websites. A NUSHARE action programme will also be published, containing objectives, implementation roadmap and ‘best practice guidelines’ (e.g. regarding lessons learnt from ETI actions in each Member State, networking techniques, task descriptions in terms of ‘learning outcomes’ and related ‘knowledge, skills and competences’, wherever applicable, assessment methodologies or international collaboration).

\textsuperscript{13} See, for example, the report on the Peer Review of EU Stress Tests [http://www.ensreg.eu/node/407](http://www.ensreg.eu/node/407)
\textsuperscript{15} ENEN [http://www.enen-assoc.org](http://www.enen-assoc.org)
\textsuperscript{17} UPM [http://www.upm.es/internacional](http://www.upm.es/internacional)
3. NUSHARE Working Package 3

The NUSHARE Working Package 3 (WP3) is dedicated to the development of a training scheme for new and existing staff working at NRAs and TSOs and to the subsequent delivery within a qualification system. This important task has been entrusted to ENSTTI. ENSTTI considers NUSHARE as flagship action, as it is a clear sign of the EC’s recognition of the Institute’s pivotal part in aligning the nuclear safety, nuclear security and radiation protection cultures and practices at the European and international level.

As a first step in the NUSHARE WP3 implementation, ENSTTI performed a desk research\(^{19}\) to gain better understanding of the functions currently carried out by NRAs in European countries with operating nuclear power plants and the support provided by TSOs to NRAs in fulfilling their responsibilities. The findings of the desk research set out, that e.g. the ‘main regulatory functions’\(^{20}\) are carried out by NRAs in all selected countries, whereas the ‘additional regulatory functions’\(^{21}\) are only carried out by some NRAs. In many countries, NRAs are supported by TSOs in performing additional regulatory functions. Further, the study determines that the scope of NRAs may range from controlling nuclear and other radioactive material in use and storage at nuclear power plants and other associated facilities, during transport, including import and export controls of these materials to controlling radioactive waste and spent fuel. In most of the cases regulatory responsibilities encompass nuclear safety, nuclear security, radiation protection and safeguards.

Considering the study’s findings and relevant IAEA documents\(^{22}\), it became clear that the impact of NRAs and their TSOs on safety\(^{23}\), security or radiation protection culture will, inter alia, significantly depend on the professional background and development of their experts. Recognizing the need for a consistent training approach for this expert group, the stakeholders of the NUSHARE WP3 recommended concentrating, as a first step, on the development of a well-structured Basic Training Programme (BTP) covering the above mentioned regulatory functions as well as all relevant areas of activities. In addition, it was recommended to take into consideration the ‘specialized and expert modules’ as well as individual tutoring programmes already provided by ENSTTI and other training providers to assure the consistent development of a comprehensive training programme that leads to continuous performance improvement at the organizational, process and job level at NRAs and their TSOs.

3.1 Target Audience

The BTP is addressed mainly to new staff at NRAs and TSOs, but should also be of interest for professionals at these institutions recently assigned to the nuclear safety, nuclear security or radiation protection sector and professionals involved in the licensing of all types of activities and facilities from the nuclear cycle as well as personnel involved in the regulatory oversight of non-nuclear power applications, such as in research and education, medicine or industry.

\(^{19}\) The desk research can be downloaded from [www.enstti.eu](http://www.enstti.eu)

\(^{20}\) ‘Main regulatory functions’ as described in the IAEA General Safety Requirements GSR Part 1 “Governmental, Legal and Regulatory Framework for Safety” [2],

\(^{21}\) ‘Additional regulatory functions’ as described in the IAEA General Safety Requirements GSR Part 1 “Governmental, Legal and Regulatory Framework for Safety” [2],

\(^{22}\) Such as: IAEA TECDOC 1329 [3], IAEA-TECDOC-1707 [4];

\(^{23}\) It is clear that safety culture cannot be directly regulated, however it is important that in particular NRA experts do understand how their actions affect the development of attempts to strengthen safety culture and that they are sympathetic to the need to improve the less formal human related aspects of safety [5].
The different training modules are designed to build-up basic generic and technical competencies among professionals holding a master degree or higher academic degree such as legal experts, engineers, nuclear scientists, physicians, agricultural engineers, veterinary surgeons, technicians and security professionals to prepare them to carry out regulatory functions or to technically support NRAs in their duties. The focus of the BTP is on the legal framework and regulations, technical concepts governing nuclear safety, nuclear security and radiation protection necessary for regulatory control of nuclear and radioactive materials in all their applications. It aims at increasing the understanding of regulators why safety systems and requirements defined by plant management are in place, why they are so important and how nuclear culture can be regulated.

3.2 Purpose and Nature

The purpose of the BTP is to strengthen nuclear safety, nuclear security and radiation protection, to foster a common culture by transferring specific knowledge and skills required to carry out efficiently and effectively regulatory functions, and to support the harmonization of regulatory excellence at the regional and international level.

The design of the BTP will focus on the use of interactive teaching methods involving trainees as much as possible in the learning process. It will include instructor-led classroom sessions, brain-storming sessions, and exercises, such as, simulations, work in groups/pairs, case studies or site visits as well as individually designed tutoring sessions.

Depending on available funds, it is planned to offering the future, selected modules through distance learning supported by mentors and/or to develop eLearning programmes for some of the modules.

3.3 Structure

The BTC will consist of four thematic modules which are independent. Each module will be divided into sessions.

| Module I: | Legal and Regulatory Framework & Regulatory Functions |
| Module II: | Technical Concepts governing Nuclear Safety, Nuclear Security and Radiation Protection |
| Module III: | Regulatory Oversight of Safety Culture |
| Module IV: | Individual Tutoring |

For each module the prerequisite is indicated as well as the learning outcomes. Each module will be described by the content, the reference publications and duration. The content of each session will be described by key words. The list of reference publications for each session will also be presented. For each module, a list of practical training sessions will be suggested. These sessions can be face-to-face like or interactive exercises as indicated in 3.2. of this paper.

3.4 Macro Learning Outcomes

After the successful completion of the BTP, learners are expected to be able to:

1. Demonstrate a systemic vision of nuclear safety by understanding the explicit and implicit connections among technological, social, human and organizational features
2. Explain the fundamental principles that form the system for the protection of human and their environment from ionizing radiation;
3. Discuss the legal basis and regulatory process that empower the NRA to govern its operation;
4. Explain the basics of regulatory oversight of licenses including the management of safety culture and to compare the different oversight approaches;
5. Identify the different steps of the safety culture oversight process and to differentiate between nuclear safety and nuclear security culture;

6. Discuss the basic, applied and advanced technical disciplines related to the regulatory control of facilities and activities using ionizing radiation;

7. Describe and discuss regulatory practices such as assessment and inspections technologies, investigation and auditing;

8. Demonstrate soft skills necessary to carry out regulatory functions

4. European Credit system for Vocational Education and Training (ECVET): an instrument for mobility and recognition

Knowledge and skills are vital for ensuring safe, secure and peaceful uses of nuclear energy and nuclear applications. As a consequence, policy attention to vocational education and training (VET) is increasing worldwide. However, the validation/recognition of non-formal and informal learning is a major challenge, particularly if learning takes place outside formal education and training institutions. The outcomes of these non-formal learning processes are not standardized and could be diverse or even multidimensional. Therefore, transparent methods and instruments need to be used to identify, assess and attribute recognition of non-formally and informally acquired learning outcomes [6].

This can be achieved by non-formal education and training providers applying the European Credit system for Vocational Education and Training (ECVET). ECVET is based on concepts and processes used in a systematic way to establish a common and user-friendly language for transparency, transfer and recognition of learning outcomes. Some of these concepts and processes are already embedded in many qualifications systems across Europe [7]. FIG.1. below sets out the principles on which the ECVET is based.

![FIG1. Principles of the European Credit System for Vocational Education and Training [7].](image-url)

In the light of the above identified challenges, ENSTTI has decided to create the necessary conditions and measures for the gradual implementation of ECVET to facilitate the mutual recognition of technical and regulatory competencies in the area of nuclear safety, nuclear security and radiation protection which will be build-up through the ENSTTI training. By applying the ECVET it will also be much easier for the employer (TSOs and NRAs) to better understand the qualifications which are achieved by their professionals at ENSTTI training and tutoring programmes.

Finally, it should be mentioned that mutual trust and confidence among ENSTTI and learners (NRAs and TSOs) can also be expressed in Memoranda of Understanding and Learning Agreements which can be concluded with countries from all regions in the world.
5. Conclusion

Regulators represent a unique component of the nuclear workforce in account of their statutory powers. In some countries nuclear regulatory authorities (NRAs) are supported by Technical Safety Organizations (TSOs) in carrying out their designated functions. In order to ensure an efficiently, safely and securely performing nuclear sector, each regulatory authority depends on highly qualified personnel who are competent in many disciplines.

The importance of vocational training in maintaining nuclear security, nuclear safety and radiation protection and in fostering nuclear safety culture cannot be underestimated. Hence, ENSTTI makes all efforts to ensure that personnel working at NRAs and TSOs have any time access to continuous professional development tailored to their training needs. The demand for skilled personnel set against a generally ageing workforce, a continuous evolution of techniques and knowledge and an on-going globalization trend in the nuclear sector makes it very clear that this effort is timely and adequate since it will put in place a training mechanism within a recognized qualification system that ensures the maintenance of the current skilled and competent personnel at NRAs and TSOs, and the flow of new recruits for long-term sustainability.

Supported by the European Commission through the NUSHARE project, ENSTTI has initiated the process to develop and establish a mutually recognized training programme for staff at NRAs and TSOs by involving the main stakeholders in the design and development of the curriculum and by applying the European Credit system for Vocational Education and Training (ECVET) that aims at promoting mutual trust, transparency and mutual recognition of acquired learning outcomes in the form of ECVET credits. All these efforts made by ENSTTI are focused to contribute to the systematic development and continuous improvement of technical and regulatory competences necessary to ensure global nuclear safety and nuclear security.
References


PROFESSIONAL MODULE-BASED TRAINING
IN NUCLEAR ENGINEERING
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ABSTRACT

The Aachen Institute for Nuclear Training (AiNT), a spin-off of the RWTH Aachen University, offers a programme for extra-occupational training and further education in the field of nuclear engineering. The institute works in close cooperation with the nuclear industry, the nuclear regulation authorities as well as educational and research institutions.

So far the modules are performed in German, but new modules in 2014 will be held in English. The AiNT training programme currently comprises seven modules, which are linked to each other, but can also be attended separately. Each module is supported by up to twenty highly educated lecturers from different institutions (industry, regulation authority, etc.), who can show several years of practical experience and a subject-specific knowledge. Several discussions and iterations with the lectures help to offer the trainees a comprehensive programme with practical aspects of knowledge transfer.

Within this paper the concept and content of the training programme will be presented and as an example the next year held in English module “Gamma-Spectroscopy” is introduced. The content for this module will include presentations by experts (scientists & engineers) as well as a practical training with different measurement equipment. For example: digital radiography, gamma ray spectrometry, integral passive neutron measurement and segmented gamma-scanning.

To keep a competence level in nuclear engineering on a high standard, a widespread knowledge transfer and an examination with the state-of-the-art of science is very important. That is why it is necessary to offer a professional training programme in cooperation with the nuclear society. One of the main goals of AiNT is to encourage the exchange of information and the creation of networks between the institutions and persons concerned. In addition AiNT wants to maintain the high level of continuous professional development for qualified personnel and the high level of safety within the nuclear sector. This is particularly important in view of the phasing out of nuclear energy in Germany.

1. Introduction

AiNT is an independent company in the field of nuclear education and training, which also acts as a mediator between industry, regulation authorities as well as the general public. In this paper the main objective of AiNT, professional training in nuclear engineering, will be presented. The first part of the paper highlights the development of nuclear technology in Germany. Our focus is on the political and social changes resulting in the phase-out of nuclear energy in Germany. Which effects had this hastily decision on the academic and scientific situation, including an already on-going national loss of competence in the nuclear industry? In Germany, some topics, like decommissioning and the waste management for final storage will become a more important part in education and training.
The second part of the paper focuses on alternative training possibilities beyond academic education, which are possibilities to fill the gap of missing expertise. The concept of a module-based education programme is introduced, including its advantages for the maintenance of competence in the field of nuclear engineering. The seminar “Gamma Spectroscopy” is taken as an example for an AiNT course module.

2. Nuclear Technology in the Federal Republic of Germany

Since the beginning of the 20th Century the scientific advances and developments in nuclear technology have made a great contribution to both enable the prosperity of the German population, as well as build a broad-based and advanced R & D landscape in Germany.

Great efforts were made in Germany to develop nuclear technology. The major research centres, for example in Karlsruhe and Jülich, were founded in the 1950s and 1960s as "nuclear research centres". These facilities operate today under the umbrella of the Helmholtz Association and lay their research focus mainly on the areas of "health", "energy" and "environmental research". The research and development work in the nuclear industry have put forward innovative ideas for other research areas and technology developments. The use of radiotracers and the use of ionizing radiation for imaging techniques has opened up new insights in medicine and non-destructive material testing. Nuclear technology has become a key technology for other research disciplines and has contributed to the fact that the competence has widened in Germany in many areas.

3. Political and Social Changes

The change in social and political attitudes towards nuclear technology, especially nuclear energy, however, has contributed to the appeal for a nuclear engineering degree having been greatly reduced. Since the 1980s, basic research infrastructure for nuclear technology is brought down to a minimum in Germany. The change in the research centres in Karlsruhe and Jülich, or the shutdown of most research reactors serve as examples of this development. As a result the expertise in nuclear technology in Germany decreases rapidly. Within days after the nuclear disaster happened in March 2011 in Fukushima Daiichi large anti-nuclear protests occurred in Germany. Protests continued and, on 29 May 2011, the German government announced that it would close all of its nuclear power plants by 2022. Eight of the seventeen operating reactors in Germany were permanently shut down following Fukushima. This additional accelerated the loss of competence.

In all aspects of nuclear technology there already is a lack of qualified recruits. This is mainly due to the decrease in training capacity in a nuclear phase-out-oriented policy. This gap will be larger in the foreseeable future, since about 1/3 of the current professional staff will go into retirement in the next few years. Thus bit by bit the know-how in the field of nuclear technology inevitably gets lost and not only inhibits the progress of decommissioning and dismantling projects, but also leads to a problematic situation regarding the nuclear safety in Germany. Even opponents of nuclear power have recognized that this trend has a negative impact on the safety of nuclear installations in Germany: “Even if nuclear power plants should be shut down quickly, we still need more nuclear engineers, if only to keep up the reactor safety research and the evaluation of the nuclear programs of other countries” [1].
Due to the staff shortages and the challenges in the field of radioactive waste disposal will be more difficult to manage and may require additional expertise from abroad.

4. Consequences of Political Decisions – Loss of Competences

Driven by the exit decision of the federal government as a result of the energy transition, this negative trend is more acute, since potential students are insecure and not decide on a relevant course. In the master program "Nuclear Safety Engineering" at RWTH Aachen 17 students had enrolled in winter term 11/12. In the winter term 12/13 there were only nine students. At other universities, it looks partially even worse. The study program "Management and Radioactive Waste Management" at the TU Clausthal for example did not take place, because this subject has not been chosen by any student.

The German newspaper “Süddeutsche Zeitung” writes already in June 2011: "Currently the German universities simply do not have the places and the teaching staff to train more specialists for the nuclear industry. To meet their needs many companies proceeded to employ and to train mechanical engineers and chemists […]" According to industry estimates, about 1,000 new highly skilled professionals are needed annually. In comparison, "... there is this year 150 doctorate students who write their dissertation in nuclear topics," says Dr. Astrid Petersen, chairman of the Nuclear Society [2].

The figures show that soon there will be a shortage of qualified recruits or there already is. Despite the phasing out of nuclear energy experts are needed to address the upcoming challenges such as the dismantling of nuclear power plants and the disposal of radioactive waste. The maintenance of competence not only remains significant in terms of Germany's role in international economic and scientific comparison, but also in relation to the associated responsibility to society - especially regarding the issue of evaluation of the safety in the construction of nuclear power plants in neighbouring countries.

5. Preservation of Competence through Appropriate Training Opportunities

In the current situation in Germany, it is important to offer additional training opportunities to the university courses that provide knowledge in nuclear technology beyond and additional to an academic context. Preservation of competence in a highly complex field such as nuclear energy can only be carried out through the cooperation of various experts from different institutions, including industry, universities, nuclear regulatory and licensing authorities as well as technical safety organisations.

Furthermore, many areas of work in the field of nuclear technology are subject to dynamic development (e.g. methods for waste disposal), so that knowledge of the present state of the art is an important challenge for any employer and employee in this field. This is why AiNT has developed a corresponding training programme in addition to the established E & T concepts, to provide a career-long training and further education programme.

In the course modules we deal with basic knowledge in nuclear engineering as well as special subjects. The programme addresses employees with different engineering or scientific background, who work in the nuclear industry or other organizations in the nuclear sector. Furthermore, representatives of the media and political institutions are addressed.
6. The AiNT modular-based E&T programme

At present the training programme offered by AiNT consists of eight modules matching one another (see Figure 1). These modules, which mostly last two to four days, are carried out at selected conference hotels in the centre of Aachen, or at customer’s premises. Depending on the module, as much as 20 different teaching staff members will participate. When conceiving the training programme, AiNT obtains active participation commitment from the teaching staff members, in order to satisfy the requirements of nuclear industry by offering attractive training events. Knowledge, essential for a basic and continuous expertise in the field of nuclear technology, is passed on as well as directing the focus on the current issues and challenges the industry is facing. The modules can be taken separately and are structured thematically independent, but nuclear physics basics are required for the advanced modules (Modules 3-8).

Figure 1: The modular-based E&T programme of AiNT.

This reflects the approach to cover a wide field of experts. The integration of internationally recognized faculty staff from a variety of disciplines ensures that specialized content is taught purposeful. The training programme developed by AiNT differs to those of other partakers in the market as far as relevance, sustainability and visibility are concerned. Figure 2 shows the unique features of the programme.
In the development of a professional E&T programme, the Aachen Institute for Nuclear Training not only places special emphasis on the content, but also on the application of didactic principles. The size of the learning group is limited so that group discussions are possible and, if necessary, individual issues can be resolved (see Figure 3).

By the selection of instructors and a diverse group of participants an exchange and further discussion are promoted, so that comprehensive synergies are formed in addition to the actual course content. The content of the training program can be flexibly adjusted in each module and expanded to respond to the ever-changing developments and requirements in research, industry and politics. Only in this way a meaningful and useful discussion of the state of science and technology is assured.
Next to application oriented teaching, organisation and carrying out of specialised events are a second field of activities that AiNT attends to. With these events the company offers a platform for discussions for the stakeholders and hundreds of other participants. Potential partakers in these events will be addressed through marketing campaigns in the specialised press and through specific contact with potential customers or companies. After the political decision to phase out of nuclear energy AiNT organised the First Conference on Nuclear Decommissioning in January 2012 (see Figure 4). This conference was the first platform, which critically discussed the consequences of the political decision and the question how to manage the future challenges such as parallel dismantling of eight power reactors in Germany. In November 2013, the follow-up conference will be held (www.icond.de).

![Figure 4: First Conference on Nuclear Decommissioning in January 2012](image)

### 7. Organisation & Planning of Events

The organising and planning of the training programme, as well as of specialised events mostly runs according to the same scheme. The particular feature when organising specialised events consists in the integration of partner companies or of an advisory council. Once AiNT has worked out the rough programme, which includes main topics, time schedule and place for the individual modules or specialised events, contact is established to potential members of the teaching staff or to cooperating partners. A detailed programme is then worked out together, with AiNT acting as a coordinator. Parallel to these activities, AiNT will start a marketing campaign for the events. Potential partakers are approached selectively within the frame of a broad plan of action, by means of informative letters, e-mails and advertisements in selected specialised journals. By now, AiNT has a data base containing far more than 1700 contacts in the relevant areas of nuclear technology, nuclear energy, services, etc.
During the course of organisation of specialised events, contact to potential speakers is taken up only after the detailed programme has been worked out. The corresponding presentation of papers is discussed with them. Cooperating partners will be asked to participate in support tasks if necessary. Figure 3 shows the organisation of the course modules.

**Figure 3:** Organisation of the course of modules. After AiNT has devised the rough programme, contact is made to potential teaching staff members. Next to this, the marketing campaign is started in order to get together a sufficient number of partakers for the modules.

### 8. Course-Example: Gamma Spectroscopy

In order to explain our procedure for the course organisation, we will present the development of the newest course, entitled "Gamma Spectroscopy". The topic of gamma spectroscopy is an important issue in connection with decommissioning and radioactive waste characterization. In this area of nuclear technology already a high level of knowledge is achieved in Germany, but again raises the same problem as in other nuclear disciplines: many of the experts who can demonstrate a long work experience will soon retire and there will not be a well-educated generation of nuclear engineers to succeed them.

Theoretical and practical aspects of gamma spectroscopy are subject of this course. The lectures will introduce the basics of gamma spectroscopy, the characteristics and interactions of gamma-quanta as well as the different detection techniques. There are no requirements to enter the seminar, but a basic knowledge in physics is helpful. The course is divided into three main topics: 1. Interaction of gamma rays with matter; 2. Physical principles of detectors for gamma radiation; 3 Fundamentals of electronic and signal processing. The single lecture-units include analog digital converters, multiplexers, calibration of a gamma
spectroscopy system, low-level measurements, background and shielding corrections and introduction mainly used gamma spectroscopy software. Finally there will be practical training to round up the theoretical part. The practical training includes 3 different measurement tasks, which will be completed at the research centre Jülich. The practical exercises are performed in groups of five to seven people. The first exercise is “Energy and Efficiency Calibration”, the second exercise “Detection of Background and an Analysis of a NORM sample” and the third exercise is “Shielding and the Effect of Bremsstrahlung.” Each practical part consists of an introduction, then the measurement, followed by the analysis and discussion.

9. Conclusion

With its professional extra-occupational training programme, AiNT offers an additional educational assistance to the academic education or on-the-job training. It differs from other training opportunities in its design and implementation. The key aspects of the training are:

- Module based training enables a skill-based solution for new personnel with no basic knowledge in nuclear physics or nuclear technology (Modules 1-2) and the possibility of supplementary qualification of specialists (Modules 3-8).
- Up to 20 lecturers are involved for every course module and therefore in due consideration of specific practical working experience.
- In Addition to the changing lecturers persistent support provided by a nuclear engineer and a nuclear scientist.
- Intensive training, every course module lasts only two to four days and is easy to integrate in the daily business.
- Needs-based training, taking into account the requirements of the Industry as well as the nuclear regulation authorities.
- Annual dynamic programme adaptation in policy, technical, legal or safety changes.

References

CHALLENGES IN NUCLEAR TRAINING AND QUALIFICATION AT
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ABSTRACT
Following the accelerated nuclear phase-out in Germany of 2011 and with experienced experts retiring, German nuclear regulatory authorities (NRA) and technical safety organisations (TSO) face specific problems in maintaining the necessary skills and competencies in the long term. The main difficulties of GRS lie in recruiting graduates with work experience in the nuclear field and good knowledge of the German language. Consequently, GRS has developed a strategy to cover its competency needs in the long term. This strategy consists of three main elements. First and most important is an in-house training program with a curriculum of courses developed by GRS (called GRS Academy). Newly recruited graduates in engineering and natural sciences without extensive work experience in the nuclear field are trained by experienced GRS experts on the basics of nuclear safety, radiation protection and nuclear security. This complements the on-the-job-training for new staff and provides them with a solid basis in nuclear safety. This in-house training is enhanced by selected external training in Germany, e.g. on the full-scale plant simulator in Essen, or by international training offers, e.g. from ENSTTI. Secondly, GRS is part of the German Alliance for Competence in Nuclear Technology. In close cooperation with university chairs on nuclear safety and technology GRS offers opportunities for bachelor and master theses as well as dissertations on nuclear safety and security issues. Finally, GRS also organizes lessons in German for new staff that is not fluent in the German language. Lessons in other languages like e.g. English are organized if needed as well. Overall, the GRS strategy strongly emphasizes the use of specific training for new staff on the necessary skills and competencies and thereby ensures that the strategic goals of GRS can be achieved.

1. Introduction

Germany decided to accelerate its phase-out of nuclear energy for electricity generation in response to the nuclear accident in Fukushima. Eight nuclear power plants ceased power operation in 2011, the remaining nine units will cease power operation between 2015 and 2022 [1].

This change in nuclear policy directly impacts GRS, the main Technical Safety Organization (TSO) to the Federal Government of Germany for nuclear safety and especially the Federal regulatory authority, the Federal Ministry for Nature, Conservation and Reactor Safety (BMU). GRS is a non-profit company, in which the Federal Republic of Germany together with the states of North Rhine-Westphalia and Bavaria hold a majority stake. More than two thirds of the GRS budget is financed by federal ministries and agencies.

Despite the accelerated phase-out in Germany, the tasks of GRS as the TSO to the German federal government change only in details. One important focus of GRS in the coming years
and after 2022 will be the decommissioning of nuclear power plants and especially research and safety assessments related to the search for and the construction of a final repository for high level nuclear waste. Simultaneously, there will be fewer tasks in connection to operating nuclear power plants and fuel cycle facilities. However, in another reaction to the Fukushima accident GRS has been tasked by the federal regulator BMU with providing crisis centre support in the event of a nuclear accident in Germany or outside of Germany. Based on these requirements, GRS will have to maintain its capabilities in all fields of nuclear fuel cycle safety and security assessment and research in order to support the Federal Government on operating plants and facilities as well as new-builts in Europe and internationally.

Simultaneously, GRS is faced with the retirement of experienced experts and the normal fluctuation of staff. GRS therefore needs to hire 5% up to 10% of its total staff number each year. This is not only a task for human resources acquisition, but is a challenge to the planning and performance of nuclear training and qualification of GRS staff. Therefore, GRS is currently revising its internal training and qualification program in order to meet these challenges.

The remainder of the paper is structured as follows. In section 2, the current challenges for maintaining GRS technical and scientific capabilities are shortly outlined. The following section 3 discusses in some detail the training and qualification program and the respective boundary conditions. First, the past experiences and approaches by GRS for the training of new as well as experienced staff are presented. Specifically, the now discontinued GRS trainee program is described. Then, the current status of the revision of the training program for new employees is outlined. In section 4 the cooperation of GRS on training and qualification within Germany and outside of Germany is briefly presented. Section 5 gives a short summary.

2. Current challenges for maintaining GRS technical and scientific capabilities

The role of GRS as the main TSO to the German Federal Government and the crisis centre support require GRS to maintain its competences and capabilities in the corresponding fields of nuclear fuel cycle safety and security assessment and research in the long term.

Some important challenges faced by GRS are discussed in the following.

1. While the German Federal Government is committed to maintaining GRS as a key competence centre in nuclear safety and security, the phase-out policy will impact on the available funds for GRS. Currently, a certain reduction of funds is expected leading up to 2022. Moreover, there will be a shift towards decommissioning and final repository issues as well. This will impact on the number of staff GRS employees and the capabilities in the different fields of nuclear safety and security in the long term.

2. GRS was established in 1976 when nuclear industry in Germany was booming, and a lot of young people were hired in the nuclear field. 30 to 40 years later these people retire. In order to prevent a loss of competence, young professionals must be recruited and qualified. As this process is still going on, GRS needs to hire a significant number of new staff in the coming years.

3. In addition to retiring experts there is also the usual fluctuation of staff. Since the federal regulator BMU and the Federal Office for Radiation Protection face similar challenges in acquiring staff with specific experiences in nuclear safety and security, a number of GRS experts have gone there. The creation of the Federal Office for Nuclear Waste Disposal in 2014 [2] might induce GRS staff to leave in that direction as well. This fluctuation increases the need of GRS to hire new staff.
4. The changes in the social acceptance of nuclear industry in Germany since Chernobyl have reduced the availability of young engineers and scientists with specific experiences in the nuclear field on the German job market. Following the Fukushima accident, even less students with specific experiences in nuclear are expected to graduate. Therefore, GRS is faced with a dearth of home-grown experts in the nuclear field.

5. Uncertainties concerning the future prospects of a career in the field of nuclear safety and security in Germany impact on the ability of GRS to contract new staff.

3. GRS qualification and training strategy

GRS has established a professional training and development strategy for its employees. As a technical safety organisation GRS needs to keep its experts up to date with the current state-of-the-art in nuclear safety and security. Training and qualification are seen as a continuous task relevant to all employees. Specifically, each employee should receive about 5% of its yearly working time in training and qualification in the long-term average [4]. As part of its quality management program, GRS has defined a support process for human resource development and internal qualification [5] for the implementation of the training strategy.

With regard to experienced GRS staff, the respective department or division heads should define the needs for further training together with the employees. One important input to this task is an appraisal interview that is held at least every two years. Based on the identified training needs, each year a training plan is drafted by for each department. This is communicated to the human resources department, which keeps all the records on training measures. In addition, the human resources department organizes certain internal training activities, e.g. training courses in business English.

![GRS Training and Qualification Process Schematic](image)

With regard to newly hired staff, there is a standardized training concept with a modular structure. This consists of

- Basic instructions
- Internal specialized training courses
- External specialized training courses.
The individualized training program for each new staff is complemented by
- On-the-job training and private studies,
- Tutoring (if needed),
- Specific training events

The concept for the training of new staff is discussed in more detail in sections 3.1 and 3.3.

3.1. Previous training and qualification strategy for new staff

In 2010, before the Fukushima accident, the ruling coalition decided to delay the previously enacted phase-out by approximately 10 years to around 2036 for the newest German power plants. Consequently, the GRS training and qualification strategy as well as the human resources estimations of the German regulatory authorities were tailored to have sufficient expertise in the long term.

The GRS training and qualification strategy was based on internal courses conducted by GRS and courses at external institutions and consisted of two main elements.
- a trainee program for young professionals recruited from university,
- a training concept for new employees working in their departments right from the beginning.

As there was a significant overlap between both elements, several courses and modules were used for both groups of staff. In the following, a more detailed description of the trainee program developed by GRS is provided. In addition, the links to the training program for other new staff is described.

3.1.1 GRS trainee program

GRS had established a trainee program in 2009 within the GRS akademie. This one-year trainee program was tailored to GRS requirements on new staff without specific experiences in the nuclear field. In addition, the program was open to BMU, BfS and the regulatory authorities of the Länder for training and capacity building.

The trainee program has been organized around internal as well as external training courses on all areas in the fields of nuclear safety and security. It consists of
- Basic courses
- Advanced courses
- Supplementary courses
- Visits to PWR and BWR plants
- External courses on special topics
- Self-study
- On-the-job-training

The following basic knowledge modules have been defined:
- Introduction to GRS
- Basic knowledge on nuclear safety and nuclear technology
- Project management and quality assurance in the GRS
- International cooperation activities

The fundamentals on nuclear safety and technology cover the following specific issues:
- Nuclear law, regulation and oversight,
- Reactor and core physics and thermal dynamics,
- Nuclear power plant technology (PWR and BWR),
- Nuclear power plant operation and operating experience evaluation,
- Transient and accident behaviour of nuclear power plants,
- Radiation protection,
- Nuclear fuel cycle,
- Nuclear waste storage and disposal.

The basic curriculum is scheduled to be completed within the first three months of the program. Figure 2 gives an overview over the arrangement of basic courses in this period for the year 2013. Note that basic courses are denoted B1, B2 and G2, respectively. After the basic training and a period for repetitions on the respective subjects, an intermediate exam is held. In addition, advanced training is given on specific subjects (denoted VK in the schedule). These training-courses are either given by GRS experts, e.g. on the topics of

- Security of nuclear facilities,
- Thermal hydraulic analysis simulator training on transient and accident behaviour of PWR and BWR,
- Nuclear fuel cycle, transport and disposal,

or they are external courses at German training institutions. The latter include

- Reactor physics training at the training reactor of TU Dresden,
- Thermodynamics of PWR at the glass model at GfS in Essen,
- Simulator training on NPP operation and transient behaviour for PWR and BWR using plant specific, full scope simulators at GfS in Essen,
- Radiation protection laboratory at PowerTech Training Center in Essen.

Moreover, there are supplementary courses on

- Rhetoric, Communication, Presentation, Conflict Resolution and
- Technical English.

The trainee program is complemented by plant visits and finishes with a final exam. After successfully passing the training program and the exam the trainees start working in their departments at GRS.

Figure 2  Schedule of Trainee Program 2013

The first trainee year in 2009 was a pilot project. Eleven GRS trainees started that year, but one of them abandoned the programme in between. The experiences made in the first year of the program and the feedback of the trainees and instructors were used to improve the
trainee programme. The overall evaluation of and the experiences with the trainee program were positive. It has been found an effective means to train young staff from university without prior detailed knowledge in nuclear safety and technology. All of the GRS trainees passed their exams (cf. Table 1). The exams were not mandatory for the participants from the regulatory body.

Table 1  Final exam grades of trainee program participants

<table>
<thead>
<tr>
<th>Percentage of points [%]</th>
<th>2009</th>
<th>2010/11</th>
<th>2011/12</th>
<th>2012/13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Successfully</td>
<td>88 - 100</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Passed</td>
<td>65 - 87</td>
<td>6</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Participated</td>
<td>&lt; 65</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The costs associated with the implementation of a trainee program are significant, both in terms of direct cost and in work resources dedicated to training time. Consequently, the trainee program can only be implemented efficiently, if a certain number of trainees take part. As shown in Figure 2, the number of trainees decreased from year to year. In 2013, the trainee program was not renewed due to the changed boundary conditions for GRS.

3.1.2 Training concept for new GRS employees

GRS has also hired new staff outside of the trainee program. The training concept described in chapter 3, consisting mainly of basic instruction training modules and specialised instructions, is the basis on which a training plan and schedule is developed for every new employee by the department head together with the human resources department. The individual training plan takes into account the qualification and experience the new staff member has already reached. In general, every new employee should attend the basic instruction modules being about 2 days each and including

- The corporate structure of GRS and the work of the authorised experts,
- Fundamental principles of nuclear engineering, radiation protection and waste management,
• Project management,
• Quality assurance.

The topics of the modules on “Fundamental principles of nuclear engineering”, “Radiation protection”, and “Waste management” were covered by the corresponding seminars called “Behördenseminare”. These seminars are conducted by GRS on behalf of BMU for the training of regulatory staff. While the trainee program was in place, the new GRS employees did take part in the respective modules of the trainee program. Additional basic training modules for new employees were scheduled if needed.

The content of the training-on-the-job and the private studies depends on the tasks and duties of the new employee and on the instructions of the superior. According to the qualification, tasks and duties of the new staff member, he or she participated in internal and external training events, e. g. training courses, simulator courses, seminars or conferences on a national or international level. Especially with regard to specialized training courses, the cooperation and coordination with the trainee program provided significant benefits. The yearly schedule of the trainee program offered the possibility that the new staff members and the trainees could attend these training courses together.

The training is closed with a meeting of the staff member and the superior, in which the success of the training is discussed.

3.2. Training and qualification of experienced GRS staff

As outlined in section 3 above, GRS defines the training and qualification of staff as a continuous task. Moreover, GRS needs to keep its experts up to date on the current developments and insights in nuclear safety and security. Therefore, every year GRS experts should spend up to 5% of their total work time on training and qualification. This covers formal training courses, seminars and conferences as well as informal training.

Regarding formal training measures, the respective department or division heads should define the needs for further training together with the employees. One important input to this task is an appraisal interview that is held at least every two years. Based on the identified training needs, each year a training plan is drafted by each department. This is shared with the human resources department, which keeps all the records on training measures.

Formal training and qualification measures can be on all fields of nuclear safety and security. To the extent possible, GRS incorporates these measures in the training activities for new staff. For example, simulator training course participants can be a mix of experienced and new GRS staff. Additional possibilities consist of advanced level training courses of German or international training providers. In this regard, the training offer organized by the European Training and Tutoring Institute (ENSTTI) will play an increasing role in the future.

Other training and qualification measures cover personal development of GRS staff, like rhetoric and presentation or conflict resolution of leadership training. With regard to foreign languages training, activities are defined depending on the individual needs of staff and respective project requirements. The languages in question are usually English, Spanish, French and Russian. Except for English, the language lessons are often taken by attending courses at language schools or similar institutions. With respect to English, the human resources department organizes in-house training courses in business English.

In addition to the formal measures defined in the training and qualification plan, each staff member can choose from a wide range of further qualification possibilities. GRS offers access to a selection of scientific journals on nuclear safety issues and maintains a library of important nuclear technology and safety publications. Interested staff can access the training
materials of all internal GRS training activities and other training material (e.g. IAEA training courses) at their workstation for individual studies. Finally, GRS organizes internal seminars. There, GRS experts or external experts present on current issues in their work.

3.3. Current training and qualification strategy

The training and qualification strategy of GRS for new staff is currently being revised in order to adapt it to the changed circumstances, especially since the trainee program has not been renewed. Important aims of this revision are to increase the training efficiency while simultaneously improving cost-effectiveness.

To this end, the basic training modules with duration of 2 days described in section 3.1 are to be merged into one basic module with duration of one week. The training module is basically split into two parts. Its schedule is presented in annex I.

The first part covers the (almost) first two days. It comprises the basic information about GRS as a company and its subsidiaries, the divisions of GRS and GRS works council. Moreover, essential information on GRS quality and project management as well as the IT infrastructure is presented. The second part covers the three last days. There, the very fundamentals on nuclear safety and security issues are presented for the different fields. This basic module is intended to be held for all new staff, even non-scientific staff. Due to the structure of the course, the last three days of the course are seen as optional for certain staff below graduate level. Considering the fact that GRS will hire about 5% to 10% of its total staff number each year, there are currently about two repetitions of this module foreseen in each year. In this way, every new employee should be able to participate in this basic module within the first 6 months after entering the company. This is seen as one important goal for having an efficient training.

This basic training will be complemented by division or even department specific training courses. GRS is currently in the process of identifying a basic curriculum of training courses for new staff specific to each division. This curriculum will be based on some of the already developed training modules from the trainee program. For some division or departments, the curriculum could also contain external training, e.g. simulator training sessions. This curriculum will then be complemented by training measures defined on an individual basis in the respective training plan. One important task in the further development and improvement of the training program will be a check against the recommendations given in the upcoming SARCoN guidelines [8]. By having a central coordination of internal and external training measures, GRS will increase the overall effectiveness of the training and qualification measures.

Because of the low availability of native German speaker with pre-qualifications in nuclear safety and technology, GRS is hiring new staff not fluent in German. However, the work at GRS often requires proficiency in the German language for the writing of reports and contact to contractors. Therefore, lessons in German are organized for those new staff members who need them. These lessons are usually taken in respective courses at language schools or even as one-to-one language lessons.

One important aspect of achieving an effective and efficient training program is providing not only a high quality training within a reasonable short time frame, but also achieving this in a cost-effective manner. While internal training is often a good solution if there is a sufficient number of participants, the diversity of specialist issues often prevents this. Therefore, external offers will be incorporated into the respective training plans when appropriate. To this end, GRS will include the courses offered by ENSTTI into the individual training plans,
especially the advanced level training courses on nuclear safety and security issues. For the future, the importance of ENSTTI training courses might even increase, since the hiring levels of GRS will probably decline in the medium to long-term future. Cooperation between European TSOs on nuclear training and qualification under the roof of ENSTTI of new and experienced staff could become an important building block for an efficient training program.

4. National and international cooperation on qualification and training

GRS is actively using national and international cooperation on education and training. On the national level, GRS is a member of the German Alliance for Competence in Nuclear Technology (cf. Figure 4), which was founded in 2000 and is supported by the German Federal Government. Within the alliance, GRS has especially close links to the Technical University of Munich (TUM) at the university campus in Garching, forming the competence center “South”. Students from TUM are doing their bachelor or master thesis within GRS projects, e.g. in the nuclear safety research division. Similar cooperation is possible with the research centre in Dresden-Rossendorf or the technical universities in Aachen and Clausthal. In addition, GRS also offers doctoral thesis work in cooperation with universities. Apart from the technical and scientific progress reached in the respective projects, the graduates form an important recruiting pool for GRS.

![Figure 4](image)

**Figure 4** German Alliance for Competence in Nuclear Technology [9]

On the international level, GRS is actively involved in the activities of ENSTTI. As an example, GRS has hosted the yearly ENSTTI Induction to Nuclear Safety training course [10] for the last 4 years. In addition, GRS provides lecturers for a number of ENSTTI training courses and tutoring offers. As already mentioned in section 3.3, GRS incorporates the ENSTTI training offer into the training and qualification program of new and experienced experts.
As part of the activities of the European TSO Network (ETSON), each year the ETSON summer school is organized by the ETSON partners. The summer school is dedicated to a different topic each year and brings together young experts from the European TSOs for a common work in nuclear safety and security. GRS actively participates in the summer school as part of its international cooperation.

5. Summary

Highly qualified experts are a prerequisite for a TSO like GRS. Because experienced staff member are retiring, GRS needs to hire a significant number of new employees each year. However, after the accelerated phase-out from nuclear power in Germany enacted after the Fukushima accident, GRS faces challenges in recruiting new staff with prior knowledge in nuclear. This requires a revision of the GRS training and qualification programme, which is currently under way.

Already in the past, GRS has defined a training strategy and has implemented a comprehensive training and qualification programme for new and experienced staff members. One notable example was the GRS trainee program. The program started in 2009 and was conducted successfully for four years. The trainee programme was not renewed for 2013 due to the changed boundary conditions.

The experiences made in and the materials developed for the trainee programme are used for the revision of the training concept for new staff members. There will be a one week basic training directed at all new employees at GRS. This will be complemented by division and department specific training courses, both internal courses and courses at external providers like the simulator training centre. Individual Training plans will be developed for new and experienced employees by the department head together with the employee depending on the qualification, experiences, duties and tasks of the employee and will be forwarded to the Human Resources Department. The training and qualification comprises not only technical skills but also language skills, if needed, including German for staff members whose mother tongue is not German. GRS is also actively pursuing national and international cooperation on qualification and training, for example by supporting bachelor and master students or by the involvement into the training activities of ENSTTI.

Overall, GRS is well prepared to cope with the challenges in nuclear qualification and training of its staff.

6. References

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[5] GRS, QM-Handbuch, Teil 2: UP 02 Personalentwicklung, revision 02/11/2010, unpublished (German only)
[6] Leitstelle Kerntechnik, Richtlinie der Technischen Überwachungsvereine und der Gesellschaft für Anlagen- und Reaktorsicherheit zur Einweisung und Weiterbildung der Mitarbeiter für Sachverständigentätigkeiten im atomrechtlichen Genehmigungs- und Aufsichtsverfahren, revision June 2013, unpublished (German only)
[7] GRS, Behördenseminare, http://www.grs.de/content/behoerdenseminare, last accessed 26/09/2013, (German only)
### Annex I – GRS Basic Training Schedule

<table>
<thead>
<tr>
<th>Time</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td>Inception and “GRS as a company”</td>
<td>Quality management</td>
<td>Non-mandatory nuclear regulation</td>
<td>Radiation dose and radiation effects</td>
<td>Decommissioning of nuclear facilities</td>
</tr>
<tr>
<td>09:45</td>
<td>Employment at GRS</td>
<td>Project management</td>
<td>German nuclear design concepts</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>10:30</strong></td>
<td>Coffee Break</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:45</td>
<td>IT und Information systems</td>
<td>International projects</td>
<td>PWR fundamentals</td>
<td>Radiation protection fundamentals</td>
<td>Transport of nuclear materials/waste</td>
</tr>
<tr>
<td>11:30</td>
<td>GRS works council</td>
<td>Documentation and supervision tools</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>12:00</strong></td>
<td>Lunch Break</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13:00</td>
<td>Presentation of divisions</td>
<td>Internationale cooperation and networks</td>
<td>PWR fundamentals (continued)</td>
<td>Nuclear fuel cycle (Overview and strategies)</td>
<td>Fundamentals of nuclear security</td>
</tr>
<tr>
<td></td>
<td>- Reactor safety research</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>- Repository safety research</td>
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</tr>
<tr>
<td></td>
<td>- Reactor safety analyses</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13:45</td>
<td></td>
<td>Non-nuclear activities of GRS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>14:30</strong></td>
<td>Coffee Break</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14:45</td>
<td>Plant operation</td>
<td>Fundamentals of nuclear physics</td>
<td>BWR fundamentals</td>
<td>Clearance and release of nuclear materials/waste</td>
<td>Treatment of disposal of nuclear waste in Germany</td>
</tr>
<tr>
<td>15:30</td>
<td>Radiation and environmental protection</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Projects and internal affairs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16:15</td>
<td>Central Services</td>
<td>Statutory fundamentals of nuclear regulation</td>
<td>Chernobyl and Fukushima accidents, GRS nuclear emergency center</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Project Management Agency/Authority Support</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>17:00</strong></td>
<td>End</td>
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</tr>
</tbody>
</table>
A SIGNIFICANT PROGRESS IN THE QUALITY OF TRAINING ORIENTED ON PERFORMANCE IMPROVEMENTS

F.J. GONZALEZ, J.L. DELGADO, J.L. MARTINEZ-SORIA,
 Nuclear Training, Tecnatom

Abstract

Tecnatom has conducted several actions to enhance the quality and standards of training services. The approach, based on performance improvement of NPPs, has involved a number of initiatives to increase the systematization of processes, to develop new and advanced training methods, as well as improving instructor competencies.

These actions had their origin in 2008, in a joint initiative of Spanish NPP’s (represented by UNESA) to strengthen personnel competencies by means of improving their training and qualification. Under this framework, UNESA and INPO reached an agreement in 2009 to carry out an assessment of Spanish training programs of operating personnel, compared with the accreditation criteria and standards established in the NPPs in the U.S. As a result of this evaluation, different areas of improvement were identified, triggering a set action plans for each one of the Spanish plants.

In this context, due to the significant involvement of Tecnatom in Spanish Nuclear Plants training activities, Tecnatom sets its own action plan including a large number of initiatives and investments, some completed while others in progress, related to the following topics:

- Improvement of training processes and methods.
- Development of new instructors’ competencies.
- Development of new training programs and improvements of training material.
- Adaptation of the model to provide training services.

Everything is performed to achieve very high levels of training quality, approaching the highest standards. Our commitment to safety forces us to work in organizations with cultures of continuous learning, having the best qualified professionals.

1. INTRODUCTION

Tecnatom has conducted actions to improve the quality and standards of training services regarding means and methods of training, as well as to improve instructor competencies. This paper exposes the main actions undertaken and the main goals achieved.

The approach based on performance improvement of NPPs has implied a large number of actions and initiatives in the systematic improvement of processes, quality and training qualification. Thereby, this approach systematically ensures, the qualification of workers at the plants and the maintenance and continuous improvement of their qualifications.

In 2008, Spanish NPPs (represented by UNESA) decided to strengthen workers’ skills and performance, by improving the training and qualification processes with the aim of contributing to a safe and reliable operation. After an exploration of international standards, in 2009, and within an agreement between UNESA and INPO, an evaluation of operating personnel training programs was carried out against the standards established in American NPPs.

In the U.S., these types of evaluations are carried out by the National Academy for Nuclear Training (NANT), integrated in INPO, this entity manages the accreditation of training programs by means of evaluation processes based on objectives and criteria that constitute excellence standards. The assessment tool and accreditation process focus on performance improvement, and constitutes one of the fundamental principles in the management of NPPs.
Thereby, in this assessment performed by INPO (called Gap Assessment) areas of improvement or weaknesses were identified, by comparing our means, methods, and even our involvement and commitment to training, with the objectives and criteria for accreditation. These areas of improvement led to action plans in each of the Spanish plants. And many of the actions were planned long term, requiring skilled resources, new training facilities and major changes in the processes.

Due to the significant implication of Tecnatom in the training of NPPs’ workers, Tecnatom set, based on the Gap Assessment outcomes, their own action plan. In this regard, Tecnatom has conducted several activities, some of them completed and some ongoing, to improve the quality and standards of training services concerning the means and methods of training, as well as aiming to improve instructor competencies. This paper gathers the main actions undertaken and the main goals achieved.

The actions carried out to enhance the training area capabilities can be grouped into the following sections:

- Improvement of training processes and methods.
- Development of new instructors’ competencies.
- Development of new training programs and improvements of training material.
- Adaptation of the model to provide training services.

Below, we expose each of them in detail.

2. IMPROVEMENT OF TRAINING PROCESSES AND METHODS

Initiatives aimed at acquiring "know-how" and making changes in training processes to improve quality, are included under this heading. The following statements are highlighted:

- The training processes are set under SAT (Systematic Approach to Training) Methodology, which forms the basis of training programs. Given the importance of this aspect, the definition of high standards has been one of the most significant actions. By means of an agreement between INPO and Tecnatom (4 year-long), there has been a knowledge transfer through the training and qualification of ten Tecnatom trainers. Thus, these trainers have been able to extend their new knowledge to the Spanish plants; specifically, every organizational manager and training coordinator has been trained in SAT Methodology. To this effect, manifold training sessions and seminars have been performed between 2010 and 2012, an activity that continues nowadays. The implementation of these processes requires commitment and participation by the organizational managers, method knowledge and proper role assignment duties.

- One of the improvement actions identified by INPO was the implementation of training processes based on training and evaluation of tasks of Field Operators. It is based on the performance of training in the workplace (On the Job Training) and the evaluation of their performance according to the expectations, both technical and human behaviour. Benchmarking visits to plants, conducting a pilot project, development of procedures for the design, development and implementation, and the qualification of instructors and evaluators, are among the various significant improvements that are being incorporated into the plants.

- One way to acquire methodology, to identify and understand the standards and expectations set in the U.S. plants is through active participation in INPO assessment teams on their Accreditation Visits of training programs, Accreditation Team Visits (ATV). Within the Tecnatom-INPO agreement, shares are being conducted. The involvement of technicians and training managers from Tecnatom in the accreditation process allow taking a closer look and accurate criteria, strengths, as well as difficulties obtaining a favourable evaluation. All that brings great value to training experts, identifying opportunities for improvement in a day to day basis.
• Use of operating experience in training is another of the expectations to perform an efficient training. In this section, Tecnatom has developed a management tool (EXPERT) which facilitates the systematic use of operating experience in training. The tool is fed and continuously enriched, keeping the knowledge, always focused on event prevention. The tool is shared by the instructors, allowing the interchange of training materials for future use in other training activities.

• Methodologies have been developed and performed, also an important provision of facilities for training in dynamic environments: field simulators, Human Factors simulators, training stations and training in laboratory environment. Guidelines have been developed in such environments, applying evaluation processes.

• We have carried out actions to measure training effectiveness and continuous improvement. Within this section, it is important to emphasize the implementation of manager and front line supervision in training, as well as the establishment of a set of indicators that allow us to measure where we are and the paths to follow.

• An important part of SAT is to measure how the training becomes a performance improvement in the workplace. By doing this, a gap in the worker’s performance whose cause is attributable to a lack of knowledge and / or skills is identified, a training plan can be developed, an indicator is set to measure the results of the plant before and after training, while observing the evolution of the indicator as a result of training.

![Number of Rejections Leaving Controlled Area Normal Operation](image)

**Figure 1. Outcome indicator and its evolution after training**

3. DEVELOPMENT OF NEW INSTRUCTORS’ COMPETENCES

The instructors are a key element in training. The actions aimed at improving their skills have been many, some are ongoing. Below, we describe initiatives that were aimed at improving the performance and qualification of instructors, reinforcing their skills or adding new ones, in all aspects: improvement of technical knowledge, methodological and pedagogical methods:

• After analysing and studying the tasks and competencies of instructors, an action plan is set to enhance their Initial and Continuous Training Programs. The main topics are:
  
  o To complement the technical training by strengthening all areas of knowledge related to the plant personnel trained.
  o To strengthen their qualification in SAT methodology.
  o To include competences to develop a constructive culture behaviours in training: Emotional Intelligence and Positive Reinforcement.
  o Reinforcement of the Fundamentals of Operating Experience and uses thereof in the initial and continuing training.
- Reinforcing feedback to students, coaching and correction tools.
- Optimization of the continuous training in plant, to reinforce knowledge in core tasks and integrate with exploitation.

- Activities to exchange experiences with the best training centres. There has been benchmarking activities with Koeberg, Callaway, Farley, Beaver Valley, Oconee and Laguna Verde.

- Attendance of instructors to INPO seminars and courses: "Instructor Certification Program" focused on developing instructor qualification in training methodology and pedagogical methods; "First Line Supervisor Seminar" addressed to training supervisors and "Operation Supervisor Professional Development", the seminar addressed to Control Room Supervisor, with direct application for the instructors responsible for the training of such personnel in Spanish NPPs.

4. DEVELOPMENT OF NEW TRAINING PROGRAMS AND IMPROVEMENTS OF TRAINING MATERIAL

The target of these initiatives is to have the capacity and capability to meet training deficiencies and emerging training needs of plant personnel. This subject offers new training programs and develops and improves some of the existing ones. The most significant actions to date have been the following:

- Developed the Initial Training Plan for Shift Supervisors, as well as the performance of professional development seminars under the direction of INPO.
- Developed the First Line Supervisors Training Plan, and delivery of 15 professional development seminars between 2010 and 2012. These have been carried out with the participation of INPO mentors and NPPs from other countries.
- Developed a professional development seminar for Control Room Supervisors and taught under the direction of INPO.
Also, a major effort has been made to provide teaching aid focused on the execution of tasks. The training methods and means evolve seeking maximum efficiency and focused on implementation of tasks in learning environments close to real plant conditions. An example of such environments is the Field Simulator. This training facility is designed and developed to simulate the performance of work under the conditions of the plant. In this sense the “ANAV - Tecnatom Human Factors Simulator” represents the real example. In this type of installation, real equipment is available, being the same as in the plant, and in addition simulates working conditions. Likewise, in this facility Behaviour Expectations, as well as Human Error Prevention Tools are trained. Under this approach, Tecnatom is developing different Field Simulators for all Spanish nuclear power plants.

Figure 3. Human Factors Simulator

5. ADAPTATION OF THE MODEL TO PROVIDE TRAINING SERVICES

Finally, the allocation of resources, the greater technical expertise about the facilities, their technology and their processes, and the integration of the training as part of the operation of the plants, require a dedicated organization and close to the plant operation. Tecnatom has evolved from a situation predominantly centralized toward a mix model of decentralized organizations, structured in Training Schools integrated with the exploitation and maintaining centralized common services that complement the needs of occasional services.

Under this model, Tecnatom offers NPPs the highest quality service in all areas of competency, with maximum efficiency. Training Schools have qualified instructors in the technology involved
in all phases of training: need analysis, design of training, material development, implementation and evaluation of results.

Currently, the organization is compounded by Training Schools of Almaraz-Trillo, Asco-Vandellos, Cofrentes and Santa Maria de Garona. Also, since there is already a large number of training activities outside our borders, an International Training School has been created with instructors with specific competencies for new plants and plants already in operation, like China, US, UAE, Brazil, Argentina and the UK.

The SAT process implementation within the Training Schools requires (as well as human resources, facilities and materials) a referral process shared by end customers of the training service, staff plant and the supplier of the training. Tecnatom has developed a process that establishes the roles and responsibilities of all actors of the learning process to facilitate a robust implementation of SAT.

6. CONCLUSIONS

Throughout the paper it was noted that in recent years, Tecnatom has conducted multiple actions to improve the training processes: incorporation of proven efficient methods; improvement of training personnel qualification, instructors and managers; involvement and awareness of operational staff in training programs; development and improvement of qualification programs; and the incorporation of new means and learning environments.

Everything done is a drive towards very high levels of quality, approaching the highest standards. We must remember that our commitment to safety requires us to work in organizations with a culture of continuous learning, having the best qualified professionals. Tecnatom is aware that training should be a fundamental tool in the management of safety, given that it helps to prevent errors and, therefore, improving the results.

Organizations that do not stop in the search for new ideas, best practices and in identifying new opportunities, walk backwards. The organizations with learning culture are able to take advantage of new ideas at all levels of the organization. They transfer knowledge, create corporate memory and provide the necessary feedback for decision making.

Through this significant boost in the application of new skills and techniques, we will be able to increase our contribution to improving staff performance and the results of nuclear plants.
“MINDING THE GAP”- CONSISTENT REGULATORY TRAINING PROGRAM EVALUATIONS: AN APPROACH TO A COMPETENT WORKFORCE IN CANADA’S NUCLEAR SECTOR

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Abstract

Canada’s nuclear sector encompasses the full fuel cycle, with the exception of reprocessing of fuel. The inherent risk associated with the spectrum of nuclear activities across the fuel cycle differs greatly.

An essential component in the safe and reliable operation of nuclear facilities is a sufficient number of qualified and competent workers. Qualified and competent workers complement the design and safety features of these facilities.

Recognizing the existence of a gap between incumbent education/training/experience and the entry-level requirements one must possess in order to enter a licensee training program, staff from the Canadian Nuclear Safety Commission (CNSC), Canada’s Nuclear Regulator, verifies that licensees have the proper controls/measures in place to account for this reality. During the conduct of licensee training program evaluations, CNSC staff uses a subset of objectives and criteria, which are based on the principles of a Systematic Approach to Training (SAT), as a means to verify that licensees are “minding the gap”. This is aligned with the CNSC’s risk-informed approach to regulation, and consistent regulatory approach to verifying, and ensuring worker qualification. This risk-informed approach considers not only the risk of an activity, but the phase of operation of the facility, the role of each worker's position in the safe operation of the facility, and any other known factors that could challenge the licensee’s ability to provide a sufficient number of qualified workers.
1.0 Background

Canada’s nuclear sector encompasses the full fuel cycle (uranium mining, milling, refining, fuel fabrication, electricity production and long-term storage) with the exception of reprocessing of fuel.

The Canadian Nuclear Safety Commission (CNSC) has a long history of evaluating nuclear facility training programs. Training programs play an integral role in providing workers with the qualifications they require to carry out their duties. At Nuclear Power Plants and Research Reactors, CNSC Designated Officers (DOs) also certify workers, such as Reactor Operators, who occupy specific positions that have a critical role in the safe operation of the facility. The requirement for certification of personnel at these facilities provides additional assurance that workers assigned to positions that have a direct impact on the safe operation of the facility are qualified and competent to perform their duties.

Licensees use a training system to systematically analyze, design, develop, implement, evaluate, document and manage all initial and continuing training for all workers who are employed in positions where the consequence of human error presents risks either to the health or safety of persons, to the environment, to the security of nuclear facilities or nuclear substances. In its training system governing documents, the licensee identifies these positions for its organization, and these are subsequently subject to CNSC staff review and approval.

The requisite level of analysis, documentation, and action the licensee undertakes through their training system for each position may vary in proportion to its relative importance to safety; safeguards and security; the magnitude of any hazard involved; the lifecycle stage of the facility; the mission of the facility; the particular characteristics of the facility; and any other relevant factors (1).

Canadian nuclear facility licensees are reporting a varying degree of availability of incumbents with the prerequisite education/training/experience for various positions. The IAEA has attributed this to a variety of factors such as a smaller cohort of University and College graduates with easily transferable knowledge and skills that apply to the nuclear industry, hiring practices and economics affecting the nuclear industry (2). An added challenge some of these facilities face has to do with their geographic location, and how it is perceived by the candidates they wish to attract, e.g., northern Saskatchewan, Canada.

This paper presents a regulatory perspective on “minding the gap” between an incumbent’s education/training/experience and the entry-level requirements one must possess in order to enter a licensee training program. This is part of the CNSC’s risk-informed approach to regulation, and consistent regulatory approach to verifying, and ensuring worker qualification. This approach, based on the principles of a Systematic Approach to Training (SAT), provides assurance of a qualified workforce in Canada’s nuclear sector.

2.0 Introduction

(This section contains content previously published in Reference 3)

The legal framework governing the regulation of nuclear facilities in Canada, specifically the General Nuclear Safety and Control Regulations (4), requires all licensees to ensure that they employ a sufficient number of qualified workers to safely perform the activity permitted by their operating licence. In addition, these regulations require licensees to train their workers in order to ensure that they can perform the duties of their positions safely. As a
result, it is the responsibility of the licensee to ensure that all of their workers are trained and qualified.

In addition to the licensee providing qualified staff, the International Atomic Energy Agency (IAEA) and Canadian Standards Association (CSA), in their respective GS-R-3 “The Management System for Facilities and Activities” (5) and N-286-12 “Requirements for Management Systems at Nuclear Facilities” (6), document the need for competent workers. “(Licensee) Senior Management shall ensure that individuals are competent to perform their assigned work and that they understand the consequences for safety of their activities. Individuals shall have received appropriate education and training, and shall have acquired suitable skills, knowledge and experience to ensure their competence.” (5) “Competence criteria shall be determined for positions based on the work to be performed and include education, experience, knowledge, ability and performance requirements”. (6)

The CNSC has been implementing improvement programs in order to continue to ensure that the health and safety of Canadians is protected. These improvement initiatives stem from two external audits of the CNSC: an audit by the Office of the Auditor General of Canada (OAG) in 2000 (7) and an audit by an International Regulatory Review Service (IRRS) in 2009. The results of these audits recommended a risk-informed approach to regulation and a consistent regulatory approach to confirming competence of operators (workers) at all facilities (8).

In response to the OAG audit (7), the CNSC then embarked on an ambitious multi-year improvement program in all regulatory areas to improve its policies and programs to ensure that the resources allocated to regulatory activities were based on a risk-informed approach. In a follow-up audit conducted in 2003 and 2004, the OAG found that the CNSC had made significant progress in this area.

The second major CNSC improvement initiative stemmed from an external audit by an IRRS (9). One of the suggestions presented by the IRRS team was that CNSC staff should review their current approach and continue to adopt a consistent process for confirming the competence of operators commensurate with the risks and hazards posed by the facilities (9).

CNSC staff who conduct training program evaluations have noted that the varying levels of entry-level education, training, and experience of incumbents causes “strain” on licensee training systems, and their resulting training programs. As such, licensees must adapt their training systems and resulting programs to account for these factors; and subsequently, the regulator must, in the interest of safety, assess these adaptations to ensure that trainees continue to attain the knowledge, skills and attitudes needed for safe operation of these facilities.

3.0 Minding the Gap: Proactive Licensee Approaches

Due to a variety of work sector influences, nuclear sector demographics, and educational shifts, it has been widely recognized that there often exists a gap between incumbent education, training, experience, and the entry-level requirements for acceptance into a licensee training program. Furthermore, it is important to note that the magnitude of the gap differs depending on the stage of the nuclear fuel cycle, the roles and responsibilities of the position within the facility that is required to be filled, and the geographic region.

Gradually, licensees have had to adapt training programs to compensate for the varying ability of incumbents to meet the prerequisite entry-level requirements, while continuing to
ensure that they attain the knowledge, skills and attitudes needed for safe operation. The target audience receiving training differs, and the training system must be built to accommodate this. Furthermore, given the severity of the gap in certain instances, the industry has had to adapt not only the prerequisites and the training programs but in certain cases has partnered with provincial ministries of education to fund and create separate educational and skills institutions to address market-driven requirements, e.g., University of Ontario Institute of Technology in Canada, which was founded in 2002 as a direct response to a provincial need for a career-focused university emphasizing science and technology. While separate training centres serve a specific population, given the remote geographic location of some facilities, the gap must often be addressed at the licensee’s site.

CNSC staff recently evaluated training programs at a uranium mill located in northern Saskatchewan, Canada and noted that the licensee had recognized and remedied a gap regarding the prerequisite education, training, and experience of candidates of entry level operator positions. Operator positions at this site require a minimum of a high school diploma. It was determined by the licensee that the quality of high school education differed greatly amongst educational institutions. The licensee, upon recognizing this, created a regime to independently assess the entry-level knowledge and skills of incumbents. When a gap between the candidate’s proficiency and the prerequisite requirements is identified, the licensee has created a variety of training courses and subsequent assessments designed to address this gap.

CNSC staff views these licensee undertakings as an essential step in ensuring that all personnel are qualified to perform their role in the safe operation of the facility.

4.0 Regulatory Evaluations of Training Programs - Systematic Approach to Training to “Mind the Gap”

Given the aforementioned gap, using a risk-informed basis alone does not account for a sound, consistent regulatory oversight of personnel training. Rather, the regulator must ensure that licensees have accounted for their target audiences and have tailored the training programs appropriately. In the event that the entry-level requirements are not met by an incumbent, the regulator must ensure that the licensee uses a training system that will systematically address the identified gap.

Having a training system that follows the principles of a SAT can enable the licensee to address an identified gap. SAT is a proven and highly successful education and training methodology. It is also widely known as the Instructional Systems Design Model (ISDM).

The SAT methodology is the nuclear industry standard for training development and is the most widely practiced model in existence today (1). A SAT-based training system provides interdependent functions consisting of analysis, design, development, implementation and evaluation. It is a cyclic process that enables training to be systematically defined, designed, developed, implemented and evaluated in order to not only meet operational and organizational requirements, but also to react quickly to changes in those requirements (1).

From a regulatory perspective the key components to “minding the gap” are: Identifying a gap; Adapting training programs for the gap being mindful of elements critical to safety; Assessment; and Evaluation. These components provide assurance that a licensee has identified and addressed any potential “gaps” in their training programs.

Identifying a gap: As part of the Analysis phase a “target audience analysis” should be conducted by licensees. A target audience analysis determines the numbers and categories of workers to be trained and, where possible, the characteristics of the individuals who will
receive the training (e.g., current job experience and prior background, experience, education, and training). This information helps to ensure that the training is designed, developed, and implemented at the correct “level”, and in accordance with the learning objectives that define exactly when, what and how well the trainee must be capable of performing on the job upon completion of the training. It will also ensure that any additional training prerequisites are identified (1).

Adapting training programs for the gap being mindful of elements critical to safety:
The basis of a SAT-based training program is a job and task analysis where the jobs and associated tasks are formally identified. Then through the process of task analysis, each task is further examined to identify the knowledge, skills and attitudes that are essential to safe and effective task execution. Typically, based on a Difficulty, Importance and Frequency (DIF) rating of each task, decisions are made as to which tasks require either initial training, continuing training, both or none.

Stemming from the results of the target audience analysis, the initial and continuing training decisions arising from the DIF rating may have to be adapted. Thus, the training program is designed (or adapted), developed and implemented to account for the education, training, experience and learning characteristics of the audience. It is essential that the elements critical to safety are included, identified and proportionally weighted as test items within the training program. The variance in the training program, however, lies in the manner and with the frequency in which the training ensures that the knowledge, skills and attitudes are attained.

Assessment: A properly designed assessment is essential in determining if the required knowledge, skills, and attitudes have been acquired by the trainee. A methodologically robust test or evaluation scheme must discern those trainees that have acquired the necessary knowledge, skills, and attitudes from those who have not. In some cases, an adaptive approach to testing may be essential. For example, on the job (field checkout) or oral testing may compensate for trainee limitations regarding literacy level, while still providing a robust assessment.

Effective assessments must have four key characteristics. They are:

1. **Valid** (providing useful information about the concepts they were designed to test),
2. **Reliable** (allowing consistent measurement and discriminating between different levels of performance),
3. **Recognizable** (instruction has prepared students for the assessment), and
4. **Realistic** (concerning time and effort required to complete the assessment) (10).

Evaluation: In the evaluation phase of a SAT, feedback from the analysis, design, development, implementation, and evaluation phases provides important information, which allows for training program adaptations and improvements. In addition, feedback both formal and informal, at each phase is essential in ensuring that training programs continue to meet the licensee’s needs, and adapt to industry events, operational experience, and procedural and equipment changes. Consequently, evaluation of training effectiveness is of the utmost importance. Fundamentally, it must be determined if the training programs are yielding qualified and competent workers. The most well-known and used model for measuring effectiveness is the Kirkpatrick model (11) which refers to four levels of evaluation.

Level 1: Reaction - What was the trainee’s response or reaction to the training program?
Level 2: Learning - What was the extent of trainee’s improvement in knowledge, skills and attitudes as a result of the training program?

Level 3: Behavior - Is there a change in trainee's behavior in the workplace as a result of the training program?

Level 4: Results - What organizational benefits have been realized that can be attributed to the training program?

Although the difficulty of undertaking each level of evaluation increases as one moves from level 1 to 4 it is important to note that each level of evaluation provides important information and is indicative of each previous level’s success. For example: if the desired organizational goals were not met (or as expected)-Level 4 is an indication that the trainee’s behavior did not change as a result of the training-Level 3. In addition, the training did not improve the knowledge, skills and attitudes of the trainee-Level 2 and the trainees might have had a poor response to the training program-Level 1.

5.0 Verify Compliance: Criteria used by CNSC staff to “Mind the Gap”

When conducting regulatory evaluations of training programs, CNSC staff uses criteria that are based on the principles of a SAT.

CNSC staff has been evaluating training programs to account for the gap by applying criteria during inspections that verify whether:

- a licensee has defined and documented entry-level qualification requirements of each position.
- the characteristics of the workers to be trained are determined and documented (e.g., current job experience and prior background, experience, education and training, learning characteristics).
- training objectives are developed to establish the training content, taking into consideration minimum entry-level knowledge, skills, experience and interdependence of tasks.
- elements critical to safety are appropriately identified, included, and proportionally weighted as test items for written and oral examinations and job performance measures.
- test items identified as elements critical to safety for written and oral examinations and job performance measures are assessed appropriately.
- results of trainee assessments are analyzed so that the assessment tools and the training program may be improved.
- results of evaluations of the training programs are incorporated into a training program improvement process.

These and other criteria provide a basis for developing inspection guides, which are used by CNSC staff to provide focus on predetermined areas of a licensee’s training system.
CNSC staff evaluation findings and conclusions regarding the strengths and deficiencies of the licensee training program are documented in a formal inspection report. Once approved by CNSC management, the report is formally sent to the licensee. Licensees are then required to produce and implement a corrective action plan to address any deficiencies.

6.0 Conclusion

The emergence and subsequent recognition of a gap between incumbent education, training, experience, and the entry-level prerequisites the nuclear sector requires has led to both the licensee and the Canadian regulator having to consider, assess and adapt their respective approaches to training programs and regulatory oversight.

As the onus for ensuring that workers are properly qualified rests with the licensee, it is understood that the training programs must be adapted to the education, training, and experience that incumbents possess.

Staff from the CNSC, Canada’s Nuclear Regulator, is well equipped to verify that licensees have the proper controls/measures in place to account for this reality. Indeed, during the conduct of licensee training program evaluations, CNSC staff uses a subset of objectives and criteria, which are based on the principles of a Systematic Approach to Training (SAT), as a means to verify that licensees are “minding the gap”. This is aligned with the CNSC’s risk-informed approach to regulation, and consistent regulatory approach to verifying, and ensuring worker qualification. This risk-informed approach considers not only the risk of an activity, but the phase of operation of the facility, the role of each worker’s position in the safe operation of the facility, and any other known factors that could challenge the licensee’s ability to provide a sufficient number of qualified workers.

The CNSC, through its verification activities, continues to provide assurance of a competent workforce in Canada’s nuclear sector.
7.0 Acknowledgements

I am grateful for the significant contribution that my colleagues from the Directorate of Safety Management of the Canadian Nuclear Safety Commission have made to this paper.
8.0 References


10. Svinicki, M. D. (1999a). “Evaluating and grading students, teachers and students: A sourcebook for UT- Austin faculty” (pp. 1-14). Austin, TX: Center for Teaching Effectiveness, University of Texas at Austin.

ABSTRACT

This paper presents the training capabilities analysis of the Spanish nuclear industry developed by the CEIDEN Fission Technology Platform (PT CEIDEN). The analysis includes the creation of a catalogue of training capabilities in the Spanish Nuclear Industry. This catalogue is the first initiative of its kind performed in Spain and, in order to see it through to completion, the overall Spanish Nuclear Training Industry has been surveyed about their courses (Available or potentially available) as well as their training tools. This info was analysed to identify the potential weaknesses and strengths. The electronic catalogue can be found in the CEIDEN webpage (http://www.ceiden.com/programas/indice-formacion/).

1. Introduction

The CEIDEN Fission Technology Platform (PT CEIDEN) was set up in 2007 with the main objective to coordinate the needs and R & D efforts in the field of nuclear fission technology in Spain. CEIDEN comprises all sectors related to R & D and Innovation in Spain and its scope includes both plants currently operating and new reactor designs. One of the CEIDEN programmes is the CEIDEN F+ working group. The objectives of this group are to promote the coordination of Education and Training (E&T) programmes at national level and provide support for Spanish participation in international programmes and networks (EU EUROSAFE, IAEA, Foratom, Latin America, among others).

The first task performed by CEIDEN F was the compilation and analysis of degree studies (Masters) in nuclear topics that are being taught in Spain. This tasks has resulted in the development of the Spanish catalogue of Masters related to nuclear energy (see http://ceiden.com/formacion/masters/).

In 2011, the CEIDEN Steering Committee decided to expand the scope of this initiative to analyse the nuclear job-oriented training capabilities in Spain.

We understand job-oriented training as the set of training activities specifically focused on training workers to perform their jobs in the nuclear sector. Usually these activities correspond to classroom training, on-the-job training, in workshops or laboratories or specific training environments (such as simulators). This training is complementary to that received at Universities or Colleges and is necessary to meet the specific guarantees of jobs in the sector. This paper is the result of this work.

2. Objectives

The main purposes of the analysis are to:

- Create the first catalogue of training capabilities in the Spanish Nuclear Industry.
- Identify the potential strengths and weaknesses of these capabilities.

The analysis comprises the identification of a taxonomic reference to classify job-oriented training capabilities and the survey to the Spanish industry requesting their training portfolio (actual or developable).

The identification of the strengths and weaknesses of the Spanish industry has focused on training courses and activities, as well as training facilities.
3. Applied Methodology

In order to establish a taxonomic reference to classify job-oriented training capabilities we have consulted three sources: the European system "European Credit System for Vocational Education and Training" (ECVET) and the data produced by the OECD NEA and EHRO-N in their reports on nuclear education and training and needs of job profiles in the nuclear industry. The taxonomy of the CEIDEN F + itself has been developed using these references and other supplementary references derived from training experience in the Spanish nuclear sector. This distributes nuclear activities by the area of activity in which the jobs in the nuclear sector are organised and the corresponding area of expertise. Following development of the taxonomy, the survey for collecting data from Spanish companies was elaborated. The survey includes topics regarding training and developable training courses, and inventory and potential development of tools and training resources. This survey was sent to the CEIDEN Members and companies that reflect training capabilities included in the nuclear directory of the Spanish Nuclear Society (SNE). Eighteen (18) companies from the Spanish Nuclear Industry have responded to the survey. The data received were processed in order to develop a catalogue of training capabilities and to analyse the strengths and weaknesses of the Spanish industry in this area. The capability catalogue is recorded in a database that is accessible to the public through the CEIDEN website. The web search engine allows the user to query and retrieve data relative to training and developable training courses, and inventory and potential development of tools and training resources. The analysis of the strengths and weaknesses of the Spanish industry has focused on training courses and activities, as well as training facilities. The findings are described in the analysis section of this report.

Fig 1 shows an overview of the methodology applied in this study.

4. Analysis of the Spanish Nuclear Capabilities

Courses and Tools are analysed independently. The data for the Spanish training capabilities regarding courses are included in Tab 1.
The criteria set for the identification of weaknesses in the courses catalogue are the following:

- Areas of expertise that have neither available courses nor a development capability.
- Areas of expertise that do not have available courses but do have a sufficient development capability in that area.

### 4.1. Weakness analysis

The criteria set for the identification of weaknesses in the courses catalogue are the following:

<table>
<thead>
<tr>
<th>Area of Job Position</th>
<th>Area of Expertise</th>
<th>Available Courses</th>
<th>Developers of courses</th>
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</table>

Tab 1 Summary Table regarding courses and development capability

**4.1. Weakness analysis**

The criteria set for the identification of weaknesses in the courses catalogue are the following:

- Areas of expertise that have neither available courses nor a development capability.
- Areas of expertise that do not have available courses but do have a sufficient development capability in that area.

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### Tab 1 Summary Table regarding courses and development capability

#### 4.1. Weakness analysis

The criteria set for the identification of weaknesses in the courses catalogue are the following:

- Areas of expertise that have neither available courses nor a development capability.
- Areas of expertise that do not have available courses but do have a sufficient development capability in that area.
Areas of expertise either with an insufficient number of training hours or a small number of companies capable of developing courses to deal with these weaknesses.

Tab 2 summarises the training weaknesses of the Spanish nuclear industry. The areas of expertise that currently do not have courses available are highlighted in yellow. Cells marked in orange are areas of expertise with a small number of hours and only one company capable of developing the course. In green, we identify if there are companies which can potentially develop courses for the area of expertise analyzed.

<table>
<thead>
<tr>
<th>Area of Job Position</th>
<th>Area of expertise</th>
<th>Are there available courses in this area of expertise?</th>
<th>Are there companies which can develop the course?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NUCLEAR FUEL CYCLE</strong></td>
<td>Management and Supply of Enriched Uranium</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>On-site Fuel Repair</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>Fuel Manufacturing</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td><strong>COMMON AREAS</strong></td>
<td><strong>NUCLEAR SAFETY MANAGEMENT</strong></td>
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<td>Security</td>
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<td>YES</td>
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<td></td>
<td>Radiological Protection</td>
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<td>X</td>
</tr>
<tr>
<td></td>
<td>Decommissioning</td>
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<td>X</td>
</tr>
<tr>
<td></td>
<td>Operation and Maintenance of Waste Storage Facilities</td>
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<td>X</td>
</tr>
<tr>
<td></td>
<td>Decommissioning of Uranium mines and Uranium Production facilities</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Tab 2 Summary of training weaknesses

As a general conclusion, it may be stated that there are no critical weaknesses in the Spanish training capabilities, since all areas of expertise have courses available or the potential for their development. CEIDEN F+ aims to highlight these apparent weaknesses to be considered in a complete sector-specific analysis. Nevertheless, it cannot be directly interpreted from the CEIDEN F+ report that there are gaps on a national level in the areas of expertise identified, since there may be other companies with courses or capabilities who have not completed the CEIDEN F+ survey. CEIDEN F+ will continue its efforts to ensure that the largest number of Spanish organisations in the nuclear training sector which are involved in the catalogue.

4.2. Strength analysis

The criterion set for the identification of strengths in the courses catalogue is:

- Areas of expertise either with a large amount of hours of available courses or with a large number of companies with development capabilities in this area.

Tab 3 contains a summary of the areas of strength in terms of either the total amount of course hours or development capability.
The areas of strength in terms of development capabilities are not homogeneous. The following list shows those identified in the analysis:

- Risk prevention
- Radiological Protection and Dosimetry
- Inspection and testing methods
- Decommissioning of radioactive facilities such as uranium mines and uranium production facilities
- Operation and maintenance of waste storage facilities
- New reactors
- Nuclear safety and licensing
- Probabilistic safety analysis
- Safety culture
- Human factors engineering
- Radiation shielding
- Logistics and transport of nuclear materials.
- Criticality
- Environmental impact assessment

4.3. Tools and Training Methods

The survey also included the tools and training methods that are used by the Spanish Nuclear Industry during their training activities; these are as follows:

- E-learning Platform
- Full or Partial Scope Control Room Simulator
- Interactive Graphics Simulator (IGS)
- Computer-based Training (CBT)
- Human Factors Simulator (Field Simulator)
- Use of Computer Codes
- Facilities for Specific Practices
- On-site Coaching and Mentoring

Tab 4 describes the results of the survey regarding the tools and training methods. This table identifies the total number of companies that are not only capable of providing the respective tool or method to be used during the training outcomes, but also of developing and building it.

<table>
<thead>
<tr>
<th>TOOLS AND TRAINING METHOD</th>
<th>TOTAL COMPANIES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Availability</td>
</tr>
<tr>
<td>E-learning Platform</td>
<td>6</td>
</tr>
<tr>
<td>Full or Partial Scope Control Room Simulator</td>
<td>1</td>
</tr>
<tr>
<td>Interactive Graphics Simulator (IGS)</td>
<td>1</td>
</tr>
<tr>
<td>Computer-based Training (CBT)</td>
<td>4</td>
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<tr>
<td>Human Factors Simulator (Field Simulator)</td>
<td>1</td>
</tr>
<tr>
<td>Use of Computer Codes</td>
<td>2</td>
</tr>
<tr>
<td>Facilities for Specific Practices</td>
<td>3</td>
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<tr>
<td>On-site Coaching and Mentoring</td>
<td>3</td>
</tr>
</tbody>
</table>

Tab 4 Summary of the tools and training resources. Availability and development capability

Analysis of the above data shows that the Spanish Nuclear Industry possesses all the training tools necessary to conduct the training activities for professional profiles.

4.4. Web Search Engine - CEIDEN Website

The Spanish training capability catalogue is accessible to the public through the CEIDEN website, [http://ceiden.com/formacion/](http://ceiden.com/formacion/). (See Fig 2)

The web search engine is structured as follows:
Available courses.
Job oriented training capabilities that may be developed by companies.
Tools and training methods.

5. Conclusion

As results of the analysis, it could be stated that there are no critical weaknesses in the Spanish training capabilities, since all areas of expertise have courses available or the potential for their development. The same can be said about the training tools that are used during the impartation of these courses.

One of the conclusions of the report “Study of the capacities of the Spanish industry to undertake a new nuclear project” is that with the current resources of the Spanish nuclear sector, the capacity of the industry to carry out a new nuclear project amounts to 77% of the same.

Working on this idea, CEIDEN F+ is developing an addendum to the analysis described in this paper with the aim to evaluate how the Spanish training capabilities would be applicable to a new nuclear project.
6. References


QUALIFICATION AND CERTIFICATION
PROCEDURE FOR INSTRUCTORS IN THE
NUCLEAR FIELD APPLICABLE TO BOTH
EXPERIENCED AND NEW TRAINERS

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ABSTRACT

Following a systematic approach to training (SAT), and international recommendations, AREVA has developed and implemented an engineering procedure for qualification and certification of its classroom, hands-on and simulator instructors. Hereby, AREVA responded to internationally established best practices and increasing demand from customers. In the last few years, in invitations to tender dealing with training services, the qualification of instructors has played an increasing role, as AREVA’s customers are more and more interested in assuring sufficient competences with respect to technical and didactical skills of trainers.

The certification thus proves the ability of trainers provided by AREVA to transfer specific knowledge, skills and attitudes on the technical subjects and technology to the personnel of AREVA’s customers using an appropriate training methodology. A suitable tool was developed to manage and document the comprehensive and rather lengthy process for the certification of a large number of instructors, thus compiling detailed identification and documentation of required technical competences and development methods (courses, on-the-job-training etc.) for every instructor. Two examples will be discussed, namely the example of a classroom instructor on NPP NI systems, and that of a hands-on instructor on digital safety related I&C systems. The challenges encountered and the solutions found to resolve those are described, as well as recommendations for further improvement of the engineering procedure.

1. Introduction

As an Original Equipment Manufacturer (OEM), AREVA provides comprehensive solutions for new build of nuclear power plants (NPP), as well as modernization, life time extension or power upgrade of operating NPP’s and supply of safety important products for NPP’s, such as digital safety related Instrumentation and Control (I&C) systems.

In order to achieve the highest level of nuclear safety, and in accordance with principles of nuclear safety culture, an effective competence development of its customers’ personnel, such as project managers, engineers, operating and maintenance personnel, is of the utmost importance. In addition, the invitations to tender by AREVA’s customers not only require specific training services, but also the use of qualified and correspondingly certified instructors.
Consequently, AREVA developed and implemented an engineering procedure that describes the process for qualification and certification of its instructors. Certification of instructors according to this procedure will then ensure that they will be able to transfer specific knowledge, skills and attitudes on the technical subjects and technology to the personnel of AREVA’s customers, using an appropriate training methodology, guaranteeing training success.

2. Instructor Qualification and Certification Procedure (IQCP)

The engineering procedure on instructor qualification and certification is based on international rules and standards of instructor development for nuclear power plant personnel training such as IAEA-TECDOC-1392: “Development of instructors for nuclear power plant personnel training”, 2004.

As a first step different specialization and categories of instructor have been identified (see also chapter 3.). Next, a job and task analysis has been made to identify the tasks (duties) for each specialization profile. Each task (duty) of the job description corresponds with at least one training module. As a result of the SAT analysis, competence matrices are available for each profile; they allocate training modules to duties.

For each instructor specialization, a qualification procedure table (combination of education, experience and training) has been developed; see fig. 1 for classroom instructors.

### Classroom Instructor Qualification Procedure (table A)

<table>
<thead>
<tr>
<th>Pre requisites (education):</th>
<th>Bachelor in a technical degree(^{(1)}) (3 year degree) or Demonstrated experience in the nuclear field (e.g. reactor operator)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience:</td>
<td>Not required</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Courses</td>
<td></td>
</tr>
<tr>
<td>Specialty</td>
<td>Module Name / Code</td>
</tr>
<tr>
<td></td>
<td>Duration</td>
</tr>
<tr>
<td>Specialty courses</td>
<td>See table B</td>
</tr>
<tr>
<td>Self-study</td>
<td>(~2) weeks</td>
</tr>
<tr>
<td>Train the trainer</td>
<td>(~1) week</td>
</tr>
<tr>
<td>Presentation techniques</td>
<td>(~3) days</td>
</tr>
<tr>
<td>Work instruction and process training</td>
<td>(~1) day</td>
</tr>
<tr>
<td>Self-study</td>
<td>(~4) days</td>
</tr>
<tr>
<td>Common</td>
<td></td>
</tr>
<tr>
<td>On the Job Training</td>
<td>Preparation and conducting of a trial training session (evaluation).</td>
</tr>
<tr>
<td></td>
<td>Minimum duration of the trial session: (3) h.</td>
</tr>
<tr>
<td></td>
<td>Estimated preparation time: (\sim3) weeks</td>
</tr>
<tr>
<td>Minimum Duration of the Qualification Procedure</td>
<td>(\sim(7-14)) weeks (^{(2)})</td>
</tr>
</tbody>
</table>

\(^{(1)}\) bachelor degree for non technical topics instructor

\(^{(2)}\) Depending on the specialty courses made

Fig. 1 Example of qualification procedure
Training will include on the job training (OJT) for each instructor profile. The OJT will end with a trial training session. During the trial training session, an instructor performance evaluation will be carried out or validated (if it applies).

If the instructor performance evaluation results are successful, the qualification procedure is ended. The certificate will be awarded when the requirements of the procedure are fulfilled. The instructor development plan establishes the procedure to qualify instructors to teach advanced level or expert level courses.

3. Instructor Classification

Instructors will have to be classified according to different criteria, which will then be documented in their certificate.

First, we have to take into account that instructors active in different training settings will also have to use different training methods and techniques. Consequently, different instructor competences will have to be developed. In the AREVA case, we distinguish between three different types of instructors: classroom instructors (i.e. classroom setting), full scope simulator instructors (simulator setting), and hands-on instructors (training mainly in a working environment).

Furthermore, in order to fulfill different training needs, three categories of instructors have been identified: full time instructors – individuals permanently assigned to a training organization, occasional instructors – also known as subject matter experts, and contracted instructors – individuals from an external organization who are involved in training on a contractual basis.

Next, the different technical specializations (professional subjects) of instructors will have to be taken into account. As example, for NPP operator training the instructors usually specialize in different subjects like NPP systems design and operation, or reactor core and fuel physics, or NPP controls, limitations and protection as well as plant operation in different conditions. The specialty is taken into account in the respective qualification procedure, see fig. 1.

Finally, the growing experiences of instructors during their professional development will have to be considered by allocating different levels to them. In the case of classroom or hands-on instructors, a new instructor will start after certification as a Level A Instructor in a specific professional subject. To achieve a higher qualification and certification level as Level A (B or C), the instructor will have to follow a continuing training program to maintain and to improve both technical skills and training competencies. In the case of simulator instructors, they will start on the level of a Full Scope Simulator Instructor, but after having gained experience in a certain time frame they can become Senior Full Scope Simulator Instructors.

Finally, taking into account this classification of instructors will allow them to be optimally deployed in different training curricula, ensuring a high quality of training delivery in response to training needs of their students.

4. IQCP Implementation

In consideration of the different possible instructor classification variants and the different steps in the qualification procedure that had to be passed, it was decided to start with certifying full-time classroom and hands-on instructors in AREVA’s Reactors and Fuel Training Center. The latter are instructing on the AREVA product for safety related digital instrumentation and control
(I&C) systems, i.e. TELEPERM® XS (TXS), thereby contributing a great deal to the safe operation of a NPP. In this case a certification will apparently show a great benefit for the quality of training and the resulting acceptance by AREVA’s customers.

As all instructors involved already had been working for some (or even a long) time in the Training Center, implementation of the IQCP in fact implied checking and documenting whether all required training measures had been done by the instructors. In the case when a training module (e.g. on pedagogic and didactic) had not been attended, the instructor in question had to pass this module. Of course, when justifiable, exemptions may be issued, too.

Consequently the main effort in IQCP implementation consisted in verifying and documenting that all training measures had been passed by the instructors to be certified. In addition to the collection and archiving of original records (e.g. diploma or course attendance certificates) in total 9 (or, in the case of a Level C certification, in total 18) different documents (corresponding to at maximum 18 certification steps) had to be set up, reviewed and released, so that the fulfillment of each certification step could be documented.

The workflow to be followed in this case involved the participation of the instructor's section manager, the quality correspondent to the training center, and the training center manager. Thereby it was possible to guarantee that all requirements of the IQCP are fulfilled, and that this can be easily proved when requested by an internal or external audit, or even when customers ask for a specific qualification of instructors, and proof of it.

5. Tool Support

In consideration of the large number of documents and records that had to be managed and fed into the review and approval workflow for each instructor, and the large number of instructors involved, an appropriate tool was developed. Thus detailed identification and documentation of required technical competences were compiled with development methods for every instructor. The substantial technical and didactical expertise, already acquired by the instructors, can be taken into account. Consequently, the IQCP and the related tool can now be used for both new instructors and experienced instructors.

The tool itself manages the necessary information in a straightforward data base, see fig. 2 displaying the user interface (i.e. the check list) on the overview level for the hands-on instructor qualification procedure.

The professional subjects may be documented in 2 different ways: either by having attended relevant courses, or by having worked as a technical expert in a related department (often an engineering department).
6. Results, Experiences

When starting the process of procedure implementation after issuing the procedure, some effort was spent on detailing the process, specifying the related documents and records as well as the responsibilities of all roles involved. One particular issue concerned the way how technical expertise on a professional subject could be built up, and how this could be documented. It is self-evident that this will strongly depend on the subject in question, and the instructor specialization.

The results could then be used for designing and developing the support tool. Using this tool led to a considerable reduction in the effort for certification. When all basic input documents were available, the certification of an instructor could be done in approximately one day. All review and approval documents could be directly printed out, then fed into the workflow, and archived together with the basic input records afterwards. Overview documents could be printed out on demand to verify the competences of an individual instructor, without displaying personal data that should in principle be kept confidential.

For some experienced instructors it was evident that they already must have reached level C. In these cases, however, all steps leading to level C were followed and documented, without any gaps in between.

By now, the IQCP has been successfully implemented within AREVA’s Reactors and Fuel Training Center. In total 5 hands-on and 7 classroom instructors could be certified, and awarded with the certificates.
The results could already be used successfully for training offers, when the customers explicitly asked for certified instructors.

On the other hand, one particular issue in applying the procedure was identified: the challenge in qualifying and certifying occasional instructors. In this case apparently there is a need for relaxing the requirements of training on pedagogical and didactical skills, in view of the limited time available to these subject matter experts for training activities, and the large number of these experts involved in technical training.

7. Conclusions

The successful implementation of the procedure itself has led to a greater clarity about the demands on instructor qualification.

Now, the AREVA Reactors and Fuel Training Center can easily demonstrate the qualification of their instructors, and ensure enhanced and transparent quality of their training courses.

As the structure and the general procedure applied in the qualification and certification procedure is rather independent from the content of the specific job tasks (in this case instructor tasks), the procedure itself, as well as the supporting tool, could be easily applied to other job areas and positions. This could contribute extensively to raising competences in other areas important for safe design, operation and maintenance of NPPs, and certifying these competences.
FILLING A GAP IN THE FIELD OF GEN IV NUCLEAR REACTORS E&T BY USING DISTANCE-TEACHING TOOLS; THE DEVELOPMENT AND IMPLEMENTATION OF A PILOT FULL-DISTANCE COURSE ON ADS SYSTEMS IN THE FRAMEWORK OF FP7 ENEN-III PROJECT.

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ABSTRACT

ENEN-III stands for European Nuclear Education Network Training Schemes, a project within the 7th Framework Programme. The development of these Training Schemes for professionals in the nuclear field was structured in four groups, and a significant lack of international courses was highlighted in Training Scheme D: Concepts and Design of GEN IV nuclear reactors. In this context UNED’s interest and expertise on distance teaching tools and methodologies together with the long experience of collaboration UNED - CIEMAT on ADS systems moved us to propose within the project framework the development of a dedicated pilot course on “Accelerator Driven Systems for advanced nuclear waste transmutation” in a fully distance way. This course would address a number of learning outcomes outlined for Training Scheme D, aiming also to provide its development in an international environment. Our objective was double: to cope with an E&T need and also to show what distance teaching has to offer for professionals who cannot easily leave their jobs to attend a course, or who may have, if doing so, too high travel expenses, particularly in the case of some very scarce international courses on GEN IV reactor technology.

The experience has run with 10 trainees from ENEN-III project: from LUT (Finland), AALTO (Finland), Politecnico di Torino (Italy), University of Pisa (Italy), UPM (Spain), Tecnatom (Spain) and UNED (Spain). The course was delivered in UNED aLF virtual learning platform that also integrates UNED-INTECCA Webconference communication and recording system. The main learning materials were video classes and side lectures with the simulations of various case studies of ADS systems. Active interaction in the Webconference, Forums and chat was evaluated and a final exam allowed us to check for the learning outcomes acquisition.

This paper will present the design and layout of the course, based on its learning outcomes and the evaluation of their achievement by the different trainee profiles (mostly PhD students). The final evaluation of the Pilot course and the lessons learned for the next step will also be presented.
1. Introduction

Nowadays Education & Training (E&T) worldwide is redirecting towards the design of a balanced combination of face-to-face and distance teaching, taking advantage of the new tools that Information and Communication Technologies (ICT) provide, in what we know as blended learning. As a Distance Education university, UNED is characterized by a blended learning methodology since its beginnings, 41 years ago. Thus, our participation in FP7 ENEN III project gave us the opportunity to offer distance teaching and learning for international E&T in the nuclear field taking into account UNED long experience.

The work presented in this paper aims to fill a gap in Education and Training (E&T) that was highlighted during the development of the so-called Training Schemes within FP7 ENEN III project framework.

ENEN III stands for European Nuclear Education Network Training Schemes, a project within the 7th Framework Programme [1]. The development of these Training Schemes for professionals in the nuclear field was structured in four groups, and a significant lack of international courses was highlighted in Training Scheme D (TS-D): Concepts and Design of GEN IV nuclear reactors; training courses on specific GEN IV topics are very rare [2]. Moreover, most trainees assigned to the project to run the Training Schemes belonged to TS-D, so the need to provide training courses in this area was clearly identified.

Additionally, no distance course was offered in any of the Training Schemes. In this context, our long collaboration UNED-CIEMAT on Accelerator Driven Systems (ADS) and the support of our Instituto Universitario de Educación a Distancia (IUED), experts in online teaching and learning methodology, moved us to develop the full-distance international Pilot Course Accelerator Driven Systems for advanced nuclear waste transmutation. This would be as well an opportunity for our University to share its expertise on distance tools and methodologies. Also, it is worth noting that the main Learning Outcomes (LO) of the course in the Knowledge area (see Table 1) were not covered by the existing courses. Taking into account that Transmutation is one of the priorities for future research, we were also addressing a particularly interesting topic.

<table>
<thead>
<tr>
<th>Domains of knowledge</th>
<th>TSD</th>
<th>Areas of interest</th>
<th>Learning Outcomes</th>
<th>% LO</th>
</tr>
</thead>
<tbody>
<tr>
<td>General knowledge on</td>
<td>TSD</td>
<td>Gen IV and the</td>
<td>1. Describe the open fuel cycle and MOX fuel cycle</td>
<td>5</td>
</tr>
<tr>
<td>GEN IV systems and</td>
<td>K006</td>
<td>closed fuel cycle</td>
<td>2. Identify the limitations of this open fuel cycle</td>
<td>5</td>
</tr>
<tr>
<td>technology</td>
<td></td>
<td></td>
<td>3. Describe the impact of minor actinides and fission products on spent fuel</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>treatment and final disposal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4. Describe the fully closed fuel cycle</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5. Show how a double strata approach can be beneficial</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6. Compare a Fast Reactor to an Accelerator Driven System (ADS) for minor actinide</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>transmutation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7. Describe the technical concept of an ADS and its challenges</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 1. Course Learning outcomes in the Knowledge area, as stated on ENEN III D.1.5 [3].

Two were our goals: to cope with an E&T need and to show what distance teaching and learning has to offer in this field:

- Allow flexibility of dates and timetable.
• Lower expenses (travel and accommodation).
• Borderless environment.

We wanted to have a broad participation, and we finally ran the experience with 10 trainees from ENEN-III project and one extra course member: from LUT (Finland), AALTO (Finland), Politecnico di Torino (Italy), University of Pisa (Italy), UPM (Spain), Tecnatom (Spain) and UNED (Spain).

The main teacher of the Course was Enrique M. González Romero, Head of Nuclear Fission Division of CIEMAT, author of all the learning materials of the Course. The assistant teachers in the virtual platform: Javier Sanz, Francisco Ogando, Mercedes Alonso and Patrick Sauvan, all of them teaching in the Area of Nuclear Engineering at UNED (Departamento de Ingeniería Energética). The coordination of the course was made by Mercedes Alonso. The support on online teaching and learning methodologies was provided by the Head of our Instituto Universitario de Educación a Distancia (IUED, UNED), Ángeles Sánchez-Elvira.

2. The design and implementation of the full distance pilot course: “Accelerator Driven Systems for advanced nuclear waste transmutation”

The main guidelines for the design of the course have been, on the one hand, the course learning outcomes (knowledge, skills and attitudes) and on the other hand the application and use of Information and Communication Technologies for online teaching and learning. In the following sections the different steps of the design and implementation of the course are explained.

2.1. The choice of the virtual platform

Due to the fact that the course had to be offered for a small number of students (Pilot Case), and taking into account a very tight schedule and no budget coming from FP7 ENEN III Project for this purpose, we took advantage of our expertise by using our own learning platform, aLF [4], an opensource platform developed from DotLearn platform (MIT). Both, aLF and UNED-INTECCA Webconference [5] have been developed by UNED Centre of Technology (CTU), and this is the environment we use in all our Bachelors and Masters in our University with thousands of students.

This environment had previously been shown within the project. Very precise instructions in English were required to guide the use of this environment: aLF Visual Guide (by Francisco Ogando) with Adobe Captivate, and Webconference Guide (Fig 1).

![Fig 1. User guides in English for Webconference and aLF](image-url)
2.2. The scope of the course

The course was structured in seven topics, and the simulations of the case studies were covered in the Side Lecture (Table 2).

<table>
<thead>
<tr>
<th>Introduction to transmutation and ADS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADS basics</td>
</tr>
<tr>
<td>ADS source</td>
</tr>
<tr>
<td>ADS-Reactors. The Subcritical core</td>
</tr>
<tr>
<td>ADS kinetics</td>
</tr>
<tr>
<td>ADS dynamics</td>
</tr>
<tr>
<td>ADS in the fuel cycle</td>
</tr>
</tbody>
</table>

**Side Lecture:**
Illustration of the difference between critical and subcritical operation using a numerical model and 3D movies of the neutron flux in different operational conditions

**Table 2. The scope of the course**

2.3. The choice of the learning materials

A total of seven video classes were recorded at UNED CEMAV Studio, one for each of the topics of the course, consisting of a presentation by Enrique González with dedicated dynamic slides for online teaching enhancement (Fig 2).

The side lecture was available through a private You-tube session with the recorded simulations of various case studies using Mathematica (Fig 3).

At a later stage of the course, an improvement for the side lecture was offered beyond the course scope by means of an interactive application based on the CFD tool of Mathematica, prepared to explore full solutions that describe the behaviour of critical and subcritical reactors (Fig 4).
Fig 3. Side lecture example: Subcritical reactor: $K_{\text{inf}} = 1.1$

Fig 4. Interactive version of the side lecture
Complementary Bibliography was accessible in the virtual course via links to the original documents.

The Final Webconference (see the following subsection) was available both, in the virtual course and on TeleUNED private access server (online and offline) [6].

2.4. Design of the tutoring activities, interaction and communication within aLF platform

Asynchronous communication was achieved by the use of three thematic Forums, and Webconference and a Chat Room were used for synchronous interaction.

Two Webconferences were programmed: the first one for technical assistance with the platform, at the beginning of the course, attended by the course coordinator, and a Final Webconference to solve participants’ questions and doubts, led by Enrique González, with the participation of the assistant teachers and the course participants (Fig 5).

![Fig 5. Recorded final Webconference in aLF](image)

The tutoring activities were designed to assist students within the platform with the recommendation to make use of the thematic Forums that were attended by the assistant teachers of the course. The Final Webconference provided a very fruitful synchronous tutoring activity by Enrique González.

The Final Webconference was also recorded in TeleUNED private access server and it was available for online participation and off-line availability as well for non course members (Fig 6).

2.5. Design of online evaluation

A final examination for online submission took 80% of the final grade. *Learning by doing philosophy* was applied; the questions were designed to be answered within a few days, so the student would go over and really understand the whole material of the course in order to be able to answer it correctly.
The remaining 20% of the grade measured the active participation in the course: Webconference, Forums and Chat. During the Final Webconference questions could be raised by the students, and the main teacher also posed some questions to the audience. In this way evaluation of Knowledge, skills and attitudes was made.

2.6. Design of the Final Survey

The questions of the Final Survey were chosen to cover general aspects of the course, the evaluation of the educational tools, a global assessment of the course and personal comments. The Final Survey was available in aLF platform, being both, voluntary and anonymous.

3. The feedback from the course

The overall feedback from the course was obtained during its implementation via the Forums and, specially, during the Final Webconference for solving doubts and questions. Also, the Final Survey was available after the end of the course, just before delivering the final evaluation to the students. In Table 3 the average numerical results of the Final Survey are shown.

The main feedback from participants about the course can be resumed as follows:

- The time schedule was too short. They didn't have enough time to study all the material before the Final Webconference. A gradual and slower pace of the learning experience was proposed.
- The video classes were very interesting and very clear.
- They would like the side lecture to be more interactive; this is being solved with the so called “interactive side lecture”.
- It would be interesting to have PDF files on the side lecture to be able to study the theoretical background after looking at the videos.
• The Webconference was a very interesting tool to interact and to clarify doubts.
• They seldom entered the course for interaction purposes. When an important issue had to be announced we were forced to notify them to their personal emails. That means that to promote interaction and group activities could increase motivation, engagement and peer-to-peer communication, which are key elements in online courses.
• Some of the students missed some of the basic concepts to be able to understand all the video classes. They missed written documentation for these basics.

<table>
<thead>
<tr>
<th>FINAL SURVEY</th>
<th>Average (over 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>My expectations about the course have been fulfilled</td>
<td>6,8</td>
</tr>
<tr>
<td>I have found the course interesting and motivating</td>
<td>8,8</td>
</tr>
<tr>
<td>The course has been well organized</td>
<td>6,3</td>
</tr>
<tr>
<td>I have found the contents appropriate</td>
<td>7,9</td>
</tr>
<tr>
<td>The guidelines to carry out the activities have been clear and precise</td>
<td>7,1</td>
</tr>
<tr>
<td>The virtual platform has worked well</td>
<td>7,3</td>
</tr>
<tr>
<td>I am satisfied with my achievements</td>
<td>6,8</td>
</tr>
<tr>
<td>The evaluation system is appropriate</td>
<td>7,5</td>
</tr>
<tr>
<td>The teacher support has been good</td>
<td>8,6</td>
</tr>
<tr>
<td>The duration of the course is well adjusted</td>
<td>5,7</td>
</tr>
<tr>
<td>I have been able to develop the expected learning outcomes</td>
<td>6,8</td>
</tr>
<tr>
<td>The video classes</td>
<td>7,9</td>
</tr>
<tr>
<td>The side lecture</td>
<td>8,2</td>
</tr>
<tr>
<td>The new interactive side lecture</td>
<td>7,1</td>
</tr>
<tr>
<td>The complementary bibliography</td>
<td>8,8</td>
</tr>
<tr>
<td>The use of the Forums for the resolution of doubts</td>
<td>7,0</td>
</tr>
<tr>
<td>The use of the Forums to share with your classmates</td>
<td>5,7</td>
</tr>
<tr>
<td>The Final Webconference</td>
<td>5,7</td>
</tr>
</tbody>
</table>

Table 3. Average numerical results of the Final Survey

4. Lessons learned

The feedback from the course allowed us to learn a lot about the advantages of the use of e-learning methodology in an international environment linked to nuclear engineering, and how to improve the experience.

The need to promote active participation is very significant in this type of courses:

  o Webconference was found as a very interesting tool for this purpose. The recommendation is to have at least one Webconference at the beginning of the course to know each other and to explain the basics of the course, and one at the very end of the course for feedback. More Webconferences could be programmed regularly for synchronous interaction and possible work in teams maybe also planned using this tool.
  o The proposal for a self-presentation in the Open Forum also promoted interaction.
  o Fixing dates for chat meetings would increase the use of this tool.
The schedule of the course was too short; when students attend a distance course on a postgraduate basis they normally have to follow it up with their daily activities, so that leaves them less time to study than if they have to travel and stop their jobs.

Interactivity and synchronicity are highly necessary in this type of learning environment; while the course was running Enrique González developed an interactive version of the side lecture. A first part of it has been made available to the students after the teaching period and a good feedback was received concerning this improvement. The full interactive version is under development at the moment.

The importance of having written documents to complete the multimedia learning materials has arisen. They always facilitate the study of the course to learn at one’s path.

Some self-assessment exercises could be designed for self-monitoring of the adequate understanding of each lesson, giving thus more support and awareness to participants about their progress.

A program of all the activities and the time schedule for the study of the course using the calendar tool and making a small student guide is also a recommendation, as distance education methodology always prescribes.

Although a thorough complementary bibliography is proposed for the course, a guide with the indications to cover the basic knowledge and the knowledge related to each lesson would be very useful to achieve a more selective study of this bibliography. In this sense, study guides are a main feature of distance education.

A very interesting advantage of distance learning is the possibility to enlarge the course duration with no cost to be able to cope with the students’ available time for study and adapt to a suitable calendar of activities. This would be too expensive in the case of face-to-face E&T. The same applies if we increase the number of students. Once the course has been designed and developed, an increase in the number of students generates a very low marginal cost.

As a consequence of this first experience, we highly recommend to take into account the safety restrictions for internet browsing. As an example, AREVA network restrictions didn’t allow access to our course.

It would be interesting to create a catalogue of questions with the detailed learning outcomes, associated when applicable to the different learning materials.

For future video classes we would use a special tool just introduced in UNED, where both, the video of the teacher and the slides, show side to side and a better image resolution is achieved.

In the case of a more extensive course with a larger number of students different platform options should be considered, mainly: a) A Moodle based platform, or b) A platform for Massive Online Open Courses (MOOC) [7]; UNED’s platform could be modified to be “not open” and “not free”; and have specialized tutoring.

The use of TeleUNED server capabilities (or an equivalent resource as Canal UNED [8]) would allow the participation during Webconference of distance external experts who are not course members to enrich the learning experience.
5. Conclusions

Blended learning in the field of Nuclear Engineering is essential if we want to enhance the present situation. The use of online education and training to complement the traditional one is a valuable initiative that we expect to see developed in the next years in the same way as it has happened in other areas of knowledge. We expect that the design, implementation and evaluation of our Pilot course on ADS gives some more light on how to introduce online education and training in the nuclear engineering field, specially regarding the optimization of resources.

6. Acknowledgements

This work has been partially performed within the framework of FP7 ENEN-III project. The help from UNED’s CEMAV studio, Centre of Technology (CTU) and University Institute of Distance Education (IUED) has been very important to achieve a fruitful collaboration for the design and implementation of this course.

7. References

TECHNOLOGY AND MANAGEMENT FOR THE DECOMMISSIONING OF NUCLEAR FACILITIES

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ABSTRACT

With the decision of the German government in 2011 to phase out of nuclear power and shut down all nuclear power plants until 2022, Germany has to cope with new challenges in the coming decades. For facing those challenges the Karlsruhe Institute of Technology (KIT) established a new department with excellent educated specialists in order to provide special education and research in nuclear decommissioning. The KIT was founded in 2009 within the German excellence initiative program by a fusion between the large-scale research institution of the Helmholtz Association and the University of Karlsruhe. The fusion enabled a unique unity of research, teaching and innovation in Germany. In this process the specialized professorship for Technology and Management for the Decommissioning of Nuclear Facilities (TMRK) was established, focusing on the development of new technologies in the decommissioning of nuclear facilities and carry out pilot projects. This professorship is affiliated in the Institute of Technology and Management in Construction headed by Prof. Dr.-Ing. Sascha Gentes. Today, 12 research assistants are employed with the objective of maintaining expertise. Actual research projects are for instance a remotely controlled manipulator for wall decontamination (MANOLA), the development of a new treatment and disposal technique to eliminate secondary waste of an applied cutting process (NENAWAS) and the numerical simulation to qualify the new vibration technology for decontamination of tubings (SimViDekont). Besides these technical projects, focus is also given to the field of management, leadership and human elements in the decommissioning of nuclear facilities (FoRK). This professorship also introduced a new lecture course focusing on the decommissioning and dismantling of nuclear facilities. The lecture comprises in particular the institute`s own technologies and enables insights on practical experience by including special industrial guest. The priority is set particularly on the topics like decontamination, dismantling and management methods, including the development of new technologies. The connection between science and practical engineering allows to convey experiences of current decommissioning and dismantling projects, transfer knowledge to students and show career opportunities. This abstract portrays an introduction to the focus of the current activities at the TMRK. In conclusion it has to be emphasized, that nuclear research and education will have to be strengthened in order to cope with upcoming challenges of decommissioning and dismantling of nuclear facilities and allow the maintenance of the nuclear expertise.
1. Decommissioning of Nuclear Facilities in Germany and Europe

With the decision of the German government in 2011 to phase out of nuclear power and shut down all nuclear power plants until 2022, Germany has to cope with new challenges in the coming decades. At the moment only nine remaining Nuclear Power Plants (NPPs) are still in operation. Since 2011, eight NPPs have been put in transition phase and another 14 facilities (NPPs and RRs) are under current decommissioning. It’s commonly known that, due to the advanced age of the world wide current reactors, a large number of further units will be shut down in the upcoming decades. This outlook shows the enormous demand for further development of Decommissioning and Dismantling (D&D) research and the optimisation of existing techniques, methods, cost and time efficiency.

Fig 1. Overview of Germany's NPPs
2. Karlsruhe Institute of Technology (KIT)
In 2009 the Karlsruhe Institute of Technology (KIT) was founded as a merger of the large-scale research institution of the Helmholtz Association and the University of Karlsruhe. The combination of these two institutions positions the KIT along its three strategic fields of action: Research, Teaching and Innovation.

![Organisation of KIT](image)

3. Technology and Management for the Decommissioning of Nuclear Facilities
Within the German excellence initiative the professorship for Technology and Management for the Decommissioning of Nuclear Facilities (TMRK) was established in June 2008 at the KIT. It has been aggregated to the Institute for Technology and Management in Construction (TMB). The professorship is headed by Prof. Dr.-Ing. Sascha Gentes and pursues the following objectives:

- setup of a scientific and technical team of experts for the decommissioning of nuclear facilities
- development of new decommissioning technologies and realize pilot projects
- establish a field of study for subject matter

The decommissioning research is focused on technologies and methods, approval-steps and management-methods. The following section will outline some of the TMRK's fields of research.

4. Fields of Research
Decontamination work is currently mainly done by personnel using hand-held devices which are exhausting for the staff and they are subject to long radiation exposure. Overall, there is a lot of potential for the development and optimisation in terms of removal rate, remote handling, avoidance of secondary waste and automation. These needs are addressed and
optimised in specific research projects. With the TMRK’s own test side of six hectares all of the new developments can be tested in build up in large scale.

In the following section the research field will be presented which are processed at the TMRK. Exemplary theme presentations will be:

- Decontamination of surfaces
- Dismantling of massive reinforced concrete structures
- Post-Decommissioning effects and consequences
- Development of a Programme-Management-System

4.1 Decontamination of surfaces
Depending on the height of the rooms in the nuclear island, contaminated components are not reachable without assistance. Due to this reason, time consuming scaffolds are usually needed. In order to avoid this, a special support system was developed to reach the difficult accessible regions of the walls, increase the removal rate and at the same time reduce staff size. These targets have been researched in the past research projects «Autonomous Manipulator for Decontamination Assignments» (AMANDA) and «Manipulator Operated Laser Ablation» (MANOLA). Both are climbing robots which move with the help of vacuum suction devices and can be equipped with either milling or laser technology for wall surfaces.

4.2 Dismantling of massive reinforced concrete structures
Another crucial factor is the improvement of the dismantling of reinforced concrete structures. There is already available equipment which is either able to crush concrete structures or allows the dismantling of the reinforcement. A combination of both processes in one equipment is still not available and up to date only made possible by a time consuming change of equipment. In order to allow the decontamination of structures in a single working operation for depths up to 30 mm (required for cracks). This is being addressed in the current

Fig 3. MANOLA  
Fig 4. AMANDA
research project named «Innovative Demolition of Reinforced Concrete Components» (INAS) in close cooperation with the Herrenknecht-AG. In addition, a direct absorption, transportation and packaging of the abraded waste should be realized in the process. Using oscillating discs allows significant reduction of force compared to conventional cutting and shows in addition high dismantling performance for concrete without reinforcement.

4.3 Post-Decommissioning Effects and Consequences
The German decision of phasing out nuclear energy will keep Germany busy in the coming decades. Beyond this, the up to now employed companies in the nuclear power plants, their employees, the population and the municipality should now prepare themselves to deal with the new situation after shutting-down of nuclear power plants. The aim of the research project FoRK is to investigate the technical, economical, social and political consequences of the decommissioning of nuclear facilities at regional and local level. With this research project, a model for the future decommissioning should be developed, which allows a forecast for economical and social consequences of decommissioning of nuclear power plants for the local population and industry.
4.4 Development of a Programme-Management-System
The existing D&D project diversity in Germany results into great opportunities for the utilization of previous experiences for future projects. The current approach of the individual sites is little interconnected and doesn’t exploit the opportunities which are given. The goal of a Programme-Management-System (PMS) is to create uniform conditions for a higher level and across locations project organisation. Through process standardization and continuous improvement, by using the Lessons-Learned, will result the strengthening and expansion of professional expertise for D&D-Management. The goal of this research project is the establishment of a PMS for D&D in Germany. The implementation will take place within a PhD thesis by the author of this paper in close cooperation with industrial partners.

5. Education in the Decommissioning of Nuclear Facilities
With the professorship a new lecture course focusing decommissioning and dismantling has been created for students. The lecture comprises in particular the institute’s own technologies and guest lecturers from different companies. Particularly topics like decontamination, dismantling, management methods, waste management and also the development of new technologies are given priority. Our lecture is designed for different departments, e.g. civil, mechanical and industrial engineering. The connection between science and practical engineering allows conveying experiences of current decommissioning and dismantling projects, transfer knowledge to students and show career opportunities. The thematic grouping is as follows:

- Fundamentals of NPPs and the current situation of Nuclear Energy in Germany
- Radiation, Radiological Protection and Measurement Techniques
- Approval Process and Planning
- Decommissioning Principles of NPPs and Management Concepts
- Current Research and Development Projects
- Examples of current D&D Projects in Germany
- Demolition and Disassembling Techniques
- Decontamination and Surface Treatment Techniques
- Waste Management
- Major Reactor Incidents and their Consequences (e.g. Tschernobyl, Fukushima)
- Excursions to different NPPs in operation and decommissioning

Fig 8. Overview education themes
With this kind of lecture the students benefit from a special training, which is unique in this form in Germany. In addition, a further course is offered at the AREVA Nuclear Professional School at the KIT. It is addressed to professionals who want to expand their knowledge. This annual event is carried out in a five day course. Furthermore, ten PhD students who are involved in the current research projects are being supervised.

6. Need for future experts
Especially in Germany the coming decades will need qualified experts for safe and efficient decommissioning and dismantling projects. This will allow that those experts will be capable in advising Germany’s neighbouring countries and support them for successful implementation of their D&D projects.
What is the situation with regard to infrastructure and tools for nuclear education and training?
EDUCATION AND TRAINING PRINCIPLES AND TOOLS FOR NEW NUCLEAR DEVELOPMENT

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José Gutierrez Abascal, 2; 28006 Madrid-Spain

ABSTRACT

To develop new nuclear power the decision makers need to consider the long term commitment; the concerns for safety, security, reliability, radiation protection, spent fuel management, radioactive waste management and economics; the need for a solid scientific and technological infrastructure, and the development of a diverse and complete education and training programmes covering all phases in the life of the power plant and directed to all actors concerned: government, regulatory bodies, plant owners, designers and constructors, operators and dismantlers. As a response to these requirements, the IAEA has published two basic documents: Fundamental Safety Principles (2006), and the INSAG document Nuclear Safety Infrastructure for a National Nuclear Power Programme Supported by the IAEA Fundamental Safety Principles (2008). From the principles and advises in those documents and to cover all education and training needs, a group of 35 experts, members of the IAEA, INSAG and the International Nuclear Industry, have published a book titled Infrastructure and Methodologies for the Justification of Nuclear Power Programmes (2012), aimed at providing expert information and self-study on the education and training needs in each one of the phases in the life of the nuclear power plant for all types of affected persons. The book is divided into three parts. Part I covers the scientific, industrial and administrative infrastructure needed to start a new nuclear power programme. Part II, based on the justification principle, analyzes the need for nuclear power; the requirements for safety, security, safeguards, radiation protection and waste management. It also covers the economics of nuclear power, the social and environmental impacts and the current and advanced nuclear technologies. Part III describes the knowledge and training which should be developed to cover each one of the phases in the life of the nuclear power plant: Siting, design and construction, commissioning and commercial operation and dismantling. There are also appendixes covering justification, safety culture, the IAEA training programme, simulator training and the NEA driven Multidesign Evaluation Programme.

1. Introduction

The arrival of the 21st century brought a renovated worldwide interest for nuclear power, the so called nuclear renaissance. Many Member States of the International Atomic Energy Agency, IAEA, requested information and advice from the Agency; a large number of new entrant countries and those with long moratoria on new constructions started to announce large new nuclear power programmes. International Organizations such as the IAEA, the Nuclear Energy Agency, NEA; the International Energy Agency, IEA; the World Energy Organization, WEO, and others projected installed nuclear capacity in 2030-2050 in ranges that doubled even quadrupled the current capacity. The March 2011 Fukushima accident arrested the enthusiasm created by the nuclear renaissance.

As a consequence of the accident some European countries decided to phase-out nuclear energy from their energy mix, while others have decided to reassess their nuclear energy programmes. Finally, other European countries, notoriously Finland, France and Slovakia have decided to continue with their new builds, while the UK is close to decide on the construction on new nuclear power plants. The European Human Resources Observatory for the Nuclear Energy Sector, EHRO-N, has recently published a document [1] in which a top-
down modelling approach is used to estimate the number of nuclear power plants which may be in operation or under construction within the European Union from 2010 to 2050, assuming that the current reactor park and new constructions will include generic third generation reactors of 1400 Mwe and 1000 Mwe for an assumed scenario of 95 to 110 reactors. It is estimated that at the end of the considered period there are needed from 7500 to 10000 nuclear experts and from 50000 to 65000 nuclearized experts. Partime contracts will amount to 70000 to 100000 new jobs. These figures give a first impression on the human resources needed within the European Union.

This document will discuss the education and training requirements which are implicit to the IAEA Safety Fundamentals, make a review of INSAG recommendations and present the contents of an experts’ book on infrastructure and methodologies for nuclear power programmes, considered as a valid tool to cover some of the education and training needs.

2. The IAEA Safety Fundamentals

The IAEA Nuclear Fundamental Safety Principles [2] were endorsed by affected international institutions and published in 2006. The List of Principles is reproduced in table 1.

<table>
<thead>
<tr>
<th>Principle 1: Responsibility for safety</th>
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<tbody>
<tr>
<td>The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks.</td>
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<table>
<thead>
<tr>
<th>Principle 2: Role of government</th>
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<tr>
<td>An effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained.</td>
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<table>
<thead>
<tr>
<th>Principle 3: Leadership and management for safety</th>
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<tbody>
<tr>
<td>Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks.</td>
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</table>

<table>
<thead>
<tr>
<th>Principle 4: Justification of facilities and activities</th>
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<tbody>
<tr>
<td>Facilities and activities that give rise to radiation risks must yield an overall benefit.</td>
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<tr>
<th>Principle 5: Optimization of protection</th>
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<tbody>
<tr>
<td>Protection must be optimized to provide the highest level of safety that can reasonably be achieved.</td>
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<table>
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<tr>
<th>Principle 6: Limitation of risks to individuals</th>
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<tbody>
<tr>
<td>Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm.</td>
</tr>
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</table>

<table>
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<tr>
<th>Principle 7: Protection of present and future generations</th>
</tr>
</thead>
<tbody>
<tr>
<td>People and the environment, present and future, must be protected against radiation risks.</td>
</tr>
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</table>

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<tr>
<th>Principle 8: Prevention of accidents</th>
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<tbody>
<tr>
<td>All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.</td>
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</tbody>
</table>

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<tr>
<th>Principle 9: Emergency preparedness and response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrangements must be made for emergency preparedness and response for nuclear or radiation incidents.</td>
</tr>
</tbody>
</table>

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<tr>
<th>Principle 10: Protective actions to reduce existing or unregulated radiation risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protective actions to reduce existing or unregulated radiation risks must be justified and optimized.</td>
</tr>
</tbody>
</table>
All principles have an impact on education and training, under that context only the most relevant ones are discussed.

**Principle 1** assigns to the license holder the prime responsibility for safety. It means that the license holder has to be sure that: the site is compatible with the plant; the design is based in proven technology; the construction complies with all quality standards; the commissioning is complete and satisfactory; the operation is safe and reliable in all modes of operation and the plant is kept safe and reliable through established maintenance and oversight procedures. A great deal of knowledge and experience is collectively needed to cover all those responsibilities.

**Principle 2** addresses the role of government on promulgating the needed legislation and creating a regulatory body. These responsibilities require that the dedicated legislative branch of government has a good knowledge of the nature of nuclear science and technology, the risks associated to ionizing radiation and the safety and security measures to be taken. Education and training for members of the regulatory body has to be based on a solid knowledge of nuclear science and technology enriched with a deep understanding of the aims and approaches of the regulatory function. These functions includes three basic aims: (1) enacting a complete and satisfactory set of safety and security regulations, (2) verifying compliance with the enacted regulations through a complete and satisfactory system of evaluations, inspections and continuous oversight, (3) enforcing compliance when discovering unacceptable deviations from the regulations. It should be stressed that the regulatory function has to be accomplished without unnecessarily engendering the economic interest of the licensee and with full respect to its responsibility for safety and security.

**Principle 3** refers mainly to the license holder. The license holder has to procure and maintain a competent organization based on excellent leadership and management to assure safety culture and reliable operation. Apart for maintaining an integrated management, operation requires well trained nuclear operators and supervisors; highly qualified nuclear experts-core criticality, fuel behaviour, safety analysis, radiation protection, radioactive waste -; nuclearized engineers covering many technologies-thermo hydraulics, electrical, instrumentation and control, materials, procurement, design modifications, and a large number of skills in the mechanical, chemical, electric and electronic areas.

**Principle 9** requires that there should be internal to the plant and external programmes to be prepared and act in case of an emergency. Accidents or incidents internal to the plant are under the responsibility of the licence holder, while accidents or incidents with external consequences are covered by the local and national authorities. Regulations require that drills are periodically conducted to test the validity of such emergency plans under the surveillance of the regulatory body. To cope successfully with nuclear emergencies includes many aspects and affects many people and social institutions requiring especial programmes on information, education and training.

### 3. INSAG view on needed infrastructure, education and training

The International Nuclear Safety Group, INSAG, a group of highly qualified experts in the field of nuclear safety, under the auspices of the IAEA, has analyzed the nuclear safety infrastructure which is needed for a national nuclear safety programme supported by the IAEA Fundamental Safety Principles. From the INSAG report [3] the need for nuclear education and training is easily deduced.

Nuclear education and training for the development and maintenance of new nuclear power programmes has to cover the different phases in the live of the nuclear power plant, consider the many technologies involved in each one of the phases and the specificity of the required knowledge and experience. The phases in the live of a nuclear power plant have been defined by INSAG in the cited report from which an education and training oriented table 2 has been deduced. The table copies the five major steps defined by INSAG, from the pre-decision phase to the end of the life of the plant, slightly modifies the major activities to be performed in each one of the phases and includes the needed infrastructure, education and training.
Table 1. Main phases in the life cycle of a nuclear power plant

<table>
<thead>
<tr>
<th>PHASE</th>
<th>DURATION (years)</th>
<th>MAJOR ACTIVITIES</th>
<th>NEEDED INFRASTRUCTURE, EDUCATION AND TRAINING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pre-decision</td>
<td>1-3</td>
<td>Develop a nuclear plan.</td>
<td>A government strong project management organization.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conduct a public consultation.</td>
<td>A comprehensive training programme for leaders.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Develop basic legislation.</td>
<td></td>
</tr>
<tr>
<td>2. Decision</td>
<td>3-7</td>
<td>Develop a detail nuclear programme.</td>
<td>An independent nuclear regulatory body.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Select a technology, a site and a supplier.</td>
<td>A specific training programme for regulatory experts.</td>
</tr>
<tr>
<td>3. Implementation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.a. Site selection and</td>
<td>2-3</td>
<td>Characterize the selected site.</td>
<td>A strong owner project management organization.</td>
</tr>
<tr>
<td>characterisation</td>
<td></td>
<td>Formulate a site licensing authorization.</td>
<td>Competence on earth sciences and man-made external inputs.</td>
</tr>
<tr>
<td>3.b. Design and construction</td>
<td>5-7</td>
<td>Site preparation and detail plant design.</td>
<td>A set of siting and design criteria.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fill application for construction permit.</td>
<td>Licensee and regulatory competence on design and procurement, inspection processes and quality assurance and quality control.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Construction in accordance with requirements.</td>
<td></td>
</tr>
<tr>
<td>4. Operation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reach first criticality and perform established nuclear tests.</td>
<td>A well trained and sufficient operating personnel.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apply for operation permit.</td>
<td>Licensee and regulatory competence for the review and approval of test results and licensing reactor operators.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transfer knowledge and responsibility to operating organization.</td>
<td>An emergency preparedness and response system.</td>
</tr>
<tr>
<td>4.b. Commercial operation</td>
<td>40-60</td>
<td>Operate the plant within safety and reliability requirements.</td>
<td>A set of criteria for safe and reliable operation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Perform periodic testing and inspection of safety related components, systems and structures.</td>
<td>An integrated management organization for safe and reliable operation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evaluate malfunctions, incidents and accidents.</td>
<td>Licensee and regulatory competence on equipment maintenance, aging, radiation protection and radioactive waste.</td>
</tr>
<tr>
<td>5. End of life</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.a Decommissioning</td>
<td>5-10</td>
<td>Fill a dismantling plan for approval.</td>
<td>A set of criteria for plant closure and decommissioning.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Develop a radioactive waste management system.</td>
<td>Dismantling organization and regulatory body need training on specific dismantling activities and waste management.</td>
</tr>
<tr>
<td>5.b. Long term management of</td>
<td>15-100+</td>
<td>Establish and maintain a long term radiological control of spent fuel and high level waste.</td>
<td>Define a policy for the management of spent fuel: reprocessing or geological disposal.</td>
</tr>
<tr>
<td>spent fuel</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The pre-decision phase is a responsibility of the government in synergy with those national or private enterprises generating electricity. It requires a strong management organization composed of well trained persons with knowledge on the basic aspects of nuclear energy, the scientific and technical capabilities of the country, the foreseen human resources and how they can be educated and trained on safety, security, safeguards, radiation protection, waste management and project management.

The decision phase requires the construct of a regulatory body with the capability of establishing a well defined regulatory system to cover the succeeding phases in the life of the power plant. The members of the regulatory body require a specific training to develop regulatory requirements, verify project compliance with the established regulations and to correct and enforce any deviation.

The implementation phase requires a solid management structure within the future plant owner and operator and a complete and satisfactory set of regulatory requirements. Both the licensee and the regulator need to have competence on earth sciences and man-made events for site characterization; experience in design evaluation, construction management, equipment procurement, inspection processes and quality assurance and quality control, during the construction phase.

The operation phase starts with the commissioning activities and continues with commercial operation of the plant. To achieve that, a sufficient number of well trained operators and supervisors are necessary. During the commissioning period they are generally coached by the plant supplier. Once the plant has been transferred to the plant owner the licensee becomes fully responsible for the safe and reliable operation of the plant. Their initial training has to be maintained through continuous training programmes. The operation of the plant includes many and varied technologies needing a strong integrated management system to secure safety, security and reliable operation.

The end of life phase includes two very distinct activities: Dismantling the plant and long time management of the spent fuel. Dismantling is a technology by itself now being developed. It includes cutting big metal radioactive pieces, concrete walls scarification, to remove surface contamination, and demolition, as well as a strict radiation protection system and radioactive waste management. Dismantling is generally performed under the responsibility of national organizations. The funds to dismantle nuclear power plants come from taxes imposed to the plant owner-operator and are collected during the commercial operation of the plant. The national policy on spent fuel is the responsibility of the government. Spent fuel can be considered a waste or a source of energy when recycled to recuperate and reuse the plutonium produced through MOX fuel in current nuclear power plants. The policy to follow has to be determined by the government.

From table 2 it has been possible to deduce table 3 on the needs for education and training. Table 3 makes it clear the large list of specialities and skills that are needed for the development of a nuclear power programme. In general, most of these specialities required some type of university degree, which must be complemented by specific training offered by the suppliers of the power plants. The needed skills during construction and operation require training diplomas from vocational schools and skills academies.

Education and training for members of the regulatory body has to be based on a solid knowledge of nuclear science and technology enriched with a deep understanding of the aims and approaches of the regulatory function. Initial training of regulatory staff is complicated and experience can only be obtained from collaboration with advanced regulators.

Education and training for operating personnel is the responsibility of the licensee. It is conducted by specific organizations, such as Tecnatom in Spain, or by the licensee. In most countries, some of the operators have to be licensed by the regulatory body through a well regulated system. The US Institute for Nuclear Power Operations, INPO, has created a Systematic Approach to Training, SAT, procedure which includes an elaborated training programme accreditation system, which is also followed by Eskom in South Africa and by EDF-Energy in the UK.
<table>
<thead>
<tr>
<th>PHASE</th>
<th>TRAINING REQUIREMENTS</th>
<th>TRAINING FACILITIES AND TOOLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pre-decision</td>
<td>Nuclear fundamentals needed to acquire technical capabilities, appreciate the international framework and understand nuclear economy.</td>
<td>University courses. IAEA International courses. World Nuclear University. European Nuclear Energy Leadership Academy.</td>
</tr>
<tr>
<td>2. Decision</td>
<td>Nuclear science and technology, nuclear systems, nuclear safety and security, nuclear regulation.</td>
<td>High level university degrees and specific courses. Specific training courses for nuclear regulators</td>
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<tr>
<td>3. Implementation</td>
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<tr>
<td>3.a Site selection</td>
<td>Expertise needed on the earth sciences- meteorology, geology, seismology - and on environmental impact of nuclear power plants.</td>
<td>High level university degrees and courses covering earth sciences and environmental impacts (physical, chemical, social and economic)</td>
</tr>
<tr>
<td>3.b. Design and construction</td>
<td>Expertise needed on bid invitation and selection, design, construction and assembly of structures, systems and components and quality assurance</td>
<td>High level university degrees and experience in large projects. A large variety of expertise gained in vocational schools and skill academies</td>
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<tr>
<td>4. Operation</td>
<td></td>
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<tr>
<td>4.a Testing and commissioning</td>
<td>A long specific training on plant operation of a large and sufficient number of reactor desk operators and supervisors, turbine operators, maintenance and radiation protection experts.</td>
<td>A long specific initial training is provided in full scale simulators and human factors training facilities operated by dedicated companies or in plant training resources.</td>
</tr>
<tr>
<td>4.b Commercial operation</td>
<td>Increasing expertise in all aspects and modes of operation is maintained. Leadership and management for safety and safety culture are developed and constantly improved. Own and outside operating experience is analyzed and lessons applied.</td>
<td>Initial, for new comers, and continuous training, for all personnel, is provided in full simulators and human factor facilities. On the job and mentor training is also provided to cover all aspects of nuclear plant operation</td>
</tr>
<tr>
<td>5. End of life</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.a Decommissioning</td>
<td>Decommissioning includes technologies for removal of large radioactive components and system, demolition of active structures, separation of active and non active waste and site restoration.</td>
<td>Decommissioning requires experienced managers with university degrees and a large number of technical persons trained in vocational institutions and skill academies.</td>
</tr>
<tr>
<td>5.b Management of spent fuel</td>
<td>It is a high level decision requiring a good knowledge of alternatives, their cost and social implications and the international context.</td>
<td>High level university degrees on international policy and regulations, economics, nuclear technology and sociology.</td>
</tr>
</tbody>
</table>
4. The book on infrastructures and methodologies

With the information above a group of experts with training experience, regulatory know-how, international background, from research and academic institutions and nuclear industry organizations, decided to publish a book to cover the science, technology and administration they considered necessary to develop a nuclear power programme. The effort done was completed with the publication in 2012 of a book title *Infrastructure and methodologies for the justification of nuclear power programmes* [4]. The book was published almost a year after the Fukushima Daiichi accident, when most of the book was already written and edited. The text of the book was reviewed, references to the accident were included when considered necessary; it was also estimated that the accident reinforced the need for education and training and that nuclear power development will continue worldwide, although at a lower rate. The list of chapters and authors is included in table 4.

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<td>Appendix 5, J. Reig,</td>
<td>Multinational Design Evaluation Programme: multilateral cooperation in nuclear regulation and new reactor design</td>
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4.1 Part 1: Infrastructure on nuclear power programmes

Part 1 of the book is developed in five chapters covering: The lifecycle of a nuclear power programme; the role of government in establishing the framework for nuclear power programmes; regulatory requirements and practices; Responsibilities of the nuclear operator; the need for human resources, and national technical capability development in nuclear power programmes.

The role of government is considered critical for the success of a nuclear programme. The main responsibility of the government is enacting appropriate legislation and the creation of an independent regulatory body. The government is also responsible for education and training, research and development and for complying with the many treaties and international conventions on safety, security, safeguards, waste management and third party liability. The regulatory functions require an intense and specific education and training programmes, but initial experience can only be obtained in countries with a well established nuclear power programmes.

The license holder should be aware of his prime responsibility for safety, but the operation of a nuclear power plant engages hundreds of persons with diverse knowledge and skills, which have to be organized into a cohesive workforce and with a clear collective vision on what the team has to achieve. This requires and effective and successful leadership. Successful leaders do not only need knowledge and have experience, their manners, honesty, integrity and the quality of engendering respect and trust are even more important.

The need for human resources and how individuals should be educated and trained is a key chapter of the book. It addresses the human resource requirements of nuclear stakeholders, the specialities to be covered in each phase in the life of the power plant, the level of education and training required by nuclear professionals, nuclearized engineers, technicians and craftsmen and the national and international programmes and facilities to cope with the foreseen challenges.

The chapter on the national technical capability development stresses the need for developing national scientific and technical capabilities to respond to the initial and long term requirements demanded by a nuclear power plant. The chapter recommends orientation training for those people participating in the early decision and the development of a well trained technical core group to ensure the maximum national participation in siting, construction an operation.

4.2 Part II: Justification of nuclear power programmes

Justification of nuclear facilities and activities is the fourth principle in the 10 IAEA Fundamental Safety Principles. It establishes that “facilities and activities that give rise to radiation risks must yield a general benefit”. The principle compares the economic, social and environmental benefits of a nuclear development with the associated risk. When the benefits outweigh risk the proposed nuclear development is considered justified. Although these two terms are easily identified its quantification and comparison is a difficult task including many uncertainties and different opinions. Chapter 8 defines and develops the terms in the justification equation, including nuclear risks and detriments of nuclear energy. Chapter 9 is an account of the available and advanced nuclear technologies.

Means and procedures to quantify risks are included in chapter 10 on nuclear safety. The chapter introduces the early deterministic approach to nuclear safety and the most recent probabilistic methodology and the risk-informed decision-making process. Radiation protection is the science related to the health effects of ionizing radiation. An extended chapter 11 contains the scientific bases and standards used on protecting workers and the public. Emergency preparedness and response is the last barrier available to mitigate the consequences of radioactive releases. Chapter 12 includes references on the international conventions of Early Notification of a Nuclear Accident (1986) and on Assistance in the Case of a Nuclear Event (1986) established after the Chernobyl accident. Non-proliferation of nuclear devices is an international concern; chapter 13 on nuclear safeguards considers the
Non-proliferation Treaty and the international safeguards developing by the IAEA to ensure non-proliferation.

Radioactive waste and spent fuel need to be managed, first during the operation of the plant and later on during extended periods of time. Chapter 14 includes an account on the policies and strategies for the management of both. The management of spent nuclear fuel is of particular interest as it can be classified as a waste or be declared as a useful resource of energy.

The singularities of nuclear power economics are considered in depth in chapter 15. It is well known that the initial investment is high but operation is cheap. The chapter discussed the current and future economics of nuclear power its risks and uncertainties.

Chapters 16 and 17 consider the social and environmental impacts of nuclear power respectively. Methodologies have been developed to quantify the national and local social benefits of nuclear power, but the methods are elusive and generally not accepted by social groups. The polls clearly indicate that there is a link between the social nuclear education level and acceptance of nuclear power. Environmental impact is well regulated at the international and national level. The radiological impact is considered very small and acceptable, while there is some concern on some physical impacts, mainly the heat discharged to the environment to comply with the second principle of thermodynamics.

4.3 Part III: Development of nuclear power programmes

Part III includes seven chapters including information of training interest. It includes chapters on site selection, bid invitation, licensing, quality assurance, commissioning and operational safety and decommissioning. Once decision has taken, the next steps are site selection and characterization and preparation of a bid invitation specification, BIS. Site selection, chapter 18 is based on the compatibility of the site characteristics with the design of the plant. The BIS depends on the desired type of contract and should end with the signature of a contract. The chapter describes in detail the intention and contents of the different documents in the BIS.

Licensing is based on the applicant submitting to the regulatory body a set of well defined documents and the regulatory body verifying compliance with the previously establish regulations and requirements. The process may last several years and end with the granting or denying the licence. Chapter 20 describes the general process; it also includes an Appendix describing the peculiarities of the licensing system in the United Kingdom an in Germany.

One of the most relevant activities is quality assurance. Chapter 21 describes the quality assurance criteria and processes during design, construction, commissioning and operation. It also covers the assessment of the quality assurance programme through independent peer reviews and self-assessments.

Commissioning is a short –one to two years – but crucial phase in the life of a nuclear power plant, as it serves to verify that the plant has been designed and constructed as required in the contract and within the safety requirements establish by the regulator. It also serves to test the performance and qualification of the operating personnel. The chapter describes the relevant applicable codes and standards, the different commissioning stages – preoperational, subcritical test and first criticality, low and power tests and final acceptance power test.

Commercial operation is the productive longest phase in the life of the nuclear power plant. Based on the IAEA requirements for nuclear power plant operation, chapter 23 describes the management organization and puts emphasis on the initial and continuous training and qualification of the operating personnel—management and supervisory personnel, control room operators and shift supervisors, field operators, maintenance personnel, technical support and general employee. Of specific interest is the training organization and training facilities, as considered in the IAEA standards.

Decommissioning will considerably grow in the future as old plants are reaching the end of their useful lives; nevertheless experience is accumulating in the dismantling of the early prototypes and demonstration facilities. Chapter 24 includes a brief history of
decommissioning development, cost estimates, decommissioning technologies, research activities and the management of decommissioning waste.

4.4 Part IV: The Appendixes

The book includes five appendixes covering: 1. The United Kingdom experience in a test conducted to apply the justification principle to new nuclear builds. 2. The concept of nuclear safety culture, how it can be measured and the benefits it may provide. 3. The IAEA training programmes, the four quadrants competencies for regulators and SARCoN Guidelines. 4. Simulator training with recommendations on who should received a full-scale simulator training, operating scenarios, competences to be acquired, best ways to train in simulators and simulator requirements. 5. The NEA driven Multinational Design Evaluation Programme, MDEP, is a valid intent to achieve international harmonization in design codes, standards and safety goals; enhance multilateral cooperation within existing regulatory frameworks and facilitate licensing reviews of new reactors.

5. References


The Fukushima Accident Impact on Simulation Training Tools

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Abstract

As what happened with the TMI and Chernobyl events, it is expected the Fukushima accident will drive to significant changes in the simulation training tools. The importance of analyzing and understanding the plant behavior under severe accident conditions is growing, leading to motivating the reinforcement of training on severe accident phenomenology and emergency management.

Full scope training simulators are one of the primary tools the plants have available to address their training needs, however few simulators in the world possess severe accident capabilities, mostly because the control room is not normally the right place to handle severe accident sequences (e.g. extended SBOs). Likewise international standards haven’t yet required this feature.

Technical Support Center (TSC) members, and other emergency center staff, need specific training since they may not have the necessary skills to understand and operate, in depth, their plant evolutions in case of a major accident.

After careful analysis on the available solutions Tecnatom decided one year ago to start a project aimed at extending the use of simulators to the emergency center staff for training purposes in emergency drills. The project has addressed the following major points:

• To extend the simulation scope of available classroom simulators by integrating a severe accident module that has been developed based on MAAP4, code (MAAP technology is owned by EPRI: Electric Power Research Institute and used by the Spanish NPPs for PSA analysis).
• Integration of the severe accident module with a PWR full scope training simulator operated by Tecnatom. Simulation continuity has been guaranteed between normal operation and accident conditions.
• On-line switch between real time and faster than real time execution.
• Stimulation of emergency support tools. The Technical support Center staff will receive the information in the same manner they would receive it in case of a real accident sequence.

The project successfully finished last year with an implementation plan that is currently under analysis.

1. Introduction

As a consequence of the accident that took place at Fukushima, there has been an increase in the importance of reinforcing the training in severe accident management in nuclear power plants. Full scope training simulators are one of the primary tools the plants have available to address these new training needs.
From the point of view of severe accident simulation, the technology is fairly mature and available, with several previous experiences about the use of severe accident codes with training purposes. However, severe accident scenarios are hardly used in training.

On the other hand, Technical Support Center (TSC) members and other emergency centers staff need specific training and do not have the necessary skills to understand and operate, in depth, their plant evolutions in case of major accident.

At Tecnatom we work on different activity areas related to nuclear safety, including simulation technology, control rooms design and modernization, plant operation support, plant staff training and safety management. This experience provides Tecnatom with a multidisciplinary point of view as well as a general approach to safe operation of a NPP and an effective response in the event of an accident.

The conclusion is that reinforcing severe accident management training is one of the challenges that NPPs have to face in the near future and severe accident simulation technology needs a new angle in order to be really useful.

2. Background

Back in 2005, Tecnatom developed a methodology for the design and integration of severe accident simulation models in training simulator environments. This methodology was applied and validated by developing a severe accident simulation model, based on the MAAP code (MAAP is a technology owned by EPRI: Electric Power Research Institute, Inc.) and by implementing it in a full scope training simulator.

3. Project Design Criteria

Project design criteria taken into consideration were:

- The control room simulator may not always be the most appropriate environment, for instance to train on severe accident phenomenology
- Plant staff, other than operation crew, is not qualified to operate the NPP from the control room
- Accident scenarios duration exceeds usual training sessions´ time
- There are no specific support tools connected to simulators for nuclear emergency training purposes

These considerations led to the conclusion that there is a need to integrate simulation technology supporting severe accident phenomenology within the specific training necessities of plants and Technical Support Center staff.

4. Project Scope Main Features

In the light of all of these considerations, Tecnatom embarked on a project aimed at extending the use of simulators to the emergency centers staff for training purposes in emergency drills. The project consisted of implementing new features in available training simulators, enabling its use in emergency centers. Amongst others, the project addressed the following major points:

- Extension of the simulation scope of available classroom simulators by integrating a severe accident module, based on the code MAAP4 (technology used by the Spanish NPP for PSA studies)
Integration of a severe accident module in a PWR training simulator operated by Tecnatom. Simulation continuity has been guaranteed between normal operation and accident condition.

On-line switch between real time and faster than real time execution. This feature allows fitting a severe accident sequence within a training session timeframe by speeding up the simulation while the information is not relevant.

Duplication of the most important classroom simulator displays in case of emergency. That way, the displays may show either the instrument values, so the staff will receive the information in the same manner they would receive it in case of real emergency, or the physical values calculated by the model, associated with the instruments, which is of great help to understand the accident progression.

Stimulation of the emergency support tools SACAT-GGAS, developed by Tecnatom.

Possibility of different type of training configurations, oriented to different type of training sessions. For instance, sessions only with control room operation crew, only with TSC members or mixed sessions, and a phenomenology training configuration, showing the physical values in the displays.

5. Emergency support tools stimulation

5.1 SACAT – Technical Support Center Support System

Tecnatom has developed several computer-based tools for emergency training and management, named SACAT, running at the Technical Support Centers.

SACAT includes different modules and displays which show the main operating parameters, radiation monitors and external radiological impact estimates due to all possible leakage pathways.

![Fig 1. SACAT: main operation display](image)
5.2 SACAT-SAMG: Severe Accident Management Guidelines

The second tool, SACAT-SAMG, is a computerized module of the Severe Accident Management Guidelines, customized for every Spanish NPP. It consists of a general display with the available guides, allowing consulting tables and providing computational aids during the follow up of a specific guide, as well as checking the state and availability of equipments, systems and strategies.

![SAMG computerized module](image)

Fig 2. SAMG computerized module

The stimulation of the emergency support tools by the simulator supports the training of the Technical Support Center members, allowing the follow-up of the accident through these tools and helping in the decision making process, since they provide the most relevant data and information about the most important parameters as well as the SAMG strategies available at every moment. Furthermore, it allows the TSC members to be trained with the same tools they use in case of real emergency.

6. Different training configurations

Amongst the different training configurations:

- Session with operation crew alone, to train on their own Control Room Severe Accident Management Guidelines
- Session with TSC members alone, to train on their Severe Accident Management Guidelines
- Session with TSC members and operation crew coordinated under the same scenario, making possible for them to develop team skills in emergency situations
- Phenomenology training session, following the data calculated by the severe accident module and therefore the accident progression
7. Simulator validation

One of the most important phases of the project is the validation. In this case three different validation processes were required.

The first step was to validate the online switch between real time and faster than real time. In order to do that, some sequences were executed at different simulation speeds. For instance, the SCRAM sequence was executed at real time and 5, 20 and 60 times faster than real time, obtaining the exact same results:

![Time switch validation. Pressurizer level in SCRAM sequence](image)

As a second step, the integration of the severe accident module in the classroom simulator was validated, checking that all the variables were correctly exchanged. This validation was carried out according to the ANSI/ANS-3.5 standard, which sets the functional requirements for full-scope nuclear power plant control room simulators for use in operator training and examination. Ten sequences were executed and the main operation parameters compared between the simulator before and after the integration of the severe accident module. For example, for the sequence of loss of feedwater, the following results were obtained, finding that both performances were qualitatively identical:
Finally, the simulator severe accident performance was validated. For this purpose, a series of severe accident sequences were executed, such as a prolonged Station Black Out, loss-of-coolant accident (LOCA) with failure of LPSI pumps or total loss of feed water accident with failure of HPSI pumps. These sequences were run following the Emergency Operation Procedures and the Severe Accident Management Guidelines with experts in severe accident phenomenology. For instance, some of the results for the LOCA sequence with failure of the Low Pressure Injection System and later recovery of these pumps are the following:
8. Conclusions

Although severe accident simulation is an available technology, a new approach is requested in order to get the most out of the training in severe accidents management.

As identified in this paper, the new features implemented within the full scope simulators domain make them efficient tools for such important points as the definition, assessment and training in severe accident management as well as the deep understanding of its complex phenomenology.
MULTIMEDIA TOOL FOR WWER TRAINING

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ABSTRACT

The Institute for Energy and Transport of the Joint Research Centre (JRC) of the European Commission, jointly with the International Atomic Energy Agency (IAEA), have developed an innovative multimedia knowledge package which is based on systematically collected and consolidated knowledge of top-experts in WWER (i.e. the Russian version of a pressurised water reactor) Reactor Pressure Vessel (RPV) Embrittlement and is meant to support training in the field. The tool is addressed to nuclear engineers and researcher who need to be trained on WWER RPV Embrittlement issues. The modules provide very compact knowledge; an expert is recorded while giving a lecture (usually composed of 10-20 topic related questions answered) and his speech is subtitled. The presentation is powered with eye-catching animations that make simpler the learning process and that attract the user attention. At the end of each lecture the trainee can test his understanding on the topic with a multiple-choice questionnaire and receives a score based on his performance. A powerful search engine is built in the package to ensure the easy navigation across all Modules in, text, video and sound.

These multimedia modules are designed as an on-line resource and include the possibility to easily share and discuss on social medias (i.e. twitter, Facebook, etc.) the selected presentation/slide.

The package is completed and programmed in HTML 5 language to allow high flexibility and make the content browsable also on tablets and phones. For classroom training an offline version can be generated.

1 Introduction
1.1 Methodology

The Institute for Energy and Transport of the European Commission Joint Research Centre has developed a methodology for consolidation of nuclear knowledge [1]. The method, shown in Fig.1, relies on the mobilisation of all identified leading experts in the European Union (EU) or beyond, re-evaluating old knowledge and consolidating what is necessary to create training and education material for new generations of nuclear engineers, researchers and experts.

These experts are asked to provide the papers in their possession related to a specific nuclear expert field. Furthermore, they are asked to identify still more key-experts in that area.
Fig. 1 Nuclear Knowledge Preservation Circle

All papers are collected centrally and stored in a protected database DoMa, which is a document database located within ODIN (http://odin.jrc.ec.europa.eu), managed by the Institute for Energy and Transport. The papers are stored in pdf format and additionally have information about the title, authors, keywords and abstracts stored separately in MS Word for an easy search function implementation.

After the identification of some possible reviewers amongst the expert group, the subject is subdivided in subfields, in order to reduce the heavy work of review, summary and preliminary consolidation.

When the reviewers have finished their work, they prepare a summary report for their subfield, which is then sent to all experts participating to the upcoming consolidation workshop. At the workshop the reviewers present their summary and conclusions on the subfield reviewed, which is afterwards discussed among the experts. The task of the chairman is to lead the experts to an as agreed as possible consolidation of the knowledge in each particular subfield. Finally, recommendations are made at the end of the workshop, which lead to further consolidation efforts in certain subfields or to a final consolidation document in others.

An additionally very important item in the consolidation process is the identification of commonly agreed (consolidated) open issues in the subfields. They complement the final goal of a State-of-the-Art report in the specific expert area.

1.2 Knowledge preservation of WWER Reactor Pressure Vessel Embrittlement

WWER (acronym of Water Water Energetic Reactor) is a type of Nuclear Reactor designed in Russia and similar by construction to a Pressurized-Water-Reactor (PWR) more common in the western countries. Approximately 50 WWER reactors are still in operation worldwide and 20 of them are located in European Union member states [2]. There is a huge amount of information and knowledge in WWER Reactor Pressure Vessel (RPV) embrittlement available, either published or easily available, but there are
also publications that are difficult to trace. Especially those at risk of being dispersed or lost due to a series of factors, including:

- retirement of Senior Experts who were present at the time when most WWER Nuclear Power Plants were designed and put into operation,
- generational gap (due to years of decline in new constructions, only a limited number of people started their career in that area)
- non-electronic publishing in the past
- limited dissemination possibilities
- language (many non-English publications from Eastern countries)

Therefore, the Institute for Energy and Transport has decided, jointly with some key experts, to perform a pilot study using the previously described methodology for consolidation of WWER RPV embrittlement knowledge.

Fig. 2 Subdivision of WWER RPV Embrittlement Expert Fields

It has to be mentioned that the last State-of-the-Art document was produced in 1981 by Alekseenko, Amaev, Gorynin and Nikolaev [3, 4], which needs upgrading. In a brainstorming session at the beginning, the predefined fields of expertise in WWER RPV Embrittlement were discussed and defined as described in fig. 2

1.3 Conclusions on the Methodology

It is evident that this pilot-project alone cannot solve a structural shortage of nuclear experts and vice versa, that initiating such a pilot-project cannot prevent the experts from
retiring with their specialist knowledge. The key problem is the effect of these developments: a shortage of human resources qualified to do the work to be done. This shortage causes difficulties everywhere in the field and it will make it even more difficult to collect the knowledge of the retiring experts in a complete and systematic way.

The above described methodology applied to the knowledge of WWER RPV embrittlement has proven to be a step in the right direction. The experts themselves, mostly active in the field from the beginning of the nuclear area, are proud of their work. They contributed in a very idealistic and positive way to this first circle of knowledge consolidation. Some even did the reviewing work in their spare time at home. The atmosphere during the discussions of the proposed consolidated conclusions per subfield was relaxed and constructive, as were the discussions on the consolidated open issues per subfield. The outcome was preserved in several summary records (to be found at http://capture.jrc.ec.europa.eu). It was interesting to notice that the experts were agreeing on their consolidated conclusions and open issues on the basis of a limited number of papers per subfield. It was clear that the complete (tacit) knowledge and experience of the experts were taken into consideration when making such a judgement, not only the knowledge by reviewing the limited amount of papers. This may be a very powerful tool in order to save time in the consolidation process.

A further advantage of this consolidation methodology is that the summary reports of the subfields can be published openly, pointing to all reference papers, but not violating intellectual property rights (IPR). A wide dissemination to the interested public is guaranteed free of charge and to the benefit of engineers, experts and researchers who constitute the identified target group of this exercise and who needs to be trained in RPV issues.

![Fig. 3 Process Scheme from Knowledge Consolidation to dissemination](image)

Fig. 3 Process Scheme from Knowledge Consolidation to dissemination

It seems promising to continue applying this consolidation methodology to other fields of
possible nuclear knowledge loss. This could be done not only for materials, but also for technologies, components, systems, etc.

Therefore, in summary, the first pilot study on WWER RPV Embrittlement is being carried out with some encouraging preliminary results:

- The consolidation methodology proves to be efficient
- The participation of the experts to the consolidation is excellent
- Unified keywords are essential to trace the information needed
- The consolidated summaries per expert sub-field give a good general overview on results, open issues and key references without violating IPRs

### 2 Multimedia Project

#### 2.1 Basis

As described before, the EC-JRC recognised the importance of WWER reactors knowledge preservation. The next step after the consolidation process would be a wide distribution of the gained knowledge to the target group. Therefore an initiative on “Preserving WWER RPV Embrittlement Knowledge using Multi Media Technologies” has been launched. To ensure the best quality of the final product, which is the Multi Media Training Course on WWER RPV Embrittlement, EC-JRC asked the International Atomic Energy Agency (IAEA) for cooperation. This initiative is part of the Practical Arrangement signed between the IAEA the EC-JRC where a closer cooperation in the development of Multi Media Material for Nuclear Knowledge Dissemination and Education is indicated. For a visual impression of the process Figure 3 is a good illustration.

#### 2.2 Execution and Technical Details

Starting from March 2010, video recordings of key experts were conducted at different locations, main papers and documents were reviewed, materials from key conferences were preserved and multiple-choice tests to evaluate students’ understanding were created. After a first pilot module the others follow shortly and by today 10 modules were successfully completed, one for each of the 10 expert fields identified in Fig. 2.
The entrance page, shown in Fig.4, allows an easy selection of the modules and the beginning of the multimedia experience. The tool offers a modern interface with a rational disposition of all the offered features: the window is divided in several frames as shown in Fig.5. The knowledge presented is compact and easy to assimilate: an expert is recorded while giving a lecture (usually composed of 10-20 topic related FAQs and is subtitled); slides are appealing and have eye-catching animations to attract the user's interest. The interface presents the following characteristics:

- Big central animated presentation slide
- Three drop-down menus to select either one of the 10 modules, a lecture recorded during a workshop or a variety of questions asked to the expert.
- Video of the expert recorded while giving the presentation
- Subtitles of the presenter's talk for better understanding
- Additional material (papers, book chapters, presentations, etc.) on the topic easily downloadable through a drop-down menu
- Social-button: allows to share the selected slide on social media such as Facebook, Twitter, Google+, Digg-it
- Multiple choice test at the and of each module to check the user's learning process
From a technical point of view the tool is modern and innovative under certain perspective in fact presents the following features:

- The tool was completely developed in HTML5, making it browsable on PC/laptops and on mobile devices as well (tablets, phones…) regardless of the screen size or of the operative system running on the device.
- The tool can be hosted either on Windows or Linux server with PHP support.
- For classroom training or location without internet access, an off-line version can be recorded on a DVD.
- The platform is modular and scalable, allowing to add different modules or to use it for other knowledge-preservation projects.
- Results of the multiple-choice tests can be stored and a completion certificate can be printed at the end of the ten modules.

3 Summary

The encoding was finished and the platform was incorporated on the CAPTURE website in autumn 2013 and can be used in its online form free of charge at the following web-url: http://capture.jrc.ec.europa.eu/wwer, an off-line version can be requested to the authors of this publication.

The tool has been used already during a classroom pilot training course in connection with the CORONA project (financed by the 7th framework programme of the European Commission http://projectcorona.eu/): participants had at their disposal a multimedia PC with Internet connection and this allowed the trainer to tailor the course on the individual needs of each of the 16 participants, directing them to the modules of major interest for their background/requirements.

The platform in this form proved to be easy to use and scalable to different needs and can become a powerful tool for future knowledge preservation tools.
4 References


ABSTRACT

At the senior undergraduate and graduate levels, course catalogues of many University nuclear programs and departments fail to cover the breadth of specialties that are now standard in nuclear science and engineering. This is largely a result of many typically small faculty sizes and the ever expanding overlap of nuclear science with other disciplines. In this regard, distance learning and online courses have been invaluable in filling in the gaps in course material. Furthermore, such courses are geared for a student audience and are designed to be easily assimilated and cover fundamental concepts. We have prepared an online course sponsored by the US Nuclear Regulatory Commission, which is aimed at teaching students the fundamentals of radiation effects in electronic materials. The course consists of a series of five modular video lectures, ranging between 15-20 min long, that cover topics from basic nuclear interactions and materials science to defect evolution models and semiconductor physics. Accompanying these lectures are a series of video labs intended to help supplement the students' newly developed theoretical knowledge with demonstrations of the various phenomena discussed in the lecture modules. The labs also help introduce the experimentally inclined to the basic tools and techniques used in experimental radiation engineering.

1. Introduction

University courses teaching core topics and delivered in a classroom setting are an indispensable ingredient in a student’s academic upbringing. Given the faculty size of many nuclear science and engineering programs and the priority of teaching core fundamentals, however, it is often difficult to provide a broad coverage of specialized material pertaining to particular sub-fields. While many individuals in academia will typically only specialize in a single sub-field it is generally a benefit to a student’s resume and career to be literate in a number of different areas. Students at the graduate level may gain experience in such areas through research conducted with their faculty advisors expert in those areas but as academic expertise is highly localized at particular universities, only students at those universities will have direct exposure to it.

Self-study is another tool to help students become literate in sub-fields not covered by their normal course offerings. However, there is little educational infrastructure to support self-study. Students taking this approach must show considerable determination and follow through to absorb the more difficult concepts without the aid of a professor, course instructor or TA. A recent phenomenon of open courseware published by public and private Universities in the United States has facilitated free and open self-study in the general public. The most developed open courseware, however, is primarily available only for core undergraduate classes. Furthermore, the open courseware for advanced classes or classes
covering special topics is a byproduct of what is, first and foremost, meant to be material delivered in a classroom setting.

Short modular video lectures are a useful tool in self-study because they are not tethered to a classroom, they are designed to encapsulate all of the information covered in the course, and by being short, and they can be completed by a moderately motivated student who might have other scholastic or time commitments to balance. In a similar vein, the short video module is a convenient way to deliver continuing education material for individuals in industry or academic staff positions who have many job responsibilities and little time or inclination to complete a full course.

We have constructed a series of modular video lectures to teach students the basics of radiation effects in electronic materials. The topic is multidisciplinary in nature and incorporates aspects of nuclear engineering, materials science and solid state physics. Students who are interested in radiation detector design, electronics for space or nuclear reactor applications, accelerator engineering, and microelectronics will find that the material covered is a valuable supplement to their knowledge. It is assumed that the student has a familiarity with basic terms like neutron, atom, electron, crystal etc. and that he or she has taken math classes up to and including differential equations. The course material is appropriate for upper level undergraduate students in the natural sciences and engineering or students starting graduate school.

2. Course Structure

The course consists of the following 7 modular video lectures:

1. Nuclear interactions and interatomic potentials
2. Stopping power and the damage cascade
3. Defects and damage evolution
4. Electronic properties
5. Radiation effects on electronic properties
6. Introduction to scanning electron microscopy
7. Irradiation by beams and radioactive sources: uses in materials science

Each lecture of the first five modules is about 15-30 min in length and covers a different topic related to radiation damage in electronic materials. The lectures are modular in the sense that information is encapsulated as much as possible within a particular lecture. In this way, a student who wishes to review a concept only has to review one of the modules instead of the whole series. Additionally an individual with good familiarity in one area might choose to only use selected modules. For example, someone familiar with solid state physics could choose to skip module 4 while someone familiar with radiation effects could choose to skip modules 1, 2 and 3. However, in general, it is assumed that the student will want to work through all seven modules in order as the information builds to a rounded survey of the subject matter.

The material, being fairly technical in its nature, must necessarily be dense in order to fit within the 15-30 min format. However, an advantage of having short, on-line lectures is that the student may pause the lectures as they see fit or review them additional times if necessary. The material is not comprehensive as it only takes a cursory look at some basic concepts within a large body of knowledge. Therefore, some recommendations for textbooks and review articles are provided within the first module which will aid the student in any subsequent literature research that they wish to pursue.
The content of the video comprises a series of presentation slides with text, equations, and figures on them and an audio track with the instructor narrating. An example of a slide is shown in figure 1. The narration closely follows the text on the slide so as to conform to both auditory dominant and visual dominant learning styles. Several example problems are provided in the modules in cases where it helps to show how various mathematical formulae and concepts are united in a practical way. Figures 2, 3 and 4 are slides presenting an example problem and its solution. It is necessary that the example problems are made with enough assumptions that the solutions are fairly simple. In this way the student can better understand the gist of the solution and not get distracted by algebraic manipulations. For more in-depth and challenging practice using the concepts and theory, each lecture is accompanied by a problem set. Some students find that problem solving exercises helps them to cement their knowledge. The problem sets are provided as a resource should they want the additional challenge.

**Figure 1: An example slide from a lecture module**

Displacement Energy

- During the displacement event, an atom is removed from its equilibrium position past repulsive barrier atoms and into an interstitial position (a normally empty space in the structure).
- The resulting hole in the structure is termed a vacancy. The vacancy-interstitial pair is a Frenkel pair.
Example

- Consider an n-type Si doped with P. Vacancies will complex with P to form a V-P center (or E-center).

\[ \text{V} + \text{P}_s \rightarrow \text{VP} \]

- The energy level of the V-P center is 0.4 eV below the conduction band (near mid-band). Assuming that the P concentration is sufficiently high so that the only secondary irradiation effects are V-P centers and neglecting Si interstitials, derive an expression for the conductivity as a function of neutron fluence for small fluence levels.

Solution

- We first need an expression for the cumulative number density of vacancies, \([V]\), produced at a given neutron fluence. This is simply the fluence, \(\Phi\), times the displacement cross section, \(\sigma_d\), and the Si number density, \(N_{Si}\), correcting for in-cascade clustering and recombination (\(\varepsilon_v\) and \(\varepsilon_r\)).

\[ [V] = N_{Si} \sigma_d \Phi (1 - \varepsilon_r) (1 - \varepsilon_v) = K \Phi \]

- Since we assume all vacancies complex with P atoms we have the concentrations of P and VP-centers as a function of fluence:

\[ [P(\Phi)] = [P(0)] - K \Phi \]

\[ [VP(\Phi)] = K \Phi \]

- From the mass action law the constraint relating the carrier densities \(n_e\) and \(n_h\) is given by

\[ n_e n_h = n_i^2 = \text{constant} \]
3. Video Laboratories

Along with the lecture videos, there are four video laboratory demonstrations aimed at stimulating some of the hands on lab experience that the students in a conventional university setting might get. The labs are designed to demonstrate some of the concepts in a way that is simple, direct and also alludes to the radiation hardness testing of practical electronics. Although not a complete surrogate for the actual experience a student gets when performing a lab and doing the data analysis by herself or himself, the video lab does help make some of the lecture material more concrete.

Summaries of the four labs are as follows:

i) Sample irradiation – The instructor shows how an irradiation is conducted to accumulate neutron damage in an electronic component. A PN junction diode is placed in a vial and then shuttled into the core of a research nuclear reactor. The sample is left to decay until its activity has subsided.

ii) Minority carrier lifetime measurement – A measurement of the minority carrier lifetime of the diode irradiated in the first video lab is conducted using electronics testing equipment. The setup includes a function generator and a digital oscilloscope communicating to a computer through Labview software. Comparisons of the measurement of an unirradiated diode with the irradiated one are used to show the effects of neutron damage on carrier lifetime.

iii) Transistor gain degradation – Gain vs. base emitter voltage measurements are made for an irradiated and an unirradiated NPN transistor. The measurement setup involves three source measure units in a semiconductor parameter analyzer and a test fixture. Degradation of the gain in the irradiated transistor shows that recombination current in the base increases due to irradiation induced defects.

iv) Diode leakage current – An increase in diode leakage is demonstrated for the PN junction transistor. Current-voltage (IV) curves are measured before and after irradiation using a source measure unit. An increase in the reverse saturation
current indicates an increase in the concentration of carrier generation sites (i.e. deep level traps) in the space charge region.

In each video lab there are cutaways to still frame diagrams of the experimental setups, graphed results of the processed data, and figures illustrating the physical explanation of the observed phenomena. One such cutaway used in the minority carrier lifetime lab is shown in figure 5.

![Figure 5: Cutaway of plotted results from a video lab](image)

4. Delivery

The first use of this course material is as part of the lecture material for a semester long course on radiation effects in electronic materials taught by the University of Kansas. It covers some of the topics contained within the full course. The material will also be hosted on a University of Texas at Austin password protected website where it can be accessed by students within the Nuclear and Radiation Engineering program or students from other academic disciplines.

5. Conclusions

A modular course of on-line short video lectures and video labs was made at the University of Texas at Austin to teach University students about the basics of radiation effects in electronic materials. The short on-line modular lecture is seen as an effective format for teaching subject matter which is outside the normal core course material in a typical nuclear engineering or science program. This is, in part, because such short courses provide the student with a moderate amount of information without demanding a large time commitment, and, in part, because they are non-traditional classroom based courses, they don't compete with the main course offerings or professor time. Furthermore the on-line format allows them to be distributed to other educational institutions or offered to the general public if desired.
6. Acknowledgements

We are grateful to the US Nuclear Regulatory Commission for funding this project entitled “Characterizing Neutron Radiation Damage in Microelectronics Materials” through a subcontract from University of Kansas. We are also indebted to Juan Diaz at the Faculty Innovative Center in the Cockrell School of Engineering in videotaping the lecture and laboratory portions.
DEVELOPMENT OF NUCLEAR POWER TECHNOLOGY PROGRAMMES IN SOUTHEAST TEXAS (USA) THROUGH USE OF A COMMUNITY-BASED EDUCATIONAL COALITION TO ACHIEVE COOPERATION BETWEEN STAKEHOLDERS

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ABSTRACT

Nuclear power technology programmes were developed at several community colleges in southeast Texas in 2007 to meet the manpower needs of the nuclear power industry in the area and elsewhere in the USA. The programmes now offer Associate and Baccalaureate of Applied Science degrees that are based on the Uniform Curriculum Guide for Nuclear Power Plant Technician, Maintenance, and Nonlicensed Operations Personnel Associate Degree Programs of the Institute of Nuclear Power Operations (USA). This report examines the process of establishing and expanding nuclear power technology programmes at community colleges through the development of an educational coalition to achieve community-wide consensus concerning the training programmes and to establish crucial linkages between educational, industry, civic, and economic development partners. It also examines the collaborative efforts of the coalition partners to secure financial support for the programmes, the strategies for recruitment of young men and women into the programmes, the achievement of racial and ethnic diversity in enrollments, and the use of state-of-the-art nuclear instructional equipment and computer-based simulators for ‘hands-on’ training of the students.

1. Introduction

In March 2007 the U.S. Department of Labour (DOL) published Identifying and Addressing Workforce Challenges in America’s Energy Industry [1], which discussed the energy industry’s needs for new workers, who would be recruited and trained with new skill sets in the coming 10 years. It also noted that the average energy industry worker in the USA was over 50 years of age and that approximately 50% of them were planning to retire within five to ten years. That meant that there would be a need to replace approximately 500,000 energy employees nationwide. In addition to the DOL assessment, two other workforce survey reports pointed out the same concerns. These survey reports included Gaps in the Energy Workforce Pipeline [2] by the Centre for Energy Workforce Development (CEWD) and 2007 Workforce Pipeline Survey [3] by the Nuclear Energy Institute (NEI).

The NEI workforce report noted that Texas would need three new nuclear power plant maintenance training programmes and at least one new non-licensed operator training programme. At the time of the NEI study, Texas had only five generic nuclear training programmes and one radiation protection programme. Based solely on estimates of retirements and normal attrition, NEI recommended that two of the existing generic programmes be restructured to comply with the Institute of Nuclear Power Operations’ Uniform Curriculum Guide for Nuclear Power Plant Technician, Maintenance, and Nonlicensed Operations Personnel Associate Degree Programmes (ACAD 08-006) [4] for maintenance staff and that another programme to be restructured for operators.
To meet current and scheduled employment needs of its nuclear plants (i.e., South Texas Project Nuclear Operating Company and Comanche Peak Nuclear Power Plant), the State of Texas faced the daunting task of educating new workers while upgrading incumbent worker skills to fill attrition and new vacancies. It was determined that workforce and education systems had to improve existing training programmes and develop new programmes, competency models, and career ladders.

In response to the specific needs of the nuclear power industry in southeast Texas, representatives of industry and economic development boards formed the Midcoast Industry and Education Alliance in 2006 to explore ways to promote nuclear technology programmes in southeast Texas. From this alliance evolved the Texas Nuclear Power Technician Programme Partnership that was formed in 2007-2008. This partnership was a coalition of stakeholders, including community colleges, industry partners, universities, professional organizations, community-based organisations and civic groups, school districts, chambers of commerce, and economic development agencies. The purpose of the coalition was to address two critical issues, namely: (1) the lack of adequate nuclear power technology training facilities, faculty, equipment, and curricula aligned with industry standards that were needed to educate and train workers to meet industry needs; and (2) the need for community colleges in southeast Texas to develop uniform accredited nuclear power technology curricula and to expand industry-specific certificate, associate, and baccalaureate degree programmes.

To fulfill industry needs, the partnering colleges required well-trained faculty to develop and teach curricula aligned with industry standards and in compliance with the Uniform Curriculum Guide (ACAD 08-006) of the Institute of Nuclear Power Operations (INPO). The community colleges realised that they would need to upgrade equipment to provide adequate classroom and laboratory training that would be compatible with industry standards and with the Uniform Curriculum Guide. The colleges also realised they would need to develop comprehensive recruitment and retention strategies to attract and retain students in the newly developed and expanded nuclear power technology programmes.

2. Literature Review

The theoretical basis for this report included organisational behavior studies of the institutionalisation of organisations [5,6,7,8], organisational change [9], organisational development [10,11], and organisational alignment with the environment [12]. It also included examination of the effort to establish nuclear training programmes at community colleges as an example of a community-based “coalition” in action. Community participation in health, safety, community development, and educational planning, especially through community-based coalitions, is noted in numerous theoretical perspectives found in the literature of organisational behavior.

Community participation in health, safety, and community development planning (including planning for education programmes) occurs through a variety of community-based advisory groups, but especially through community-based coalitions. These ‘coalitions’ can be loosely defined as a group of individuals representing diverse stakeholders (i.e., organisations, factions, or constituencies) within a community who agree to work together to achieve a common goal (adapted from Feighery and Rogers) [13].

Community participation in health, safety, social, and educational projects can take a variety of forms, and there can be variations in the extent of community participation. It has been found that community-based coalitions as organisations have many of the characteristics of ‘minimalist organisations’ as defined by Halliday, Powell, and Granfors [14,15] and can demonstrate progression through the stages of development noted by Aiken et al. [16]. Studies of community participation through the use of community-based coalitions have demonstrated repeatedly that these organisations have been successful in addressing a variety of health and social issues, including educational needs in communities. Coalitions as organisations are highly flexible and can engender strong support locally from the communities participating in this type of planning process.

Butterfoss [17] noted that the concepts and assumptions underlying community development, citizen participation, empowerment, community capacity, community
competence, and social capital provided the groundwork for the coalition as a community-organising model and as a strategy for resolving community issues and achieving community goals [17: p.12]. It also noted that community coalitions have ‘the potential to involve multiple sectors of the community and to conduct multiple interventions that focus on both individuals and their environments’ [17: p.16] and that community coalitions are ‘a promising strategy for building capacity and competence among member organisations and, ultimately, in the communities they serve’ [17: p.17]. This is true of coalitions focusing on health issues as well as coalitions focusing on educational and job-skills training issues.

In an examination of the principles of collaborating and partnering in community health contexts, Butterfoss [17] developed definitions of collaboration, identified the intensity of collaboration, provided models of collaboration, and provided an explanation of the types of coalitions. The various types of coalitions [17: p.32-34] included the following:

- **Grassroots coalitions**: Organised by volunteers to pressure policy makers to act on an issue.
- **Professional (agency-based) coalitions**: Formed by professional organisations in times of crisis or as a long-term approach to increase their power and influence.
- **Community-based coalitions of professional and grassroots members**: Formed to influence more long-term health and welfare practices for their community. This type could also be used to exert long-term influence regarding a particular issue or issues of importance to a community or region.
- **Organisation-set coalitions**: Groups of cooperative organisations that provide resources or services under an umbrella organisation.
- **Network coalitions**: Subgroups of organisations loosely organised within an organisational system that provides services to a particular population or lobbies for a specific cause.
- **Action-set coalitions**: Issue-specific and can be more or less formal, depending on the purpose of the coalition.

The Texas nuclear power technology partnership has characteristics of several types of coalitions, including those pertaining to community-based coalitions of professional and grassroots members and action-set coalitions. The IAEA found that this type of integration and partnership is very conducive to the development of sustainable nuclear technology training programmes [18].

3. Methodology

This qualitative study of the establishment and development of the nuclear power technology programmes at community colleges in southeast Texas (namely, Wharton County Junior College and Brazosport College) utilised a variety of observational research methods, including attending and participating in planning meetings; attending and participating in specific subcommittee meetings; interviewing members of the coalition; interviewing key participants (including representatives of educational institutions, nuclear utilities, local economic development boards, civic organisations, and interested citizens); assisting with drafting applications for financial support from local, state, and federal sources; and examining documents related to the operation of the programmes since their inception in 2007-2008. It also included attendance at conferences sponsored by the Nuclear Energy Institute (NEI) and the Centre for Energy Workforce Development (CEWD).

4. Nuclear Power Technology Coalition Members

The following colleges, utilities, universities, economic development boards, state and federal agencies, school districts, and groups were important stakeholders in fostering and gaining community-wide consensus concerning establishment of nuclear power technology programmes at community colleges in southeast Texas. The Nuclear Energy Institute and the Nuclear Power Institute provided additional support for the effort to establish nuclear power technology programs and to align them with the Nuclear Uniform Curriculum (ACAD 08-006) of the Institute of Nuclear Power Operations.
Table 1. Stakeholders and Types of Organisation

<table>
<thead>
<tr>
<th>Name of Organisation</th>
<th>Type of Organisation</th>
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<tbody>
<tr>
<td>Brazosport College, Lake Jackson, Texas</td>
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<tr>
<td>Wharton County Junior College, Wharton, Texas</td>
<td>Community College Partner</td>
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<tr>
<td>Victoria College, Victoria, Texas</td>
<td>Community College Partner</td>
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5. Implementation of the Nuclear Power Technology Plan for Southeast Texas

The four colleges in the Texas nuclear technology training partnership included Wharton County Junior College, Brazosport College, Victoria College, and Texas State Technical College. These colleges jointly explored ways to obtain funding to develop and operate new or expanded nuclear power technology programmes. They sought funding to hire faculty, purchase state-of-the-art nuclear technology instructional equipment and simulation software programmes, and develop curricula that would comply with the Uniform Curriculum Guide (ACAD 08-006). Approvals for the colleges to develop new training programmes and expand current ones were quickly obtained from the Texas Higher Education Coordinating Board, which oversees academic and vocational training programmes in Texas.

Texas Agricultural and Mechanical University (i.e., Texas A&M University) provided significant assistance and guidance to the colleges as did the South Texas Project Nuclear Operating Company (an industry partner). Initially, the Texas Engineering Experiment Station at Texas A&M University provided ‘start-up funding’ as well as guidance in obtaining
federal funding. The Nuclear Power Institute (NPI) at Texas A&M played a major role in providing guidance to the Wharton programme and in advocating for it at national and international meetings. The NPI made extraordinary efforts to highlight the achievements and quality of the nuclear power programme at Wharton County Junior College (WCJC) and arranged for Mr. Rudolph Henry, Director of Nuclear Power Technology Programme at WCJC, to participate in the September 2012 General Conference of the International Atomic Energy Agency. While at the conference, Mr. Henry met the leadership of IAEA and representatives of several national delegations, many of whom wanted to know more about the Wharton programme. The NPI also arranged for Mr. Henry to present a report in December 2012 concerning nuclear power technology programmes to members of the U.S. Congress, congressional staff members, the Deputy Secretary of Energy, and the Assistant Secretary for Nuclear Energy in Washington, DC. Discussions were also initiated in 2012 concerning admission of students from overseas into the Wharton programme and development of internships at the South Texas Project Nuclear Operating Company for these students. [Personal communication with Dr. Kenneth Peddicord, Fall 2012.]

6. Support from Industry Partners

The South Texas Project Nuclear Operating Company (STPNOC), as the industry partner, played a major role in the effort to establish nuclear power technology programmes at community colleges in southeast Texas. It facilitated meetings of the Midcoast Industry and Education Alliance, which led to the formation of the educational coalition in support of nuclear training programmes. To assist the college programmes, STPNOC provided timely letters of support, in-kind support, and an educational incentive programme for entry-level employment at STPNOC. The incentive programme is an effort to award grants, through a competitive process, to students enrolled in the nuclear technology programmes. Students selected for the award receive additional trainings at the STP facility during internships.

A second important industry partner in promoting and facilitating the establishment of nuclear power technology programmes at community colleges in southeast Texas was the Nuclear Energy Institute (an industry association), headquartered in Washington, DC. Both the Wharton and the Brazosport programmes were developed in strict compliance with the Uniform Curriculum Guide (ACAD 08-006), which requires adherence to a standardised curriculum for training nuclear technicians.

7. Funding for Nuclear Power Technology Programmes in Southeast Texas

Since 2008, the Wharton and Brazosport nuclear power technology programmes have been the recipients of grants from federal, state, university, and economic development agencies. These grants focused on upgrades to laboratory equipment and development of curricula and included major grants from the Bay City Community Development Corporation, Texas A&M University, Nuclear Power Institute, Texas Workforce Commission, American Recovery and Reinvestment Act (ARRA) Programme, U.S. Nuclear Regulatory Commission, and U.S. Department of Education.

Additionally, since 2009, the U.S. Nuclear Regulatory Commission has provided more than $1,000,000 in scholarship funds for students specialising in nuclear power studies at the Wharton and Brazosport programmes.

The award from the U.S. Department of Labour (2009-2012) was shared by the four colleges that originally participated in the Texas nuclear power training coalition. However, Victoria College withdrew from the partnership in 2011 after plans for constructing a nuclear power generating facility in its service area were cancelled. The training programme at Texas State Technical College has remained small and focused primarily on radiation protection. It has not participated in the ongoing expansion of the region’s nuclear power technology programmes during the last five years.

The following table provides information on the funding that was obtained by the two leading colleges in the Texas partnership that have the largest number of trainees. These funds were used for facilities, operations, curriculum development, instructional equipment, and scholarships for students.
<table>
<thead>
<tr>
<th>Period</th>
<th>Funding Source</th>
<th>Amount</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>Bay City Community Development Corporation</td>
<td>$4,500,000</td>
<td>Purchase &amp; renovation of a large facility to house the nuclear &amp; other programmes</td>
</tr>
<tr>
<td>2007-08</td>
<td>Residents of Bay City, Texas</td>
<td>$1,500,000</td>
<td>Instructional equipment for nuclear &amp; process technology programmes</td>
</tr>
<tr>
<td>2008-10</td>
<td>Texas A&amp;M University, Texas Engineering Experiment Station, Texas Workforce Commission</td>
<td>$105,000 (WC)</td>
<td>Implementation &amp; operations of the nuclear power technology programme</td>
</tr>
<tr>
<td>2009-12</td>
<td>U.S. Department of Labour</td>
<td>$1,888,487 (for 4 colleges)</td>
<td>Nuclear instructional equipment &amp; operations</td>
</tr>
<tr>
<td>2009-11</td>
<td>Texas A&amp;M University, Nuclear Power Institute, &amp; Texas Engineering Experiment Station</td>
<td>$175,000 (WC)</td>
<td>Operations &amp; expansion of the WCJC nuclear power technology programme</td>
</tr>
<tr>
<td>2009-10</td>
<td>U.S. Nuclear Regulatory Commission</td>
<td>$150,000 (WC)</td>
<td>Scholarships for nuclear technology students</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$120,000 (BC)</td>
<td></td>
</tr>
<tr>
<td>2009-10</td>
<td>Jobs &amp; Education for Texans (JET) Office of the State of Texas</td>
<td>$350,000 (WC)</td>
<td>Instructional equipment for nuclear &amp; process technology programmes</td>
</tr>
<tr>
<td>2009-10</td>
<td>Bay City Community Development Corporation</td>
<td>$193,500 (WC)</td>
<td>Instructional equipment for nuclear &amp; process technology programmes</td>
</tr>
<tr>
<td>2010-11</td>
<td>U.S. Nuclear Regulatory Commission</td>
<td>$120,000 (WC)</td>
<td>Scholarships for nuclear technology students</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$120,000 (BC)</td>
<td></td>
</tr>
<tr>
<td>2010-11</td>
<td>U.S. Dept. of Education</td>
<td>$220,000 (WC)</td>
<td>Instructional equipment</td>
</tr>
<tr>
<td>2012-13</td>
<td>U.S. Nuclear Regulatory Commission</td>
<td>$120,000 (WC)</td>
<td>Scholarships for nuclear technology students</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$120,000 (BC)</td>
<td></td>
</tr>
<tr>
<td>2012-13</td>
<td>U.S. Nuclear Regulatory Commission</td>
<td>$199,280 (WC)</td>
<td>Nuclear technology curriculum development</td>
</tr>
<tr>
<td>2013-15</td>
<td>U.S. Nuclear Regulatory Commission</td>
<td>$150,000 (WC)</td>
<td>Scholarships for nuclear technology students</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$120,000 (BC)</td>
<td></td>
</tr>
<tr>
<td>2013-15</td>
<td>U.S. Nuclear Regulatory Commission</td>
<td>$156,500 (WC)</td>
<td>Nuclear technology curriculum development</td>
</tr>
</tbody>
</table>

Abbreviations: WC = Wharton County Junior College; BC = Brazosport College.

The benefits of the original U.S. Department of Labour (DOL) grant to the Texas nuclear power technology educational partnership were significant, including:

- **Instructor Training**: The DOL grant provided funding for faculty members to receive an average of 120 hours of training at the South Texas Project Nuclear Operating Company (the industry partner), under the supervision of subject matter experts.

- **Curriculum Development**: The DOL grant provided for the faculty of the participating colleges to work with South Texas Project administrators to develop and modify curricula to conform to the *Uniform Curriculum Guide* (ACAD 08-006) of the Institute of Nuclear Power Operations. Additional funding for curriculum development was provided by the Nuclear Power Institute, the U.S. Nuclear Regulatory Commission, and the U.S. Department of Education.

- **Laboratory Development**: The DOL grant provided support for significant upgrades of laboratory facilities used in conjunction with the curricula for the nuclear power technology programmes. These included funding for nuclear instructional equipment, workstations, computer-based simulators, and ‘hands-on' training skids (i.e., ‘HOT
skids’), which ensure that students are being trained to use and operate the same state-of-the-art technology as currently found in the power generation industry.

8. Wharton and Brazosport Nuclear Power Technology Programmes

At the conclusion of the Department of Labour project, the Wharton and Brazosport programmes continued their partnership. Both colleges are public, two-year community colleges that are fully accredited by the Commission on Colleges of the Southern Association of Colleges and Schools. The colleges are authorised by the Texas Higher Education Coordinating Board to offer Associate of Arts and Associate of Applied Science degrees and curricula in preparation for baccalaureate programmes. Brazosport is authorised to award a baccalaureate degree. The Wharton and Brazosport service areas extend across eight counties in southeast Texas. The South Texas Project Nuclear Operating Company is located within the region served by the two colleges.

**Wharton Nuclear Power Technology Programme.** The training programme at Wharton County Junior College gained international recognition in 2011, when the International Atomic Energy Agency (IAEA) noted in its *Status and Trends in Nuclear Education* [18] that the Wharton programme was a ‘best practice’ programme among two-year nuclear power technology training programmes. The Wharton programme offers an Associate of Applied Science degree in Nuclear Power Technology. Upon completion of the two-year AAS degree, students have the prerequisite skills and training to work in the nuclear power generation industry in southeast Texas and elsewhere in the USA.

The Wharton programme offers three degree specialisation options, namely, (1) Non-Licensed Operator, (2) Electrical Technician, and (3) Instrumentation and Controls Technician. It also offers an Enhanced Skills Certificate in Nuclear Power Technology upon completion of the Associate of Applied Science degree in Process Technology and completion of required nuclear technology courses.

**Table 3. Course Requirements for All Specialisations (during 1st Year)**

<table>
<thead>
<tr>
<th>Fall Semester (all students)</th>
<th>Spring Semester (all students)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Course</strong></td>
<td><strong>Course</strong></td>
</tr>
<tr>
<td>NUCP 1371</td>
<td>NUCP 1370</td>
</tr>
<tr>
<td>ELPT 1370</td>
<td>NUCP 1471</td>
</tr>
<tr>
<td>or PTAC 1302</td>
<td>PTAC 1432</td>
</tr>
<tr>
<td>BCIS 1305</td>
<td>CHEM 1405</td>
</tr>
<tr>
<td>MATH 1314</td>
<td>CHEM 1411</td>
</tr>
<tr>
<td>or MATH 2312 Pre-Calculus</td>
<td>NUCP 1472</td>
</tr>
<tr>
<td>or ENGL 1301 Composition &amp; Rhetoric I</td>
<td>Organisation &amp; Processes</td>
</tr>
</tbody>
</table>

- **Nuclear Option 1. Non-Licensed Operator (during 2nd Year):** DC-AC Circuits with Lab; Nuclear Power Plant Systems I and II; Principles of Quality; Digital Measurements & Controls; Social Science Elective; Humanities Elective; Critical Thinking & Problem Solving; Discipline-related Elective; Public Speaking; and Cooperative Education (Internships in Nuclear Power).

- **Nuclear Option 2. Electrical Technician (during 2nd Year):** AC/DC Circuits; AC/DC Motor Controls; Digital Measurements and Controls; Electromechanical Systems; Principles of Quality; Electronic Troubleshooting, Service, & Repair; Social Science Elective; Humanities Elective; Public Speaking; Critical Thinking & Problem Solving; and Cooperative Education.
Table 4. Nuclear Power Specialty with Enhanced Skills Certification

<table>
<thead>
<tr>
<th>Course</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELPT 1370</td>
<td>Introduction to Power Generation Technology</td>
</tr>
<tr>
<td>NUCP 1370</td>
<td>Nuclear Fundamentals I</td>
</tr>
<tr>
<td>NUCP 1371</td>
<td>Mathematics &amp; Chemistry Fundamentals for Nuclear Power</td>
</tr>
<tr>
<td>NUCP 1471</td>
<td>Nuclear Fundamentals II</td>
</tr>
<tr>
<td>NUCP 1472</td>
<td>Nuclear Power Plant Organisation and Processes</td>
</tr>
<tr>
<td>NUCP 2470</td>
<td>Nuclear Power Plant Systems I</td>
</tr>
<tr>
<td>NUCP 2471</td>
<td>Nuclear Power Plant Systems II</td>
</tr>
</tbody>
</table>

Brazosport College also offers a Bachelor of Applied Technology degree that is
designed to broaden career opportunities and better prepare nuclear power trainees
for promotion to supervisory positions. The upper division classes expand students’
understanding of business operations (including management, human resources,
accounting, legal issues, and technology). Coursework incorporates internships and other
practical real-world learning activities to ensure that students acquire technical competencies
and managerial skills in order to be effective supervisors.

Additional Information about the Programmes. The Cooperative Education
courses (i.e., NUCP 1380 and NUCP 1680) provide options for internships at nuclear power
facilities. A student can select NUCP 1380 for a 16-week internship at a nuclear power
facility during a regular semester. After the AAS degree requirements have been completed,
a student can select NUCP 1680 for a 7-month internship at a nuclear facility.

Students participating in the Wharton and Brazosport training programmes may be
eligible to receive a National Academy for Nuclear Training Certificate (NANT Certificate)
upon graduation. This certificate is administered jointly by the Institute of Nuclear Power
Operations (INPO) and the National Academy of Nuclear Training (NANT) in collaboration
with each college and its nuclear industry partner. To be eligible for this certificate, students
must obtain a minimum passing grade of 80% in all required courses.

9. State-of-the-Art Instructional Equipment

The courses offered at the Wharton and Brazosport programmes are aligned with the
Uniform Curriculum Guide (ACAD 08-006) for training nuclear technicians, including
operations, electrical, and instrumentation/control technicians. Experiential learning
exercises are designed to be almost identical to actual on-the-job industry training, job
shadowing, and industry discipline. In addition to course work in nuclear power technology
fundamentals, the programmes include ‘hands-on’ laboratory exercises as reinforcement for
classroom lectures. This experiential learning component includes training on state-of-the-art
instructional equipment such as the following:

- ABB Digital Fieldbus Technology Demo Box
- Hampden Boiler/Turbine Generator Power Distribution Skid
Intellitek Electrical Training Modules
Computer-based simulators for operating Pressurised Water Reactors (PWRs) and Advanced Boiling Water Reactors (ABWRs)

The computer-based simulation exercises reinforce lecture material and facilitate experiential learning for the students by providing opportunities for ‘hands-on’ use of actual state-of-the-art nuclear power generation equipment. Training modules have been developed that integrate computer-based nuclear power plant simulation applications into the training programmes. The computer-based nuclear power plant simulations provide an opportunity for faculty to train students to become familiar with plant startup and shutdown, plant operations, and analysis of common problems at nuclear power plants. The curriculum developed for operating PWRs and ABWRs at nuclear power plants has been made available through the Nuclear Energy Institute for distribution to other educational institutions offering training programmes in nuclear power technology.

10. Programme Results

The Wharton and Brazosport training programmes have been successful in recruiting and training students, who will become the next generation of highly skilled workers in the nuclear power generation industry in southeast Texas and elsewhere in the USA. The following table shows the accomplishments of these training programmes.

| Table 5. Wharton and Brazosport Nuclear Programmes – Combined Results |
|-----------------------------|-------------------|----------------|-------------|---------|---------|---------|
| Enrollments                 |          |          |          |          |          |          |
| Total Students              | 13       | 72       | 140      | 116      | 109      | 87       |
| Gender                      |          |          |          |          |          |          |
| Male                        | 11       | 58       | 117      | 93       | 90       | 70       |
| Female                      | 2        | 14       | 23       | 23       | 19       | 17       |
| Race/Ethnicity              |          |          |          |          |          |          |
| White non-Hispanic          | 10       | 46       | 92       | 75       | 68       | 57       |
| Hispanic or Latino          | 3        | 19       | 29       | 32       | 31       | 22       |
| Black non-Hispanic          | --       | 1        | 5        | 8        | 8        | 8        |
| Other/No Response           | --       | 6        | 14       | 1        | 2        | 0        |
| Graduates of the Nuclear Technology Programmes |
| Associate Degree            | --       | 5        | 43       | 22       | 33       | 33       |
| Certificate                 | --       | 4        | 12       | 6        | 6        | 1        |
| Status Post-graduation      |          |          |          |          |          |          |
| In Nuclear                  | --       | 5        | 32       | 10       | 9        | 4        |
| In Non-Nuclear              | --       | --       | 2        | 13       | 30       | 24       |
| In Other Studies            | --       | --       | 7        | 2        | 3        | 3        |
| Unknown                     | --       | 4        | 14       | 3        | 3        | 3        |

Diversity in enrollments and graduations is an important goal for the Wharton and Brazosport programmes and both colleges have made efforts to foster gender, racial, and ethnic diversity in their programmes. Beginning in 2009-10, diversity in enrollments was achieved, with approximately 35% of enrollments being students from the racial and ethnic minority communities in the region.

For the 2013 Fall semester a total of 64 students enrolled in the Wharton and Brazosport programmes. This drop in enrollments can possibly be linked to a significant decline in actual job openings at nuclear power facilities in the USA. The nuclear power industry in the USA has an aging workforce and the original industry projections in 2007-08 showed there would be hundreds of retirements of senior technicians. However, the industry’s original projected retirements have not yet started to occur. During the past three years, students began to realise there might not be jobs for them when they completed a nuclear power technology training programme. They became hesitant to enroll and opted, instead, to enroll in other training programmes. As the projected retirements begin to occur
at some point in the future, enrollments in the Wharton and Brazosport nuclear power technology programmes are expected to increase.

References

THE UTILIZATION OF REACTOR LR-0 FOR TRAINING PURPOSES
J. MILCAK, R. REZAC, V. JURICEK
Reactor operation, Research Centre Rez
Hlavni 130, 250 68 Husinec-Rez, Czech Republic

ABSTRACT
The LR-0 research reactor is a light-water, zero-power, pool-type reactor. It serves as an experimental reactor for measuring neutron-physical characteristics of VVER (Water-Water Energetic Reactor) type reactors. As a research reactor it has unique characteristics that can be used for education and training and offers excellent opportunity to teach practical lessons. Based on this fact the Research Centre Rez (CVR) began with enhancement of the training activities. The LR-0 reactor has a large experience with training of the nuclear experts, has a regulator-approved program for training the reactor operators, and now provides opportunity for universities to teach their students via trainings, customized and delivered by their teachers together with the research institute experienced staff. The courses are typically built on the framework of existing curricula covering basics of reactor physics. All courses consist of theoretical and practical part, complementing each other during the whole course. A typical general course is one week long. The courses are divided to three categories. It is served basic, special and on-demand courses. The all training programs are led according to the approved methodology. Also courses for nuclear and non-nuclear professional are being prepared.

1. Introduction
Owners and operators of many research reactors are finding that their facilities are not being utilized as fully as they might wish. Every research reactor facility is capable of being used for education and training purposes. When reviewing the potential uses of existing reactors, then this application should not be dismissed lightly as being a trivial or unworthy mission. Conversely, it should be thoroughly explored and utilized to the benefit of the facility [1].

2. History of training activities
Research Centre Rez has a regulatory-approved program for training of the reactor operators and other reactor staff. All the training is according to the quality assurance conducted by schemes and syllabus with defined records [2]. To secure high standard during the training the most skilled and experienced persons are involved.
As a nuclear facility the reactor is often visited by students from technical universities and other type of schools for technical visits and short term lectures and demonstrations. This collaboration is not treated as commercial activity but as a part of open access to research infrastructure. Part of the open access is also to provide open days and excursions for general public.
Certainly CVR provided several courses for external participants in the past as well, however these were not done regularly and had no central coordination. The management brought a idea to build a training centre as one department of the research institute to assure high quality training and education. At first the focus was aimed at LR-0 reactor for better utilization of this facility.

3. Foundation of the training centre
At begging of 2013 CVR started to build the training centre with own staff responsible only for training and education. The staff is mainly responsible for a new courses development, courses coordination, communication with customers and business strategy preparation. The members of the training centre cooperate with experts across the research institute and external experts regarding to develop the courses content. Due to the previous experience with the staff education, the technical qualification of the lectors has high level. To assure not only quality of the courses content but also a pedagogical high level of teaching and presentations CVR started to cooperate with Czech universities and training centres to provide regular educational soft skills seminars for our internal lecturers.
Strategy and plans of the activities, which are necessary to be done, have been prepared at the beginning of the establishment of the training centre. Other steps went to the concept of providing courses. Three kinds of courses as basic, advanced and tailor-made have been defined to cover whole spectra of potential topics and training methods for candidates. As it was mentioned above training centre was established mainly to support LR-0 nuclear reactor and to secure better occupancy. However there are plans to enhance it beyond reactor courses to offer other trainings coming from various fields which are supported by CVR.

Main milestone during the centre preparations was the creation of a main text book which will provide the basic coverage of topics and experiments [3] and web site for better provision of information [4]. The textbook has been prepared in the form for self study of reactor physics mainly focusing on LR-0 experiments and as a study material for theoretical teaching containing also the experiment descriptions and methodology.

The first course which was carried out was „Basic Reactor Physics“ course. This course consists of theoretical and practical parts. The trainees repeated the necessary theoretical background, but the program is mainly focused on reactor physics experiments. Farther CVR started to define topics of advanced courses and explore environment to find topics of tailor-made courses.

4. Current status of the training centre
Currently CVR provides three different kinds of courses. The first one contains basic summary of the nuclear reactor physics and experiments. The trainees are acquainted with topics like nuclear reactions, principals of fission reactions, characteristic of the ionizing radiation, construction of nuclear reactors or introduction to nuclear safety and basic demonstrations and experiments are demonstrated to them.

Typical time and topic schedule of the basic course is listed in the next table:

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Radioactivity, ionizing radiation (IR), IR types and characteristics, shielding Detector properties, dead time, gamma and neutron detection</td>
<td>▪ Neutron instrumentation modules and detectors, counting and current mode, measurement with a neutron source:</td>
<td>▪ Nuclear safety: basic principles and standards, operational reactor safety, instrumentation and control system Safe achieving of initial critical state, basic critical experiment</td>
<td>▪ Overview of experimental program on LR-0 reactor: measurement of criticality dimensions, power distribution, absolute power Gamma and neutron spectrometry</td>
</tr>
</tbody>
</table>
Advanced courses are treated as second group. These courses go to the more details and prepared for more experienced user with higher level of education and knowledge. There are running various courses in this group. Here are topics with short description:

- **The Pin Power Distribution Measurement on the LR-0 Research Reactor**
  Trainees will get acquainted with various aspects of the determination of neutron fluence and power distribution in the LR-0 reactor core by means of the fission products activity measurement in irradiated fuel pins. They will master the theoretical and practical principles of semiconductor gamma-ray spectrometry and its application for fuel pins measurement on a prototypic gamma-scanning device. They will participate in relevant parts of reactor experiment and they will analyze the measured results.

- **The Neutron Fluence Determination in LR-0 Reactor by Activation Detectors**
  Trainees will get acquainted with various aspects of the determination of neutron fluence distribution in the LR-0 reactor core by means of the activity measurement of radionuclides induced by neutrons in activation detectors. They will master the theoretical and practical principles of semiconductor gamma-ray spectrometry and its use for the activation foils measurement. They will participate in relevant parts of reactor experiment and they will analyze the measured results.

- **Semiconductor Gamma-Ray Spectrometry and Its Experimental Reactor Physics Application**
  Trainees will get acquainted with principles of semiconductor gamma-ray spectrometry with a view to HPGe detectors. They will learn about detectors fabrication and their qualities, about interaction of gamma-ray with the semiconductor, about electronics for processing the signal from detector and about programs for gamma spectra analysis. They will apply the acquired knowledge on the gamma-spectrometric device at the LR-0 in practical problems of reactor physics.

- **Environmental Radioactivity**
  Participants learn how different radioactive substances in the environment behave and how to measure their radioactivity. They will get the answers to these questions in our course of radioactivity in the environment. The participants also learn what is the impact of the nuclear industry on the environment, what are the biological effects of ionizing radiation and radiation protection principles. In practical exercises you can try measuring the selected environmental samples at a gamma-spectrometric apparatus with semiconductor detector.

- **Experimental Verification of Nuclear Safety During NPP Temelín Commissioning**
  The participants learn basic experiments implemented during the physical start-up of the Temelín NPP (first criticality, efficiency of clusters, temperature coefficient of reactivity, effect of boron, core symmetry verification, and measurement of boron injection system lag.). Experiments of ascension power start-up, focusing on nuclear safety – physical characteristics such as temperature and power coefficient of reactivity, effects of xenon and xenon oscillation, calibration of neutron instrumentation and thermal power distribution, neutron characteristics of the core, test the core cooling system base function, the residual heat removal by natural circulation.

- **Heavy Liquid Metals Technology**
  The course aims to get the trainee familiar with issues related to materials for Gen IV reactors, in particular HLM cooled reactors. All the issues related to the basic interaction of construction materials with liquid PbBi and Pb will be considered in terms of corrosion and mechanical properties. Moreover, as a way to better understand these phenomena, focus will be placed on the chemistry of the liquid metals, in terms of impurities control and oxygen
dosing and measurement. The attendants will have the opportunity to follow the experimental procedures for testing of materials in the CVR facilities and will work on data recording and interpretation.

Tailor made courses belong to the third group. This kind of courses is made to exactly satisfy customer needs. For example it offers the courses for nuclear reactor operators, the course of nuclear power plant start-up and operation, behaviour of the nuclear fuel in the reactors, reactor dosimeter, decommissioning etc. CVR had a special requirement for a one month intensive training from French IRUP institution with request to cover concrete topics in the program. After the collaboration a very unique offer was prepared.

Trainings focus is mainly on the following target groups:
- Student of nuclear physics
- Student of non nuclear physics using results of reactor physics
- Researches of nuclear fields
- Researches of non nuclear fields
- Other employees of nuclear organizations
- The general public and enthusiasts

5. The infrastructure
The reactor LR-0 is one of the experimental nuclear reactors which are operated in CVR. It is a very unique facility for reactor physic research but also suitable for special training and education. The basic scheme is shown in Fig 1.
The reactor LR-0 is the experimental light water reactor of zero power. It is dedicated mainly for training and research of active zones, reactor lattices and typical experiments for VVER-1000 and VVER-440 type reactor. Reactor LR-0 is constructed as widely configurable and flexible. There is removable fuel assemblies type VVER-1000/440 with optional enrichment from 1.6 to 4.4% 235U. The reactivity changes are provided by the change of the level of the moderator or by cluster movement.

There are available neutron spectrometry detectors and a gamma scan apparatus with possible axial movement to measure gamma activities of the fission which is used for the study of power distribution in fuel pins. The neutron and gamma radiation is also studied as a part mock-up and benchmark experiments connected with radiation transport and core behaviour.

The training staff consists of both young scientists and professionals with over forty years of experience in the field of reactor physics. Experts like Mr. Čeněk Svoboda, who was head of the expert team during start-up of Temelin NPP, or Mr. Vojtěch Rypar, who worked as a chief of experimental reactor physics department, are the main lecturers in the training centre. Both of them have practice in the nuclear field for nearly fifty years.

During this year CVR provided many courses. Among them CVR organized two summer schools. The first one was addressed mainly for Czech students. The second one was prepared for foreigners. The research institute was visited by researches and students from around the world - participants from South Korea, Saudi Arabia, Italy and Poland participated on this event.

During the course full services like the accommodation and full board can be provided by local hotel. On every educational and training course a special social events is organized because, according to last research of psychology, education supported by emotional experience brings better memorizing of the lectures. Furthermore education is interactive as much as possible.

To increase the possible connections and expansion of the training centre, CVR has become member of two international educational programs and projects like CORONA [5]. This project is oriented to provide educational and training program for VVER type reactor specialists, operators and other personnel. The main partners are FOTUM from Finland, Tecnatom from Spain and Bulgarian power plant in Kozloduy. As a part of collaboration CVR has prepared educational materials within this project and organized a one week training course this years for the partners. The second project was started in the middle of 2013. The project groups together four universities from Czech Republic and CVR and is focused onto educational balance between the partners. The main goal is to build a multimedia lab for the distance collaborative learning within this project.

6. Future development
CVR wants to use several channels for the educational program. It means that the new courses for local training, e-learning and distance training will be developed.
In the near future the main effort is to enhance the number of the advance courses. New experiments, where students and researches can perform calculations in local PC lab and directly verify their results by experimental measurements on LR-0 reactor are going to be prepared.
To enable spreading the education simply beyond the boundary of institute, CVR begins to participate in e-learning courses on the platform Moodle to be compatible with platform which is utilized by IAEA.
To enlarge the possible way of education a new multimedia technologies will be applied. The multimedia and PC lab will consist of a interactive whiteboard and a special video conference system for the distance collaborative education which enables to train participants not only by CVR experts but also by teachers from partner’s universities.
or even from abroad. Furthermore 3D stereoscopic visualization for the core design during the training will be prepared. A teaching tool like a simulator of the reactor will be implemented and which will enables trainees to carry out operation which are not allowed for them directly on the reactor.

7. References
[1] IAEA-TECDOC-1234 The applications of research reactors
[2] Process for the preparation of personnel for research nuclear reactor LVR-15 and LR-0, Research Centre Rez, Czech language
[3] Reactor Physics - Basic course, group of authors, Research Centre Rez 2013
A Significant Breakthrough in EDF Licensed Operator Training: ANS3.5 compliant FSS using control room software replica

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ABSTRACT

The real-time, high-fidelity simulation industry, servicing nuclear training organizations throughout the world, is facing a number of challenges due to rapid technological changes. In response CORYS, the unrivalled market leader, has innovated a number of industry firsts to help utilities achieve excellence in training and plant operations.

The paper will present the challenges and solutions posed by the EDF’s project for an ANSI ANS3.5 compliant soft-replica control room interfaced with a Full-Scope Simulator for Licensed Operator Training. These innovative solutions were developed following an EDF Nuclear Energy Production division working group deliberation held in 2010, which focused on the adaptation of high-fidelity simulators to future decennial unit overhauls, the changes in the related Man-Machine Interfaces, and the avoidance of training operators on a simulator which does not fully represent their reference plant.

These simulator requirements, combined with the necessity to provide early training for operators within the framework of the 1300MW series third- decennial overhaul, created the concept of a tactile Digital Control Room (SDCN), a full-scope, faithful to operator movement, customizable and reconfigurable for an easy adaptation of trainees to the reference plant and based on touch screens, faithful to control room operation.

Different objectives are associated with this project, in particular the use of standard, easily obtainable materials in order to keep cost below that of current simulators replica control rooms, thus shortening production times and allowing easy replication. This would also minimize associated complications with the removal of obsolescence issues as well as adapted maintenance and shorter adaptation time. Its ability to be used for operator licensing will be evaluated in Spring 2014.

The paper will explore different project challenges. First, we will describe the critical technology choices required to realistically replicate the number and complexity of control room instruments and their implementation on high-resolution touch-screens with haptic feedback.

Next, we will focus on the human factor engineering approach taken by senior EDF operators, instructors and maintenance engineers in association with AREVA human factor experts and CORYS project team.

This outlook will conclude with an overview of the design choices made to ensure long-term maintenance capabilities and seamless design changes using nonproprietary software solutions, industry recognized standards, and COTS hardware, implemented on modular, open and evolutive architecture.
1. Introduction

Over the past year, the EDF, the world's largest nuclear power utility (58 reactors in operation), together with CORYS and its partner, Euriware, has been designing a 100% replica digital control room, interfaced with a full scope training simulator load, to be used for initial and refreshing operators training. This digital control room, or SDCN (Salle De Commande Numérique) meets the requirements of the ANSI ANS 3.5 standard. It could become the standard for future nuclear training simulators if it meets the objectives of EDF: high-fidelity replica of the control room panels, easy customization and flexibility, lower upfront investment, and maintenance costs.

This technical innovation is a world first and has already been well received, with the EDF planning to install these SDCN in 2014 in five of its 900 and 1300 MW nuclear stations for operator training.

This paper will successively address the six major themes that characterize this project:

- Reasons that led EDF to develop SDCN
- Guiding principles of the project
- Challenges associated with meeting the requirement for an actual fidelity control room will then be detailed as they relate to EDF user-centered design.
- Technical choices made for SDCN maintenance
- Operator assessments for licensing purposes
- Objectives of simulator cost reduction.

Fig 1: 1300 MW nuclear station control room

2. Development of SDCN

Two reasons, based both on experience as well as the future investment needs for the operating nuclear fleet, explain the EDF choice to move towards control room software replica (SDCN) for its fleet of full-scope training simulators.

The large number of personnel retirements and development projects require the continued renewal of highly qualified staff in several EDF core businesses—particularly for operator teams. In fact, due to an unbalanced age pyramid, teams will soon face a significant number of retirements. This impending shift presents a potential safety issue for the EDF and underscores the need for strengthened skills management to ensure the integration of newcomers as well as normal services. This context will lead to significant increases in the number of operators enrolled in initial training course and will likely result in a training simulator deficit at some training centres.

On the other hand, the EDF’s nuclear fleet is regularly subject to change due to continuous improvement in safety, evolving regulatory requirements, and new plant performance improvement objectives. For example, the implementation of the third decennial works at the 900 MW Tricastin nuclear station led to the incorporation of many improvements. It is
assumed that the upcoming third decennial works on the 1300 MW units will result in as many enhancements.

The design standardization on the same site enables multiple training operator teams (six at some sites) on a single full-scope simulator. However, the magnitude and duration of the modification on the same site forced its implementation to last several years. The full scope simulator is interfaced with a hardware replica of the control room and is therefore not easily adaptable. It is updated when half of the units on the site have been upgraded, which means that training is being conducted on an only semi-representative tool. Under these conditions, it becomes increasingly difficult to have a true to life simulator that is timeline compliant to EDF requirements.

Because of this, it became necessary to find a new solution in anticipation of the arrival of large-scale third and fourth decennial upgrades on the EDF 1300 and 900 MW reactors, respectively. These changes will include improved instrumentation & control systems, recorders, man-operated control relay, and adaptations to new plant regulations.

Operators will be faced with significant changes of the control room human-machine interface and therefore, training drills must precede the implementation of the new control room upgrade.

EDF then had two options: modify existing simulators, knowing that the final design of future control rooms will evolve over the project execution, or launch the concept of a digital control room, interfaced with the simulator and its process models.

In the latter case, the control room simulator becomes a series of screens. The change is to modify the images that appear on screens, rather than to replace hardware. The result is faster, less expensive modifications.

3. Guiding Project Principles

To anticipate these changes, EDF established a working group in 2010 led by plant operations training experts, to rewrite its simulator guidelines. This led to four main principles that would shape the project’s direction:

- Easily customizable and reconfigurable simulators, to represent different reference unit designs operated daily: 900 MW first and second generation, 1300 MW first and second generation with their version to the modified status (second, third or fourth decennial visits)
- Full scale SDCN, faithful to the operator movements as a shift member and within the control room, allowing the number of operators in the control room ranging from 4 to 5
- SDCN matching with component close sights and the overall control room view, as well as to the sound noises emitted by the operated components, both in nature and intensity
- Fully tactile and faithful handling of real equipment controls: there are no more buttons, neither recorders, nor alarm tiles, but screen representation of push buttons, recorders or alarm tiles on which one acts through touch screen, similar to a giant smartphone with haptic feedback.

EDF has added to these four principles along with other important rules of the game: exclusive use of off-the-shelf hardware, a significant time saving for the simulator control room manufacturing, duplication or upgrade, not to mention the significant reduction in cost compared to its current full-scope simulators.
4. The High-Fidelity Challenge

The main challenge is to identify technological solutions to reproduce on-screen components, actuators, colors, layout space, the different sounds of a real control room, with features that allow a setting as close as possible to the operator gesture that should be performed during the use of the plant operating procedure.

EDF had the experience of "simulated control rooms" in mind, as they had installed on some sites. They dictated the use of a mouse for all actions and the instructors for this reason, only used them as a supplementary tool not usable for operator training.

In the case of SDCN, a partial or complementary solution of the conventional control room was then totally excluded. EDF's request was as follows: to have a tool that allows bringing operators at the same level of competence as through the use of full-scope simulator interfaced with a hardware replica control room, requiring the use of state-of-the-art technology.

High-definition 27-inch touch screens were chosen after several phases of prototyping. Though the market offers larger monitors, for example, 55 inches with a 0.6 mm pixel, these offering proved inadequate as the pixel size could lead to errors in reading values, particularly on some paper recorders. The 27-inch provides a 0.32 mm pixel, allowing more precise displayed information, as verified during the user-centered working group sessions.

This screen choice meant installing 4 times more screens than if using 55 inches, requiring extensive studies to ensure optimized assembly and settings as well as unaffected planned maintenance. Among the solutions implemented include the use of an electronic card for multiple monitors control and a system of sliding and hoists for screen replacement.

Regarding the tactile slabs that are placed on these screens, extensive market research identified five different technologies. A technical and financial analysis concluded that optical infrared were best suited for the display rather than technology-based resistive or capacitive sensors, which account for 95% of the market. This was for several reasons: it is a "multitouch" reliable technology (the ability to detect up to twelve simultaneous contact points on the monitor), the calibration is stable for the lifetime of the monitor, the monitor can be acquired separately from the computer display.

Fig 2: SDCN single panel

Fig 3 – Tactile Slab
Finally, haptic actuators for vibrating the touch screen to give the operator the impression of a force feedback: by pressing a button, it must have the feeling that this button opposes its usual resistance. Similarly, if this button is pressed while watching another part of the panel, the force feedback confirms that the operation performed is taken into account.

These haptic actuators are glued and vibrate the tile monitor perpendicularly to its plane. Four of these sensors are placed on each tile of four screens. The technology chosen would have been able to generate a number of different levels of strength. In practice and after validation with users, three varying intensities were chosen to representatively force feedback for all components.

Finally, we can quote the graphical editor toolset that allows to design and develop high fidelity software replica of the different control panel components. A library of 60 objects was designed, each defined by its visual appearance, the sounds it produces, its operation and the touch or haptic feedback it generates, allowing the faithful reproduction of the 2300 components installed in the plant control room.

5. A User-Centered design

One of the risks of such a project, which introduces a totally new and breaking concept, is to leave the entire design responsibility to engineers without having them endorsed by experienced users. To avoid this, a User Working Group (UWG) of twenty members was established. The group included 900 MW and 1300 MW plant operators and instructors, maintenance staff, human factor specialists, and CORYS / EURWARE experts and team leaders. During the SDCN specification phase, UWG met five times for three consecutive days to validate the mock-ups, solve critical issues, and suggest improvements.
The UWG had a decisive role in design validation. It led to a detailed understanding of each control room action operators have to implement—is such button being operated with one or two fingers, should it be selected before activation. This working group made it possible to identify the most accurate way to reproduce different gestures.

Whenever a new solution had passed the first development stage, the UWG was also involved in its validation. The requirement of actual representativeness applies more particularly to the hardware components, for example the right timing of haptic feedback when a control is activated. But it also extends to the development of dynamic processes.

An example: When operating a 900 MW reactor, 40 arm-and-depress luminous buttons (ADLB) could have to be successively activated within a maximum defined allowed operation time, this in order to achieve pressure balancing inside the primary circuit. An experienced operator checked that, with the digital ADLB, the operation was achievable within the time required by the procedure, without roundabout means introduced but this technology on the effectiveness of the action of the operator.

This work on the representativeness has mobilized a lot of effort, sometimes with major difficulties because it is not always possible to digitally reproduce every component. A remarkable takeaway from the experience was UWG members themselves identifying and proposing solutions in these complex cases.

One example applies to the reproduction of a push-button that is technically impossible. According to the operation rules in place on French nuclear reactor, any push-button to be activated shall first be designated by the operator finger, and its tag name loudly pronounced to the team shift supervisor. The challenge is then to allow the finger designation without causing its maneuver (reliability Practices) Group members spontaneously proposed operations very close to reality using a finger or two fingers depending whether it was for tag name designation or maneuvering the actuator. Of course, each of these discrepancies with the reality has been duly validated. For each lack of fidelity, design work then targeted the 100 % effective, then the best representativeness.

![Push-button Diagram](image)

**Fig 6 – Movements on push-button**

### 6. Easy maintenance

Given the training stakes, complicated by the challenge of anticipated training availability, as mentioned at the beginning of this paper, EDF set a requirement for a maximum troubleshooting time; its maintenance technicians must be able to remedy any failure within 2 hours.

This constraint, which excludes the solution to repair screens or tactile slab onsite, led to the exclusive selection of off-the-shelf products manufactured in large volume and readily available to enable their availability in a replacement stock that can be easily mobilized. Two
ergonomists reporting to the project team helped defining, always with the UWG, easy to use technical solutions.

This is no more computing nor software programming, but mechanical and thoughtful gestures. For screens, a system of hoists, runner slides, check prop, and hatches was developed to enable the screens removal, rotation from the panel backside, then to descend to a storage box on wheels. The replacement screen is installed with the same equipment, following the reverse path.

Fig 7 – SDCN single panel design

For the tactile slab, suction cups, identical to that used by glaziers are implemented. Two maintenance operator can rotate it at 180°, lift and move, this move being guided by a ruler built-in the panel structure.

In both cases, screen or slab, developers must be mindful of French labor laws, which prohibits the handling of objects over 15 kg, while the complete set weight "screen + slab + haptic actuator" can vary from 12 to 21 kg.

Also for maintenance, many issues have been reviewed and improved over the first design: the type of casters for the screen storage box, the most suitable steel for the tactile slab runner slides, the way the wiring cables are embedded in the panel sides to facilitate the screens replacement. Finally, screens and tactile slab have been selected, among other criteria, for their very low failure rate.

7. Assessments of operators for licensing

The ultimate goal of the project, in addition to the initial and refreshing training, is to ensure the ability of this new tool to assess the operators to pass their nuclear operating license. Even with equipment conforming to standards, in particular the U.S. standard ANSI ANS 3.5, the question of acceptance by the operators themselves or by instructors remains. Is a software replica control room able to provide the fidelity needed in a skills assessment tool? What risk does the introduction of a new tool pose to its the operators? If their assessment results on the new tool are not as expected, who shall be blamed—the assessment or the trainee?

These issues are particularly important in France where the operators licensing emerged there only from about 10 years under the pressure of international peer reviews and more generally, from the world nuclear industry. For teams, this is a sensitive subject which still raises some concerns.

EDF has clearly identified the risks from the design and implementation stage and now mainly rely on the assessment organization to remove the obstacle. This is born by the preparation time, sequences of trainings, additional tutorials integrated imaging to make sure that operators have succeeded in the upstream tool appropriating.
8. A cost-optimized solution.

At the end of the current phase of design and manufacturing, it is possible to estimate a SDCN allow substantial financial gain compared to the interface with a replica control room. This is even truer when integrating the maintenance costs. This cost improvement is explained by the use of screens and tactile slabs that, like all electronic equipment, follow a downward trend, while the hardware components increases with their rarity. CORYS, as a manufacturer of simulators for the power and transportation industries, is regularly confronted with this problem. The full-scale replica of a nuclear control room or locomotive cabin, you have to order each component per item, with some of them having been discontinued from commercial circuits for years.

The example of the Bugey, Dampierre Gravelines simulators, three 900 MW nuclear station, is particularly illustrative. They were originally built in the 80s and have been upgraded. But to replace exactly as they were some of the relays, push buttons, alar tiles or paper recorders that are no longer manufactured, it is currently required to award an industrial vendor ready to produce, but also to redesign the A to Z. Even when the components are still available, they can be very expensive—a single paper recorder can cost up to 40,000 euros.

The use of screens and tactile slabs will completely change the perspective: fewer parts to supply, spares easily and quickly available at controlled costs and predictable returns.

9. Conclusion

As with any project where innovation plays a major role and makes a significant break from the state of the art, the challenges are many and their treatment is further complicated by a very tight schedule. However, the current project progress now allows EDF and CORYS to be confident about the ability to successfully achieve most goals.

But what is particularly noteworthy is the involvement and cooperation that exists between the many project team members belonging to various entities very different in size, culture, and organization.

As with any emerging technology, difficulties with implementation and migration remain. However, the major challenge for EDF remains the ability to transition extant hardware control room simulators to software based SDCN without compromising the quality of operator licensing assessments or their training.
OPERATOR TRAINING ON SEVERE ACCIDENT AFTER FUKUSHIMA: A REAL-LIFE EXAMPLE

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ABSTRACT

It is more than two years now from the Fukushima-Daiichi nuclear disaster. Since then, severe accident has become one of the main topics of interest for international organizations, regulatory bodies, academia, research centers and, of course, industry. Lessons learned from the catastrophe highlight the need for improved education and training, at all levels, in this subject. In particular, it is recognized that faced with accident scenarios beyond design basis, nuclear plant operators, managers and technical support teams would benefit from new training tools with specific severe accident capabilities.

Several of these solutions have been proposed already but, even today, very few of them have been fully implemented. The way these tools should be used, the goals to be achieved and the personnel that should be targeted are still a matter of considerable debate.

In this article we describe in detail the experience at Monticello Nuclear Generating Plant, sister to the badly damaged Fukushima I, in the Minnesota plains. There, as a result of a successful training simulator improvement program, carried out over the last few years and recognized by INPO in 2012, instructors can design simulator exercises which include all phases of a severe accident, from core damage to vessel and containment failure. The severe accident simulation models have been developed by CORYS by tightly coupling THOR, their widely used advanced thermal-hydraulics code, with MELCOR, the US NRC severe accident code developed by Sandia National Laboratories. The code integration is transparent to the users of the full scope training simulator and the different models are automatically called as required by the evolution of each sequence. Detailed models of the spent fuel pool are included too.

This kind of training has been conducted for over a year now so real-life lessons can be extracted in different areas. We discuss, for example, the observed benefits in operator training with a better understanding of the severe accident phenomena, and also the improved response of the integrated severe accident models as opposed to the standard stand-alone execution of the code. At this time, analogous simulator improvement projects are under way or have been recently implemented at a number of plants in the US.
1. Introduction

In March 2011 the full scope training simulator at Xcel Energy's Monticello Nuclear Generating Plant, a General Electric BWR-3/Mark I reactor, was already in the middle of an ambitious upgrade plan. Site acceptance testing of a new electric distribution model was under way while a detailed radiation transport model, including reactor building, turbine building and ventilation system, was being developed. The momentum built up after the multiple meltdowns at Fukushima-Daiichi and additional upgrades followed, making the Monticello simulator one of the most advanced in the world. Eventually, two-phase non-equilibrium thermal hydraulic models for the primary system, balance of plant and containment were coupled to the well-known severe accident code MELCOR [1] so that training sequences could progress beyond fuel damage, vessel and containment breach, and recreate a complete severe accident scenario.

This paper describes how this simulator has been used during the last year for Licensed Operator Requalification Training (LORT) on Severe Accident Management Guidelines (SAMGs) and the lessons learned from the experience.

Two and a half years after the earthquake and tsunami in the Japanese coast, and while the need for new tools to improve severe accident training at all levels has been widely recognized, the discussion about how best to achieve the desired goals remains open. Different approaches have been proposed but only a few have been developed and even less fully implemented. Regulatory changes have not taken place yet, but are expected. In this context, Monticello case is quite unique and should help to evaluate future trends and possibilities.

![Fig 1: Monticello Nuclear Generating Plant](image)

2. The Monticello full scope training simulator

By mid-2012 all the upgrades were ready. Factory acceptance testing was completed in July and site acceptance tests extended during the summer. Training was scheduled for late 2012 using the new severe accident models. By then, the simulator was a truly state-of-the-art tool, in every area, exhibiting the following features:

- High-fidelity two-phase models of primary system and balance of plant, as well as primary, secondary containments and HVAC to correctly simulate radiation and gas transport across the whole reactor and ventilation release paths. The thermal hydraulic code is THOR [2], by Corys, the most widely used real-time two-phase models in the American nuclear sector with more than forty installations in training simulators since its introduction in 1998.
- Spent Fuel Pool model, also in THOR, and support for multiple modes of operation in order to blend loss of cooling, loss of flow, and mode 5 refuel modes with vessel and containment heads removed
- Detailed electrical distribution model of all AC, DC and sub-yard, with particular attention to batteries, diesel generators and large DC loads affecting battery discharge
- MELCOR model of the reactor pressure vessel to support severe accident sequences with faulted core geometry allowing for live transition from regular scenarios
- 3D visualization tool as an additional help during severe accident training
- Earthquake simulation
- Full sound system
- Full scope glass-top simulator complementing the training sessions on hard panels

An additional change had to be made as simulator computer time increased noticeably. Computer hardware had to be updated along with the models in order to guarantee sufficient processor spare time during execution. The simulator now runs on Dell Precision machines with Dual Quad Core 3.6 GHz processors. The CPU load never exceeds 40% on the most limiting processor. Operating system is Microsoft Windows 7, 64 bit.

Even before the upgrade process was totally finished, in early 2012, Monticello commitment to excellence regarding its training simulator was recognized. As a result of a joint plant evaluation by INPO (Institute for Nuclear Operations) and WANO (World Association of Nuclear Operators), Monticello received a “strength” related to the simulator [3]. The strength is defined as “a beneficial cross-functional or significant functional area practice, activity, or process employed by a station that results in achieving a high level of performance or desired high quality results and benefits”. Obviously, the significance of the events in Japan had not been underestimated and the plant was taking decisive steps ahead of the emerging industry challenges.

3. SAMGs training implementation

Before the upgrade, Licensed Operator Requalification Training on severe accidents was limited to classroom discussions of the SAMGs using case studies. With the new models operators can evaluate plant conditions, including core collapse into the lower head and vessel breach, and take mitigating actions according to the guides [4][5]. The transition to the severe accident models, triggered by fuel clad temperature reaching 1200°F, is seamless as the sequence degrades but can be disabled by the instructor to avoid affecting license exams or some other kind of training. When the transition happens, the booth operator is notified that the simulator is now in out-of-bounds conditions.

Since the severe accident model is a continuous part of the regular simulator load and does not cause an interruption in training, it was possible to design a SAMG training exercise based on pre-existing initial conditions. The scenario is initiated by a small break LOCA followed by a design-basis earthquake which results in high power ATWS, safety relief valve tailpipe breakage and, eventually, station blackout (SBO) conditions with major fuel damage requiring hard-pipe containment venting.

The whole scenario time line evolves during several hours. At one point, the crew will identify the need to exit all EOPs (Emergency Operating Procedures) and enter all the SAMGs. Sometime later, command and control will be transferred to the Technical Support Center due to the inability to restore and maintain sufficient reactor water level. The vessel will finally fail and drywell temperature and pressure will increase rapidly. The exercise ends when the remaining DC power is lost causing all lights to go off and all indicators fail downscale.

As the training exercise cannot extend for so long, time compression is required. Figure 2 is a graphical depiction of how the scenario was developed and implemented. First, the
complete sequence was executed in real time, with no operator actions, for development. Snapshots were taken prior to the most significant events, such as high hydrogen levels after extended core damage, core collapse and, finally, vessel breach. During the training session the sequence will divert from the baseline path due to the mitigation actions performed by the operators. Then, in order to progress to the next stage, the simulator will be reset to the following snapshot and the crew briefed that the actions could not be performed, time has elapsed and what the current plant conditions are. After every snapshot, the simulator will continue to run in real time allowing the operators to follow the guides and carry out new actions.

At certain times during the exercise, the simulator will be placed in freeze to explain the severe accident phenomena and analyse plant response. A 3D dynamic visualization tool with a detailed representation of the vessel and the core is used for support. The graphic is connected to the running simulator and animated in real time. It allows the operators to understand what is happening inside the reactor and how this relates to the indications observed in the control room. Figure 3 shows the 3D graphic during a partial meltdown, with a large amount of molten fuel and debris deposited on a pool of water in the lower head.

Although the uncertainty involving the severe accident models is still high and it cannot be guaranteed that the plant will behave exactly as predicted during the severe accident phase of the sequence, the training value is clear. Operators are faced with situations they would likely encounter, sooner or later, during such an event, with plant conditions that differ greatly from the scenarios used in periodic EOP training.
In this exercise two examples can be highlighted. First, the core collapse into the lower head, causing a pressure spike, safety relief valve open alarms and hydrogen production. By seeing real time integrated indications in a control room setting, the crews were able to perform a diagnostic exercise previously done using a PowerPoint slide. This exercise allowed for discussions regarding what could cause these indications and application of operator fundamentals in understanding the differences between the indications for core collapse and injection from an emergency system. The observation of the collapse in the 3D graphic reinforced the explanations.

Second, the evaluation of the vessel breach. Prior to vessel failure containment temperature was around 300°F; multiple crews evaluated it as high drywell temperature meeting one of the criteria for indications of a vessel breach. When the failure actually happened, as observed in the 3D graphic, “high or rising drywell temperature” (the SAMGs indication) was demonstrated. Once again, by using simulator training combined with the 3D graphics, procedures steps were better understood by the operators allowing for a more robust training experience not available in a classroom setting.

At Monticello, feedback from the severe accident training has been very positive from operators and managers and additional upgrades are already being evaluated. Examples are the incorporation of revised mitigation strategies into the simulator models, such as emergency power sources or water injection from portable equipment, and the improvements to the simulation of control room conditions under long term SBO regarding indications and lightning. Extending the use of the simulator to emergency planning and engineering training is in progress.

The severe accident training exercises have also drawn interest from outside the plant and the simulator has been visited by various external groups willing to observe the training sessions, among them a delegation from the Nuclear Power Training Center in Japan (NTC) responsible for operator training at all the Japanese PWR plants.
4. The real-time severe accident model

The coupling of MELCOR, developed by Sandia National Laboratories for the US Nuclear Regulatory Commission, with Corys’ THOR is thoroughly documented in several references [6][7]. The integration of both codes is based on the design decision to continue using the THOR models, already implemented at most American simulators, for the primary system under all non-severe accident conditions. They would also continue to be used for the containment and balance of plant systems in all situations, even under severe accident conditions. In this way, only the required packages of MELCOR latest available version, 1.8.6, are incorporated into the severe accident model as most areas are left to THOR, including Emergency Core Cooling Systems (ECCS), containment and radiation transport outside the primary.

In Monticello’s case, the boundaries between MELCOR and THOR are established at the reactor vessel nozzles. After transition to the MELCOR model, all phenomena occurring inside the vessel are calculated by MELCOR, and all phenomena occurring outside remain within THOR’s scope. Figures 4 and 5 are different views of the integration of both models at Monticello. Figure 4 displays the integrated severe accident model nodalization, MELCOR for the vessel and THOR for the containment. Figure 5 describes the interface between the MELCOR model of the vessel on the left with the rest of models run by THOR on the right.

![Fig 4: MELCOR vessel and THOR containment nodalization](image)

The transition to the severe accident model occurs just before the onset of large scale clad oxidation which could result in fuel damage and loss of core geometry. At that moment, the vessel model in THOR stops execution and an interface file containing the current primary system conditions is created on the fly. The file is then used as the starting point for the MELCOR models. The entire process takes place in about a tenth of a second and is completely transparent to the trainees. As the sequence progresses, additional MELCOR packages may come into play to simulate in-vessel and ex-vessel severe accident phenomenology such as core collapse, vessel failure, corium relocation or molten corium concrete interaction (MCCI) in the reactor cavity.
Significant amounts of data need to be exchanged between the THOR and MELCOR models. At every boundary, MELCOR outputs become THOR inputs and vice versa. Figure 6 shows a schematic representation of the process. Some of the main magnitudes being exchanged are: fluid mass and energy, convective heat transfer from the vessel, energy from ex-vessel phenomena and radionuclide information which will be fed into the radiation detectors model. The data is exchanged at a high rate, ten times per second, to ensure repeatability.

The THOR-MELCOR integration has been benchmarked against standalone MELCOR runs of the same scenarios and against published MELCOR results for similar plants. The agreement is generally good and the sequences follow similar paths in all cases. Some differences between the integrated and standalone models could require further analysis but, in any case, they should not affect the quality of the severe accident training being pursued. As explained before accuracy is not, at least at the moment, the main requirement for this type of training.

At the time of writing this article, the first THOR-MELCOR models of a pressurized water reactor are being completed. The plant is Calvert Cliffs, a two-loop Combustion Engineering
reactor. Furthermore, contracts to implement the MELCOR severe accident models at two more American plants are already in place: Point Beach (a Westinghouse two-loop PWR) and Perry (a General Electric BWR).

5. Conclusions
Monticello’s experience demonstrates how full scope training simulators can provide valuable operator training in severe accidents using existing technologies. A well designed integration of robust high-fidelity thermal hydraulic models such as THOR, with well-known severe accident codes such as MELCOR, will allow the instructors to extend training scenarios beyond fuel damage and generate realistic severe accident conditions in real time. The quality of the training will be determined not only by the severe accident model, but also by the detail of the rest of plant models, especially the secondary and containment systems, ventilation, radiation transport and electrical distribution.

The potential of this type of tool is obvious and additional training applications should be explored. At the same time, the severe accident models will continue to improve as the knowledge obtained from the many research programs under development is incorporated. This will reduce the current uncertainties and bring the training in severe accident closer to the mandatory training in emergency procedures we are used to now. In the near future, regulatory requirements in this direction may come into force. As different approaches are being proposed and some of them implemented, the results will need to be shared for the benefit of the whole industry.

6. References


DIGITAL CLASSES IN PROVIDING EXPERIENTIAL LEARNING PLATFORM FOR STUDENTS WITH NO ACCESS TO EQUIPMENT AND LABS: AN EXAMPLE OF “DIGITAL NAA CLASS”

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ABSTRACT

A number of programs and classes pertaining to nuclear science and engineering worldwide do lack infrastructure in sufficient quality and quantity, and therefore lack ability and capacity in providing valuable hands-on learning and training of their students. Collaboration and sharing of such facilities, especially virtually, is one way in bringing real-lab experiences to students without direct access to infrastructure and equipment of interest to their curricula and class contents. Recently we have developed a so-called “digital NAA” as a supplement to the class on radiochemistry taught at the University in Montevideo, Uruguay. Together, we have created a real-time practice on neutron activation analysis, more specifically on how gamma spec systems operate and how we measure the samples after irradiation in a research reactor. Our practical exercise consists of sending the blind gamma spectra we generate at the University of Utah Nuclear Engineering Program, to the group of students at the University in Montevideo in Uruguay. After a week from sharing these spectra, we connect again through the Skype-system to discuss the elements as detected and shown in these spectra. We develop detailed discussions on the meaning of the spectra and provide final analysis on the nature of the samples. The class includes graduate and undergraduate students from both programs in live discussion and exercises on neutron activation analysis. We plan to develop additional exercises and establish this digital class as a practice among our programs. We will present the class practice in emphasizing it as a model for developing similar international digital classes.

1. Introduction

Montevideo, Uruguay: The Laboratory of Radiochemistry in the Faculty of Chemistry in Uruguay offers courses related to nuclear science and applications to pre and postgraduate students in Chemistry, Pharmacy, Clinical Biochemistry, Chemical Engineering and Food Engineering. Annually approximately 100 students participate in the theoretical lessons while 30 students are also involved in experimental activities both on basic topics (safe handling of radionuclides, decay law, radiochemical equilibrium, gamma spectroscopy) and on applications in areas such as health, industry and analytical chemistry. The specific topics covered depend not only on the importance of the different areas but mainly on the available infrastructure. Neutron activation analysis (NAA) is a very important application that was included in the programmes until 1990 using a $^{252}$Cf neutron source provided by the International Atomic Energy Agency. After the source was completely decayed, nuclear activation analysis experiments could not continue since...
Salt Lake City, USA: The Utah Nuclear Engineering Program (UNEP) mission is in supporting the development and exploration of advanced nuclear science and technology while bridging different engineering and science disciplines and by advancing the education with modern laboratory practices. Our program promotes nuclear power and engineering education as a resource that can help green energy development, environmental, and nuclear security needs. The program emphasizes that technical and regulatory barriers can be overcome through education, training, research and development. In 2009/2010, we successfully established a new educational program inclusive of the advanced graduate program and undergraduate minor degree in nuclear engineering centering on hands-on experience using our TRIGA reactor (UUTR), radiochemistry, radiation and measurement laboratories, and nuclear forensics laboratory, in emphasizing nuclear safeguards, radiation detection, and simulations visualizations applicable to reactor neutronics and other systems inclusive of radiation transport phenomena. In the interest of making positive contributions to nuclear energy challenge world-wide, we focus on the development of our nuclear energy-related infrastructure and basic capabilities necessary to further promote R&D in support of nuclear science and engineering educational mission. Utah has a growing economy and the University of Utah is continuously re-building, modernizing and innovating the nuclear engineering program to prepare for the growing need of nuclear engineers. Our program is also unique in becoming the only one that operates its facilities under the DevonWay Corrective Action Program (CAP) software system, and trains our graduates in mirroring in full although at the smaller scale, the environment of nuclear power plants safety rigor. [1]

In addition to education, training and research, our radiation measurement laboratories are used for creating digital classes. Namely, we develop laboratory practicies and share with the classes in the programs that do not possess laboratory equipment for hands-on training of their students. One such international example is our so called “digital NAA” class we have developed in cooperation with the radiochemistry class in Montevideo, Uruguay.

2. NAA Capabilities at the University of Utah Nuclear Engineering Program

The University of Utah is one of dozen universities in USA that operates a research nuclear reactor; the TRIGA Mark I is licensed to operate at the maximum power level of 100 kW providing good neutron population in the expected energy range as applicable to neutron activation analysis, sample irradiations and other experiments of interest to nuclear science and engineering and associated disciplines such as but not limited to medicine, agriculture, material science, space engineering, nuclear forensics, environmental engineering, and concrete chemistry. Neutron activation analysis became one of our main usages of the reactor in the last few years. Besides using it for research and sponsored projects, the NAA is used widely for training the students in sample science, safety aspects of NAA and sample handling, NAA basic science, and radiation measurements. [2] Our graduate and undergraduate students have solely developed the NAA protocol as established in 2011; the NAA protocol is shown in Figure 1. Every raw sample entering the Utah nuclear engineering facility is logged-in following internal code system. The samples are logged-in according to their origin, nature, quantity and reason for being examining using the NAA. The samples are then prepared for irradiation following strict protocol of sample science for irradiation. Our students are trained in
sample preparation that includes details on why the steps are strictly required to be followed, such as for example why samples are not to be handled by bare hands, or how to wash the instruments used to grain or cut or dissolve samples. Once samples are prepared and their mass is measured, the users are required to enter the NAA pre-calculator. [3] The easy-to-use pre-calculator is developed by graduate student and is tailored toward not just pre-determining the activity and dose rate of the samples are irradiation, but better train and educate our students and users at large. The graphic user interface of the NAA pre-calculator is an advanced tool allowing to optimize the irradiation time, reactor power and dose rate after required cooling time in the reactor. Every sample to undergo NAA has to some extent known composition. That elemental composition is developed based on our existing extensive NAA data library [4] and then used within the NAA pre-calculator. The request for sample irradiation is placed by the user into our DevonWay software system. [1] In this way, reactor supervisors plan the operation of the facility in highly organized and optimized ways. Once the sample is irradiated in the thermal irradiation port of the reactor, and after predicted cooling time, the dose rate at three feet distance is measured and compared to the predicted value. This is the first indicator of how well the estimates were provided for the NAA experiment. When the dose rate satisfies limits, the sample is moved into our radiation measurement laboratory and placed into gamma spectroscopy station for analysis and measurements. Not every sample requires the same counting time. The starting counting times are determined based on the NAA data library for similar types of samples, and if and when needed, the counting times are adjusted for better results. When the samples are measured and analysis is completed, the samples’ fate is determined based on the research involved. As shown in Figure 1, a sample can be stored at our facility for later use, destroyed or returned to the customer.

Figure 1. NAA protocol at the University of Utah Nuclear Engineering Facility

The Nuclear Engineering Program at the University of Utah in the USA and the Catedra de Radioquimica from Montevideo in Uruguay, together, we have created a real-time practice on neutron activation analysis, more specifically on how gamma spectra systems operate and how we measure the samples after irradiation in a research reactor. Our practical exercise consists of sending the blind gamma spectra we generate at the University of Utah Nuclear Engineering Program, to the group of students at the University in Montevideo in Uruguay. After a week from sharing these spectra, we connect again through the Skype-system to discuss the elements as detected and shown in these spectra. We develop detailed discussions on the meaning of the spectra and provide final analysis on the nature of the samples. The class includes graduate and undergraduate students from both programs in live discussion and exercises on neutron activation analysis.

The “digital NAA” class sequence is shown in Figure 2. [3] The class is mainly prepared and led by the UNEP students trained in neutron activation analysis and the associated radiation measurement techniques. The class is initiated by sending the NAA document to the student group in Montevideo. The document consists predominantly of a series of blind gamma spectroscopy spectra. The students learned about the NAA and spectroscopy measurements prior to receiving this document. Usually, a week or two are given to the students to work on the spectra with the goal to identify the elements based on the energy peaks in the spectra, and then provide conclusions of what are the possible samples for which these spectra are provided. While the student group in Montevideo works on the spectra analysis, the UNEP students trained in the field of NAA and gamma spectroscopy, prepare for the digital class. The class starts with the overview of NAA and gamma spectroscopy followed by the UNEP laboratory tour using Skype. Once the students virtually tour the spectroscopy stations at UNEP and their operation is demonstrated, the students start discussions on previously provided spectra and conclude the class with complete “discoveries” on the elemental compositions of the samples and the nature of the samples.

![Figure 2. Digital NAA Class Sequence](image-url)
4. Conclusion

Neutron activation analysis is non-destructive and powerful technique for identifying and quantifying elemental composition of a sample. It requires a neutron source and gamma spectroscopy system with well-equipped labs for clean preparation of analysed samples. It is as such, an advantageous educational and training technique for the students in providing them with hands-on experience and knowledge of the basic nuclear physics and nuclear engineering principles. Many universities world-wide do not possess capabilities to demonstrate theory in practice, by providing the whole experience in preparing, irradiating and measuring the samples as a part of neutron activation analysis technique. We, at the University of Utah Nuclear Engineering Program, came to develop what we call, a “digital NAA” class in providing simple yet interesting class on neutron activation analysis through cyber-space. Using free Skype-capabilities, we broadcast a few hours demonstration on the technique and gamma spectroscopy system and measurements. We have developed this class in collaboration with the University in Montevideo, Uruguay. We continue to advance this class and continue to offer to other universities world-wide.

References


How to ensure that enough motivated workforce is available for the nuclear sector?
BUILDING NUCLEAR INFRASTRUCTURE

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ABSTRACT

Historically countries started their nuclear power program by first building a Research Reactor (RR) and the related infrastructure. The focus of the national strategy was on developing indigenous human resources (HR) and when possible national nuclear industry, starting at the very beginning of the RR Project.

The method followed by the Argentine Company INVAP reinforces this approach with “on-the-job-training” of customer’s personnel during the whole RR project. This ensures at the completion of the project, that the customer will have its own skilled HRs for the operation, maintenance and upgrade of its reactor in a long-term strategy, even when the organization had no nuclear experience before the project started. When required, INVAP has the capability to start training at the nuclear theoretical level, later bridging the gap between learning and practical experience. These resulting HRs would have developed at the end of the RR Project, the capacity and competence necessary for the successful planning, bidding, awarding, and construction initiation of a nuclear power plant. Another important point to remark upon is that the customer’s nuclear organization and its regulator will have acquired experience in dealing/working together in a real nuclear project.

INVAP is also one of the main stakeholders of the University RA-6 Reactor (designed and built by INVAP). The RA-6 Reactor is an excellent example of a well-utilized RR for training, education, research, and industrial development.

“On-the-job-training” experience of INVAP in the RRs built in Peru (RP-10), Argentina (RA-6 and RA-8), Algeria (NUR), Egypt (ETRR-2), and Australia (OPAL), is outlined in this paper. INVAP participation as a stakeholder at the University RA-6 Reactor is also described.
Introduction

INVAP is a company dedicated to the design and construction of complex technological systems, developing advanced technologies in different fields of industry, science and applied research, creating "high value added technological packages".

INVAP’s main activities are focused in the Nuclear, Aerospace and Defense Areas, as well as Industrial and Medical Systems.

Since its beginnings in 1976, INVAP has grown from a small office to a surface area of over 10,000 square meters of laboratories, workshops and office space. INVAP’s headquarters are located in San Carlos de Bariloche, Patagonia, in the foothills of the Andes, about 1700 km southwest of Buenos Aires.

INVAP staff comprises more than 1000 people. This includes a body of highly skilled professionals, specialized in the handling of complex systems; an advanced Quality Management System; innovative technical and administrative projects, control systems and a quarter of a century of experience in the management of innovation.

Mostly due to INVAP, which has made an important and successful effort in the aperture of new markets, Argentina is now known worldwide as a reliable supplier of nuclear facilities, as well as of cobalt therapy and industrial automation equipment.

INVAP is the only company in South America that has worked with NASA (the US National Aeronautics and Space Administration) in complete space projects. In this field, the company has shown its proficiency as a constructor of satellites, payloads and ground stations.

INVAP has been involved in nuclear development for over 30 years. In that time its teams have worked on more than 15 nuclear reactors and related facilities across the world.

“On-the-job-project” approach

The customer training method followed by INVAP is based on the approach: “on-the-job-training” of customer’s personnel during the whole nuclear project.

Customer’s trainees are considered “INVAP employees” with the same responsibilities as those of its own staff. Trainees work in different areas, and at different stages, of the whole nuclear project under close supervision of INVAP staff. “On-the-job-training” ensures that at the completion of the project, the customer will have its own skilled human resources, for the operation, maintenance and upgrade, of its Nuclear Facility (e.g. Research Reactor) in a long-term strategy, even when the organization had no nuclear experience before the project started.

From the very beginning of the project, the customer sends its personnel to INVAP to be trained in the different required level of competences:

1. “nuclear”: professionals to receive formal education in nuclear subjects (e.g. neutron calculation, thermal-hydraulic, radiation protection, shielding, etc.);
2. “nuclearized”: professionals to receive formal education and training in a relevant (non-nuclear) area (e.g. mechanical, electrical, civil engineering,
systems) which are needed to acquire knowledge of the nuclear environment in which they have to apply their competencies; and

3. “nuclear-awareness”: personnel requiring some nuclear knowledge to work in the nuclear facility (e.g. electricians, mechanics, and other crafts and support personnel).

Theoretical Courses
INVAP starts training at the nuclear theory level, to later bridge the gap between learning and practical experience. Hands-on training in a real environment since it is considered that classroom study is not enough.

The theoretical subjects are such as:
- Introduction to Nuclear Reactor Physics
- Reactor fuels
- Fundamentals of Thermal-hydraulics
- Radiation Protection
- Nuclear and Conventional instrumentation
- Reactor Control and Monitoring Systems
- Reactor Protection Systems
- Radiation Monitoring Systems
- Nuclear Reactors
- Basic Safety and Security Concepts

The Nuclear Project as a “training school”
For INVAP each Nuclear Project is a learning school by itself.
- The “on-the-job-training” approach implies the involvement of the future operation staff of the facility from the very beginning of the basic design. Followed by:
  - Detailed engineering,
  - Construction,
  - Operation & Maintenance.
- The operation staff actively participates in the safety approach of the nuclear facility, its PSAR, and other licensing required documents. Since is the operator, not the supplier, is the party responsible of the licensing, his involvement assures a smooth licensing process.
- When required, INVAP could also train and advice the customer’s Regulator experts. For a Nuclear Project to be successful it is always necessary to have a well-qualified Regulatory counterpart.

Traditional Training
When required, INVAP could also offer “traditional training” (undergraduate and graduate) in:
- Nuclear Engineering (undergraduate)
- Master in Nuclear Engineering
- PhD in Nuclear Engineering

To this purpose INVAP works hand in hand with the “Instituto Balseiro”* (a worldwide recognized nuclear educational institution).

*National University of Cuyo
Argentina Atomic Energy Commission
INVAP could also offer “traditional training” in:
- Materials Science (undergraduate and graduate)
- Radioisotopes Production
- Nuclear Medicine
- Radiotherapy
- Radioprotection
- Radiochemistry

To this effect INVAP works together with:
Instituto Sabato*, and
Instituto Beninson*

* National University of San Martin
Argentina Atomic Energy Commission

Other National Nuclear Organizations
Technological oriented companies should work together with R&D institutions and Academia to enhance education and skills of its staff. This also creates opportunities for more effective use of the available research facilities.

INVAP works in close relationship with:
- Argentina’s National Atomic Energy Commission
- Educational Institutions (e.g. Instituto Balseiro - IB)
- Argentina’s National Regulator Authority (ARN)

National Local Industry
From the very start of a Nuclear Project, the project itself should be used to:
- develop as much as possible local customer’s infrastructure in supporting the construction, regulatory approval, operation and maintenance of the nuclear facility (and eventual decommissioning).
- improve the degree of national participation (technology transfer).
- design the nuclear facility for developing/using local technology industry/services (best method to transfer know-how to the local industry).

Operators Training Program
INVAP applies the following training program:
1. Personnel selection in the Customer’s country
2. First training stage (in Argentina)
   1. Academic training
   2. Practical training in nuclear installations
   3. “On-the-job-training” → active participation in the facility design and/or components manufacturing
   4. Operators’s licensing granted by Argentina Regulatory Body (e.g. Research Reactor)
3. Second training stage (host country)
   1. On the job training during:
      1. Erection
      2. Commissioning
      3. Facility start-up
   2. Gradual transfer of full responsibility

Training tool: RA-6 Research Reactor (Argentina)
INVAP has access to the training of its trainees, to the RA-6 Research Reactor
The RA-6 Research Reactor is the training tool of Instituto Balseiro for its Nuclear Engineering Career. It is also utilized by Professionals of CNEA in R&D. Thus, the RA-6 is utilized by university (IB), governmental (CNEA) and company (INVAP) all which allows to state that it is a well utilized nuclear facility.

Its main characteristics are:
- Power: 1 MWth
- In operation since 1982
- Open pool type
- Fuel: MTR U₃Si₂ 20% enriched*
- Moderator and coolant: H₂O
- Reflector: Graphite/H₂O
- Thermal flux (max): 1x10¹⁴ n/(cm²·sec)

*Converted from HEU in 2009

**Conclusions**
- INVAP approach: “on-the-job-training”
- For INVAP the whole Nuclear Project is a learning school
- INVAP ensures that the customer will have its own HRs for the operation, maintenance, and upgrade of its nuclear facility in a long-term strategy
- Under INVAP ’s training approach the HRs developed will have the capacity and competence for successfully planning, bidding, awarding the construction of new nuclear facilities e.g. a nuclear power plant.
- INVAP is an important stakeholder at:
  - Bariloche Research and Training Reactor (RA-6), and
  - Instituto Balseiro (Nuclear Engineering Career)
In 2010, the European Human Resources Observatory for the Nuclear energy sector (EHRO-N) analysed the demand and supply of human resources (HR) in the European nuclear field in the short, medium and long term. Before this analysis, no comprehensive picture on the demand/supply of nuclear HR was available for the whole EU-27. The availability of national data varies, indeed, from country to country. For instance, France, UK and, more recently, Finland have monitored their national demand and supply of the nuclear workforce through comprehensive national surveys. However, national data and reports on nuclear HR are missing for most EU's Member States (MSs). The same reports produced by international organizations, such as IAEA and OECD/NEA, do not always provide complete data.

The paper summarizes the result of the EHRO-N analysis. The focus is on the match (and mismatch) between the demand and supply of highly skilled workforce in the nuclear field (or "nuclear experts") at present and in the future. Data was collected by EHRO-N through an EU-wide survey. The process of data collection and analysis also benefited from the co-operation with relevant actors of the European nuclear energy sector. Such cooperation took place through the EHRO-N's Senior Advisory Group (SAG), which brings together the representatives of research organisations, industry, international organisations, etc. involved in nuclear energy across Europe. Finally, the paper puts the demand/supply of nuclear experts in the EU-27 into a broader perspective by highlighting the major lessons learnt and possible future areas of intervention.

1. Introduction

In the EU27, the total workforce employed in the nuclear sector is approximately 500,000 people. According to the competences needed for the operation of a nuclear power plant (NPP), the nuclear workforce can be divided into three categories:

- nuclear experts;
- nuclearized staff;
- nuclear-aware staff.
Nuclear experts are employees who possess a specialized formal education in nuclear subjects (nuclear engineering, radiochemistry, radiation protection, etc.). Nuclearized staff is employees who have a formal education and training in a technical area outside the nuclear domain (e.g. mechanical, electrical and civil engineering); these employees receive additional training on the nuclear aspects on which they work. Nuclear-aware staff consists of employees who are requested to possess a certain degree of nuclear awareness to be able to work (e.g. electricians, mechanics, and other crafts and support personnel). The focus of this paper is on nuclear experts only.

In the last 15 years, the OECD (2000; 2004) has reported about the need to enhance the presence of nuclear experts in Europe. The warning about the lack of nuclear experts drew the attention of the Council of the EU in 2008. In the same year, the European Nuclear Energy Forum (ENEF) welcomed a new initiative at the EU level under the name of European Human Resource Observatory for the Nuclear energy sector, or EHRO-N. The introduction of EHRO-N was prompted by the perceived need for a central information source for the nuclear energy sector in the EU. The EHRO-N initiative aims at monitoring and analyzing the current and future demand and supply of nuclear experts in the EU-27. A first report on the demand and supply of nuclear experts was issued in May 2012. It constitutes the basis of this paper.

The analysis was led by the following research: 'Is the supply of nuclear experts in the EU27 sufficient to cover the demand of the nuclear energy sector?'. Nuclear experts were defined as the working positions filled by nuclear engineers, nuclear physicists and nuclear chemists who have a nuclear higher education background (i.e. Bachelor, Master or PhD), or by that staff who has a non-nuclear technical higher education background (i.e. Bachelor, Master or PhD) with relevant competences/skills in the nuclear field (acquired, for instance, through in-house or other training).

2. Methodology and limitations

Data were collected though two surveys conducted in 2010-11. The first survey targeted higher education institutions in the EU27 which provide degrees in the nuclear domain (e.g., nuclear engineering, nuclear physics and nuclear chemistry). The list of questions asked during this survey is reported in Annex 1. The second survey targeted the nuclear industry and national authorities; the questionnaire is reported in Annex 2. Survey data were checked against other sources. Data about the supply of nuclear experts were checked against the information available from the institutions involved in nuclear education and training, and organizations and platforms such as the European Nuclear Education Network (ENEN), the Sustainable Nuclear Energy Technology Platform (SNE-TP), and the European Nuclear Society (ENS). Data on the demand of nuclear experts were checked through the EHRO-N's advisory group which includes representatives from the European nuclear industry (utilities, vendors, suppliers, consultancies, etc.) and national authorities (e.g., regulatory authorities, technical safety organizations and agencies for radioactive waste management). For the purpose of adequate triangulation,
primary data were complemented by document analysis based on relevant reports issued by international organizations, such as OECD (e.g., OECD 2000; 2004; 2012) and IAEA (IAEA 2010). Some national reports on the human resources employed and needed in the nuclear sector were also consulted (e.g., for France, UK and Finland).

The survey faced several limitations, which we list here. First, although the survey aimed at constituting a census, we acknowledge that it is very likely that not all nuclear industrial organizations and education institutions have been reached by the survey. Second, the concept of 'nuclear experts' has no commonly acknowledged definition; however the use was clearly explained during data collection to the organizations contacted. Third, some organizations were not willing to disclose internal information.

3. Analysis of the results

Somewhat less than 190 higher education institutions were contacted for the supply side. The response rate was above 90%. Data showed that approximately 1800 students from the nuclear domain completed a full course of study at bachelor, master and doctoral level in 2009 (figure 1). Around 2800 students started their studies in the nuclear domain during the academic year 2009/2010.

Figure 1: Degrees awarded in the nuclear domain (2009)

For the demand side, 358 nuclear organizations were contacted. The response rate was 67.6 per cent. The 242 organizations that responded to the questionnaire employed
about 63 thousand nuclear experts in 2010. Exactly one third of the total number of these nuclear employees fell in the age group between 45 and 55 years old. The number of the nuclear experts younger than 45 years was almost equal the number of nuclear experts older than 45 years (figure 2). The important data is that sum of nuclear experts expected to be demanded by all respondents by 2020 was more than 30 thousand.

**Figure 2: Nuclear experts per age group (2010)**

![Pie chart showing nuclear experts per age group (2010)]

Source: EHRO-N (2012)

In 2010, the number of nuclear experts older than 55 were approximately the 16.6% of the total workforce. It follows that, by 2020, the nuclear sector will lose more than 10,000 nuclear experts. Since the survey was conducted before the Fukushima accident, most organizations were confident that they would need to recruit about 30,000 nuclear experts by 2020 in order to replace the retired ones and start new projects. Less than 2000 students were awarded a nuclear degree in 2009, which leads us to assume that in the following 10 years less than 20,000 new nuclear experts will be available in the EU. The comparison between these numbers easily suggests a significant gap between the demand of nuclear experts (about 30,000) and their supply (less than 20,000). The gap increases if a portion of the new nuclear experts leaving higher education enters a technical sector of employment outside the nuclear domain.

In conclusion, the EU seems to face an alarming problem in its nuclear energy sector. The retirement rate of the nuclear experts of the first generation is not compensated by the amount of students finishing nuclear studies and willing to start their professional career in the nuclear sector. Competition from other technical fields risks to take many talents away from the no-longer fashionable nuclear option. In particularly, in the same
area of energy production, renewable energies seem to be more appealing to the younger generation. In addition, the renewable energy sector is believed to be one of the growing labour market, with the creation of a large amount of new jobs per year. On the other hand, the nuclear industry has developed mechanisms of in-house training, in order to nuclearize non-nuclear engineers according to their needs, but there are no numbers available.

Figure 3: Age distribution of nuclear experts per type of organization (2010)

Source: EHRO-N (2012)

4. Modeling the Workforce Need based on EU Energy Scenarios

Additionally to the methodology applied in the previous chapter a study was carried out dealing with an alternative approach to derive figures for the demand side information of the nuclear workforce. In this top-down modeling approach, well accepted nuclear energy demand data is used to derive the number of nuclear power plants that are in operation and under construction as a function of time from 2010 up to 2050 assuming that the current reactor park will be replaced by generic third generation reactors of 1400 MWe or 1000 MWe. Based on workforce models for operation and construction of nuclear power plants, the model allows a prediction of these respective workforces. Using the nuclear skills pyramid, the total workforce employed at a plant is broken down in a nuclear (experts), nuclearized, and nuclear aware workforce. With retirement profiles for nuclear power plants derived from the EHRO-N survey, the replacement of the current workforce is taken into account. Depending on the assumed nuclear energy demand scenario and the type (size) of new build reactors (for details refer to case scenarios in the reference), the analysis shows
that about 95 to 160 new reactors are required to fulfil the demand for nuclear energy. The total number of the involved in construction of nuclear power plants equals ~50000 (70000 peak) for the scenario in which 160 reactors are constructed and ~20000 (40000 peak) for the scenario in which 95 reactors are constructed.

**Figure 4: Case 1B example of "New workforce operations and construction" for EC Energy Roadmap 2050 (2013)**

![Graph showing new workforce operations and construction for EC Energy Roadmap 2050 (2013).](image)

Source: EHRO-N (2013)

From figure 4 it can be deviated, that the peak of the new workforce (partly replacing the retiring workforce and additionally keeping up with the growing total workforce demand) for nuclear experts is to be expected at the end of the considered period (2050) and amounts to about 7500-10000 nuclear experts. The peak workforce for nuclearized employees is also to be expected around 2050 and amounts to about 50000-65000 nuclearized employees. On the other hand, the peak workforce for nuclear aware employees is to be expected around 2020 and amounts to about 25000-50000 nuclear aware employees. Under the assumption of a typical amount of part-time contracts in the nuclear industry of about 10%, this relates to about 45000-80000 new jobs on the short term (2020) and 70000-100000 jobs on the long term (2050).

**Figure 5: Case 1B example of "New workforce operations and construction for the EC Energy Roadmap 2050" (2013)**
When comparing to historical data for the nuclear capacity being installed at the same time in Europe (figure 5), it is clear that the expected future capacity to be installed at the same time in Europe is significantly lower (factor of 2) than in the early 1980’s. However, it should be realized that the skills demand might have been more relaxed in those days. Furthermore, a steep rise in construction is to be expected within 10 to 15 years. This is due to the fact that not only additional nuclear power plants need to be built to keep up with the growing nuclear energy demand, but also to replace the current nuclear reactor park. In order to deal with this steep rise, the nuclear industry may consider buying time by extending the lifetime of the current nuclear reactor park.

5. Conclusion and policy recommendations

The analysis of the supply and demand of nuclear experts in the EU for the years to come leads to the conclusion that the need for these nuclear experts exceeds the number of young people who will be ready to enter the nuclear workforce. This conclusion must constitute an important warning for the whole European Union. Indeed, nuclear plants must be safely operated, maintained and eventually decommissioned. Specific skills are required for these purposes. More students and new talents should be attracted in order to develop an adequate flow of nuclear experts for the long term sustainability of the sector. This can be achieved only with the active cooperation of all actors involved.
First, national policy-makers must tackle this problem and anticipate such call for more nuclear experts in their governmental decisions.

Second, the nuclear industry should interact more and better with national competent ministries so that the issue of availability of expert nuclear workforce is brought up onto the national political agenda more consistently.

Third, the nuclear industry and the universities could better interact so that the available and forecast nuclear workforce is monitored.

Fourth, universities have a responsibility to better communicate to the national policy-makers about the need to reinforce nuclear education and training programmes and to attract the younger generations of students towards nuclear education programmes.

Fifth, the European Commission can sustain these efforts by a macro-level monitoring and promotion of monitoring activities by national institutions on the supply and demand of nuclear experts in the 28 Member States. The collection of data by national authorities and the analysis of these data at a European, as well as national, level will allow us to have a better view on the current situation and produce more accurate predictions on future trends.

Sixth, in the framework of the picture described in this paper, mobility of students and personnel across European universities, companies and institutions operating in the nuclear sector constitutes a source of possible solution. This mobility could in fact solve problems of weak nuclear workforce in one MS by the employment of skills coming from other MSs of the EU. However, mobility raises several issues for its practical execution, namely the mutual recognition of qualifications and skills.

EHRO-N constitutes an important European initiative for improving the interaction among nuclear organizations on both the demand (e.g., nuclear industry) and supply side (i.e., universities) and for monitoring the presence and evolution of nuclear experts available in Europe. Therefore, the initiative has been supported by European institutions, national authorities, the nuclear industry and the academic milieu.

At EHRO-N, we envisage to focus during the following years on the following priorities:

- More collaboration with national initiative for the monitoring and analysis of the demand/supply of nuclear experts through the promotion of national surveys;
  
  Contribution to the development of nuclear skills in Europe by promoting national capabilities for HR development;

- Increase in the communication activity which we will adapt to the targeted audience, i.e. governmental, higher education, and private organisations;
- Exploration to channel this communication also to the EP and the Council of Ministers in order to influence policy developments at the EU level.

References


NEW SIMULATION TOOLS ACTING LIKE A MAGNET TO ATTRACT
YOUNG ENGINEERS

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ABSTRACT

“A third of all workers in US Nuclear plants will be eligible to retire the next five years”. Such forecast along with the need of personnel for new nuclear units makes it imperative that nuclear business attracts, retains and develops their young staff.

But the new generations of young engineers who have been exposed for years to all types of gamings, are visual learners and need new learning environments. Therefore making it necessary to create interactive training environments and project an image of innovation and modernity in the nuclear industry.

Tecnatom, as a training center engaged with a full qualification process of young engineers, from their recruitment up to their assignment to nuclear plants in operation, has extensive experience in modeling and supplying any type of simulators in the power industry.

Nowadays Virtual Reality is a mature technology able to be integrated with simulation models and emulate the real world with high fidelity. Training environments, made up of accurate models with an interactive virtual reality based interface and the ability to run training scenarios in your own portable equipments, appear to be creative and motivating tools for young people.

To further analyze and implement such concepts Tecnatom has developed the following interactive training environments:

- Process Behavior 3D Visualizer

Because of the difficulty to understand the phenomena that take place in systems such as the nuclear island, an interactive environment based on high fidelity simulation models coupled with 3D virtual reality, allows the monitoring of the internal process in situations such as bubble generation in different flow regimes.

- Field Operators Training Environment

Local operations usually imply the need to access and stay in infrequently visited radioactive areas. This training tool allows the extension of the use of full scope simulators to local operators by enabling them to handle local equipment and observe the plant response in real time. First, field operators have to access and identify the right equipment, walking through the different plant areas. Once the equipment, or control panel, is identified, they can interact and get the process response. Augmented reality strategies are also used to enrich the virtual world where the trainees are immersed.
1. Introduction

The aging workforce is one of the main concerns for the nuclear power industry. The largest percentage of the workforce population in US is represented by the baby boomers, workers between 50 and 67 years, implying that the number of retirements has already started being very significant and will follow this trend in the next years. According to the Nuclear Energy Institute, a third of all workers in US Nuclear plants will be eligible to retire the next five years. This situation is not so different from Spain, where the majority of nuclear plants were constructed in the 80’s and consequently, nowadays they have an aging workforce that is beginning to retire in large numbers.

Such forecasts are not optimistic, as this large number of retirements implies a loss of experience and knowledge for the nuclear business, a business that requires thousand of skilled engineers to maintain and operate the current and new nuclear plants.

Facing this situation, attracting, hiring and retaining new engineers has obviously become a priority for nuclear plants and great efforts are focused on the training and development of this new personnel.

However, in this era when we mention new workers we are referring to the Generation Y, also called internet, net or digital generation as they have grown up with technology at their fingertips and consequently, they think, learn, communicate and process in ways that may be unfamiliar to those from another generation. Nevertheless, this is the new generation is coming and companies are forced to update their strategies to optimize new engineers’ talent.

By analyzing the differences between generations, nuclear plants may define the next steps to be followed in order to ensure the transition to the next generation of nuclear industry workers.

Visual modes of learning have been preferred by a large percentage of the population, but they are especially important for this generation who grew up with lots of visual stimuli and so, this is one clearly notable characteristic of them, they are visual learners who prefer discover rather than be told.

In addition, another characteristic of this group is that they are often able to quickly switch from one task to another, and they are more comfortable when they are engaged simultaneously in multiple activities than just doing one thing.

The know-how transfer from experienced people to newcomers along with the reinforcement of safe behaviors, systematic training designed specifically to ensure the necessary competences in the different plant jobs and the process made in Information/Communication technologies for training, have been key factors for the change.

Tecnatom, with the aim of achieving a high qualification in the power plants personnel in order to make them capable to operate the plant in a safety and efficient way, has been offering training services in nuclear power plants for over 50 years. Tecnatom training services are addressed to different categories of personnel, such as licensed operation personnel, licensed radiological protection experts, non-licensed personnel and sub-contractors and include the recruitment, selection, training and assignment of the candidates to nuclear plants in operation.

With regards to the training scenarios developed by Tecnatom it is worth emphasizing the use of the Full-scope simulators and Interactive graphic simulators that Tecnatom develops with its own simulation technology, giving the models a highly accurate level of engineering with thermo-hydraulic and neutronic codes based on best estimate simulation technology adapted to real time.

With the goal to increase the quality in training services, and based on the experience gleaned over the more than 50 years in activities associated with the area of simulation and training, Tecnatom supports today the integration of Virtual Reality tools, nowadays a mature
technology able to be integrated with simulation models and emulate the real world with high fidelity. Tecnatom has implemented it in its training services in order to simulate virtual scenarios for real world scenarios and visualize complex phenomena and thereby, adapting to the new learning methods of young engineers who are visual learners preferring learning by doing.

In line with this, student motivation has always been a factor in pushing students to become more successful and nowadays the trend to engage students, increase their motivation and improve learning outcomes is the game-based, including some of the common game elements as challenges, rewards, skill levels or recognition systems. Besides, new learning methods usually provide highly interactive technology that keeps students engaged with nonstop actions, realistic sounds and vivid colors while providing educational instruction. Training tools, provided by Tecnatom, disguised as games will capture and hold new engineers’ interest. And more over as these applications reproducing training environments, made up of accurate models with interactive virtual reality based interface, can run in their own portable, tablet or any display device what makes them tools even more creative and motivating for young people.

2. Recent experiences on creative training environment

Full Scope Simulators are well known tools in the training programs of NPP personnel. A Full Scope Simulator (FSS) provides a high fidelity replica of the control room and an accurate representation of the real-time process. However, in order to understand the phenomena that take place in systems or how field operators learn to do the local operations, Tecnatom has developed new tools using the technology that can make these activities possible in an efficient manner.

Process Behavior 3D Visualizer

In order to easily understand thermalhydraulic phenomena inside the systems, Tecnatom has developed an interactive environment based on high fidelity simulation models coupled with 3D virtual reality.

The Virtual Reality allows the visualization of the plant in 3D in a more realistic way to better understand the interaction between systems. Besides, it also allows to have the possibility to move around and to watch inside of the plant components.
Furthermore, as the tool is coupled with accurate simulation models, once the application has established communications to the server, users are able to monitor any of the parameters calculated in the codes that will be displayed in a dedicated menu in the control area. The visualization is a continuous representation of the discrete nodalization, made using chromatic information supported by color interpolation to better highlight how the values propagate in the system and when a variable is selected its chromatic scale is presented on one side of the screen for reference. The entire system appears semi-transparent and the component cell variable values are shown as color gradients according to variable value and chromatic scale. Students will be able to appreciate the variable time evolution observing component cell color changes. Furthermore, they may change the parameter displayed at any moment choosing the most appropriate for each instant, and they decide the values of the maximum and minimum scale in order to understand at a glance what is happening inside the systems and how values propagate.

This application can be executed in any display device and students can interact with the tool whenever they desire. However, Tecnatom has updated its e-learning platform including the access to this Virtual Reality tool in its training lessons in order to reinforce in a visually manner the learning of the students who will be able to follow the lesson while interacting with the tool. As an example, when describing the components, or how systems interact between them, this tool offers visual features that help to better understand these steps of the training.

In addition, explanations about the systems behavior in nuclear accidents or normal situations where made using reading texts so far. Nowadays, Tecnatom has reproduced some scenarios in the simulator and displayed the output in its virtual reality tool. The results have been recorded and added as training material with which students can play, stop or backtrack to better understand the situation, and what is happening inside the systems.

These videos including additional information in text and audio format are aimed at reinforcing the understanding of the thermohydraulic phenomena and the behavior of the system after operators’ actions and they have also been added as additional information in Tecnatom’s e-learning platform.
By using the features of the application as a help for the training lessons, users easily understand how systems interact between them and what happens inside the system. By interacting with the simulator while students are having a visualization of the plant, students better understand the consequences of their actions.

Field Operators Training Environment

Field Operations play an important role in the global NPP behavior; consequently field operators have to be soundly trained to perform frequent and infrequent but critical actions under any plant condition. Especially in emergency situations, operator proper skills and a fast response time is crucial. Traditionally, training of fields operators is performed following an on-the job approach implying an operator exposure to radiological environment. This strategy is also limited because the operator cannot perform real maneuvers for training purposes while the plant is in operation. Additionally, control room and field operators are trained with different programs without any meeting points in their training systems.

As a result the present training programs do not integrate both perspectives, showing relevant drawbacks, such as:

- Full scope simulators do not accurately reproduce local actions. They only have the so called remote functions, allowing the instructor to play a role of a field operator to perform certain local operations at the instructor station as demanded by the simulator trainees. This supposes a limitation to the training scenarios.

- Maintenance activity preparation implies visits to radioactive areas, which entails an increase in the personnel dose. To become familiar with the equipments and operation panels distributed throughout the plant as well to get the ability to localize and identify the right instrument it requires to stay long periods of time walking through the plant facility. When the equipments are located in a controlled area it is necessary to minimize the time spent to find the right equipment.

Tecnatom has considered that putting together in one integrated tool full scope simulation and virtual reality, it is possible to achieve an efficient solution to these problems and so, Tecnatom has developed a tool coupling Virtual reality with Process Simulation, so enable to integrate and coordinate both groups training needs.
Virtual reality allows us to “walk”, “see” and “feel” very close to reality without staying in radiological areas, providing not only images, but sounds and environmental characteristics, making the operator feel as if he were in the real plant. On the other hand, and related with the key factor of simulation itself, the accuracy in the expected functional fidelity will allow the field operator completing the action that he is supposed to do, and observe the consequences in the plant status.

Once both technologies are coupled, the actions taken by the field operators will impact in the simulation system, and actions performed in the control room will change the information visible to the field operator. Coupled training will also improve the communication abilities in the team.

Beyond the features that the Virtual reality provides, we also highlight the Augmented Reality capability of the tool that enhances the virtual reality by overlaying graphic three dimensional images on the virtual world. As an example, dynamic trend diagrams can be activated-deactivated by the user anytime during the plant walkthrough or a task procedure.

This tool is undoubtfully very useful to be used in:

- Requalification of field operators together with license operators
- Initial Training of field operators
- Initial Training of license operators
- Supporting operation briefings
- Supporting plant modification design
- Preparing maintenance activities and related local actions (scaffolds,...)
3. Conclusions

The need of recruiting new employees due to the generational change has become a priority for the nuclear industry. New generation of young engineers is required to enter in the labor market and so, great efforts are focused on the training and development of these new personnel.

Taking into account the transfer of knowledge required and assuming new technologies are a magnet for young people, Tecnatom has developed new training tools in order to understand the phenomena that take place in complex systems and to help fields operators in local operations.

Each of these applications not only can run independently, using the diverse features implemented on them, but also can be connected with full scope simulators. This integration makes it possible the creation of new training environments where dynamic simulation and its visualization are integrated with virtual worlds.

In addition to training purposes, the ability to run training scenarios on any display devices appears to be a creative and motivating tool for young engineers.
Recruitment of undergraduate students to any science or engineering discipline often involves offering an introductory course to attract and pique the interest of the learner. Competition for the student in specialized fields such as nuclear science and engineering is very keen with an array of choices to the undergraduates. In spring 2013 we introduced a new three credit-hour course entitled Concepts in Nuclear Science and Engineering to specifically attract students into our undergraduate Nuclear and Radiation Engineering Certificate within the Mechanical Engineering Department or the Radiation Physics option in the Physics Department. The self-contained lectures include a broad base of all topics and technologies encompassed in nuclear and radiation engineering history of nuclear science and noble prize winners, radiation in the environment, environmental effects of electricity generation, nuclides and isotopes, isotopes in everyday life, radioactivity, nuclear reactor theory, food irradiation, nuclear medicine, nuclear power and the need for the future, nuclear fuel cycle, nuclear terrorism, nuclear non-proliferation, nuclear security culture, homeland security, radium in the environment, nuclear and radiochemistry, and probabilistic risk assessment. Two on-line lectures are also given by the certified health physicist in health physics training. Three individual laboratories are given for a half-life measurement; simple radiation shielding; and determination of uranium in soil samples by neutron activation analysis. A 10-12 page paper on any aspect of nuclear science or engineering is also required along with a tour of the 1.1 Megawatt TRIGA research reactor.

1. Introduction

In the past several years there has been a noticeable increase in nuclear engineering and related programs in the USA, Canada and Europe. While some of these programs are fully fledged nuclear engineering degrees, many more are technical options, certificates, minors, etc. At the University of Texas at Austin an undergraduate nuclear engineering option has existed within the Mechanical Engineering Department for many years. However, in the past several years a serious effort was made to recruit more undergraduate students to the program from Mechanical Engineering and Physics. One of the key recruiting tools has been the introduction of a one-hour survey course given to undergraduate students to increase their knowledge of the various aspects of nuclear science and engineering and its applications. The lectures are also augmented by seminar speakers from the nuclear industry and national laboratories.

Since 1998, the successful one-hour elective course entitled Concepts in Nuclear Radiation and Engineering (ME 136N) has catered to students in Mechanical Engineering, Physics and various other departments. It was given every semester and has had an average of 20-30 students per semester. Topics have included global warming, alternative and renewable energy sources, nuclear medicine for various cancer treatments, maintaining nuclear power plants to reduce climate change and air pollution, and the uses of nuclear technology in enhancing industrial processes such as food irradiation, medical sterilization, etc. While the students have benefitted from such introductory concepts of nuclear science and
engineering, the rigors of mathematical presentations and more in-depth analysis is not permissible for a one-hour course. The re-design of this course (ME 379M) essentially elevated the content of these topics to a fully-fledged three-hour elective. This more in-depth course, better prepares students that progress on to the more advanced nuclear engineering courses in their junior and senior years.

Within the nuclear industry nearly two-thirds of all in-coming employees are either mechanical or electrical engineers. In the USA more than 14 million tests are done using medical isotopes for early cancer and other disease detection. The shortage of molybdenum-99 (Mo-99), the single most popular diagnostic radiopharmaceutical in the USA and world, has spurred the US Congress to look into the production of this medical isotope in the USA. Currently, all the Mo-99 is imported from four countries and there have been unforeseen disruptions in its delivery. A US National Research Council report in 2009 supported a US domestic supply of Mo-99. Thus, the need for many nuclear science and engineering students in the field of medical physics will continue to grow in the near future. This new course covers nuclear medicine in more depth and also allows more meaningful presentations of current Department of Energy needs, including nonproliferation, nuclear forensics and robotics in handling of special nuclear materials. We have developed educational materials for comprehensive introductory nuclear engineering concepts for undergraduate students deciding whether to enter into the field of nuclear science and engineering. These modules are used in the Nuclear and Radiation Engineering Certificate, Radiation Physics Option at the University of Texas and the Big-12 Nuclear Consortium. Additionally, three Historically Black Colleges or Universities (HBCUs) Florida Memorial, Huston-Tillotson and Texas Southern University have access to the complete course curriculum on a BOX website which also be made available to high school and middle school teachers to use for their own teaching purposes.

2. Course Description

In the first years of the course the lectures were based on introductory parts of other courses and review articles. However, an excellent survey book on nuclear science and its many applications in the everyday life entitled Radiation and Modern Life: Fulfilling Marie Curie's Dream was published in 2004 and is now the core text for the course. A critical review of this book has also been published by Landsberger (1). The book is segmented into distinctive parts. It contains virtually no mathematical equations, just very effective explanations and illustrations of basic nuclear properties and the application of radiation in a wide variety of areas in science and technology as well as the major impact it has in the public domain. A comprehensible explanation of the origin of naturally occurring radiation in the environment as well as a synopsis of radiation effects at low and high doses is given in the second chapter. The basic concepts of radiation interactions are provided in the third chapter, in which fundamental processes are clarified in uncomplicated terms. Radiation in agriculture, medicine, and nuclear power is well explained in the next three chapters. Each of these areas is treated with detailed examples of the positive benefits of radiation, such as higher crop production, control of insect pests, improved medical diagnostic and therapeutic techniques, and the production of nuclear electricity. Sections on radiation applications in industry, transportation, and space exploration are equally well written. Topics include process controls, materials composition, cars and trucks, space missions, manned voyages, and the radiation-related health effects of space travel. Additional sections on applied radiation include topics related to terrorism, crime and public safety, arts and sciences, and environmental protection. Excellent descriptions of work in antiterrorism efforts, archaeological investigation activities, soil erosion, and air pollution studies are given. In an additional chapter, the impact of radiation on the economy is also very well described.

Since the topics are broad-ranging, this course provides an opportunity for the instructor to implement risk/benefit analysis of the use of nuclear methodologies in everyday life situations. Many undergraduate students in science and engineering are taught the concepts of reverse engineering, novel design techniques, problem solving, etc. in their core curriculum. However, risk/benefit analysis (the newer version of pros vs. cons) is seldom enunciated in the classroom. In fact, this type of analysis is the cornerstone of many industrial innovations, medical professions and even military decisions. In this redesigned course there was ample opportunity to elucidate these concepts in the context of the course material. For example, the student was required to assess the various energy strategies and economics of renewable sources versus traditional ones such as coal, oil and nuclear. In non-proliferation issues the impact of various national and international policies were examined as they pertain to international and homeland security. In medicine, the risk/benefit of being administered a nuclear isotope for diagnostic or therapeutic procedure was discussed. This redesigned course will hopefully act as a conduit to spur students to consider the important aspects of risk versus benefit in their academic and employment pursuits.

Homework: Several chapters in the book are assigned to answer homework questions. Included in the weekly homework assignment are on-line videos to watch and comment upon. The videos include: Atomic Café, Lessons from Nature for Waste Disposal, Dirty Bomb, Russia’s Nuclear Navy, Medical Imaging, US Nuclear Officer Propulsion Program, Russian Nuclear Materials, Back to Chernobyl and Nuclear Terror. Additional homework assignments included questions on radioactive decay, table of isotopes, risk assessment, nuclear safety, etc.

Research Reactor: A virtual tour of the TRIGA research reactor at the University of Texas was given to all the students before they actually visit the facility. This pre-tour visual lecture was very beneficial to explicitly discuss in detail the various operational procedures of the reactor so that the students can visually familiarize themselves before the visit.

Invited Guest Speakers: Whenever possible invited guest lecturers from national laboratories, industry representatives, regulators from Nuclear Regulatory Commission or on-campus Nuclear Navy recruiters present material which augments the classroom experience. These seminars are critical to give the students an appreciation of the employment and research opportunities.

Laboratory Component: The three experiments consisted of the following:

1) Half-life measurement using an isotope prepared by neutron activation analysis
2) Shielding of beta and gamma sources
3) Determination of uranium in environmental samples by neutron activation analysis
3. Course Delivery

In the last fifteen years there has been a variety of technological advances made in various educational endeavors. These began with simple PowerPoint lectures in the 1990’s. Sophisticated Distance Learning platforms were more common in the late 1990’s, while animations were being integrated in many different lectures in the science and engineering courses. Software animation programs such as Flash are now routinely used by many students in the arts, science and engineering departments. In the Nuclear and Radiation Program at the University of Texas animations have been part of several courses including Concepts in Nuclear and Radiation Engineering, Health Physics, Health Physics Laboratory and Radiochemistry. It is well known that a “picture is worth a thousand words”, and animations, when used judiciously, can enhance the learning experience of science and engineering concepts. This is especially true when describing mathematical formulae or data such as that from gamma ray spectroscopy measurements or medical isotope production (2-8). The Faculty Innovative Center in the Cockrell School of Engineering has a team of computer graphic artists and animators that helped us develop more sophisticated nuclear engineering graphics and animations.

All lectures and homework assignments were placed on the University of Texas BLACKBOARD educational site in advance of the lectures. Answers to homework assignments are uploaded and seen on-line by the instructor or teaching assistant. Two in-class exams were also administered. At the end of the course, a ten-twelve page survey paper on any aspect in nuclear science and engineering was required to be handed in on the last day of class.

4. Grade Evaluation:

The grade evaluation of the students was made up of several components:

1) Assignments given from the course book
2) Two examinations
3) Laboratory experiments
4) Research paper

5. Course Evaluation

Evaluations for the course and instructor were done using the usual forms supplied by the University of Texas. These forms were filled out in private on the last day of class and then handed in to the teaching assistant to be submitted to the Department. The specific questions as well as overall course and instructor evaluation for this course are shown below. The University of Texas uses only the last two questions as means of evaluating the course and instructor. The first questions are given as guideline to the instructor of the strengths and weaknesses of the individual parts of the course. Each student also has ample space for hand-written comments. The students overwhelming gave high evaluations for all facets the course. The evaluation criteria are shown below with an overall course and instructor evaluation. Each grade is out of 5 with 0 being the lowest and 5 being the highest. As can be seen there was a very high degree of satisfaction with the course and instructor.
<table>
<thead>
<tr>
<th>Question</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>The course was well organized.</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>4 (25.0%)</td>
<td>12 (75.0%)</td>
<td>4.8</td>
</tr>
<tr>
<td>The instructor communicated information effectively.</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>2 (12.5%)</td>
<td>14 (87.5%)</td>
<td>4.9</td>
</tr>
<tr>
<td>The instructor showed interest in the progress of students.</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>2 (12.5%)</td>
<td>14 (87.5%)</td>
<td>4.9</td>
</tr>
<tr>
<td>The tests/assignments were usually graded and returned promptly.</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>16 (100.0%)</td>
<td>5.0</td>
</tr>
<tr>
<td>The instructor made me feel free to ask questions, disagree, and express my ideas.</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>1 (6.3%)</td>
<td>15 (93.8%)</td>
<td>4.9</td>
</tr>
<tr>
<td>At this point in time, I feel that this course will be (or has already been) of value to me.</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>1 (6.3%)</td>
<td>1 (6.3%)</td>
<td>14 (87.5%)</td>
<td>4.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Very Unsatisfactory</th>
<th>Unsatisfactory</th>
<th>Satisfactory</th>
<th>Very Good</th>
<th>Excellent</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall, this instructor was</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>4 (25.0%)</td>
<td>12 (75.0%)</td>
<td>4.8</td>
</tr>
<tr>
<td>Overall, this course was</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>4 (25.0%)</td>
<td>12 (75.0%)</td>
<td>4.8</td>
</tr>
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</table>

6. References

(3) Perry, G., C., Egnatuk and S. Landsberger, "Design of a Neutron Shielding Laboratory for Undergraduate and Graduate Student Instruction" International Nuclear Chemistry Society News, VI/3, 38-44. July 2009,


7. Acknowledgements

We gratefully acknowledge the US Nuclear Regulatory Commission for funding the development of the course.
MOTIVATING YOUNG STUDENTS TO BE PART OF THE GLOBAL RESEARCH IN NUCLEAR THROUGH THE SEMINAR OF NUCLEAR FUSION

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ABSTRACT

Jóvenes Nucleares (Spanish Young Generation in Nuclear, JJNN) is a non-profit organization that depends on the Spanish Nuclear Society (SNE). The Universidad Politécnica de Madrid (Technical University of Madrid, UPM) was chosen to host the Seminar as it is one of the most prestigious technical universities of Spain, and has a very strong curriculum in nuclear engineering training and research.

Both, the UPM and the SNE, supported strongly the seminar: the opening session was conducted by the member of to board of directors of the Spanish Nuclear Society and Nuclear Engineering professor of the UPM, Emilio Minguez and the closing session was conducted by the director of the Nuclear Fusion Institute (UPM).

1. Introduction

Finishing 2011, JJNN and the UPM started to plan a new and first-of-a-kind Seminar in Nuclear Fusion. That Seminar was highly demanded by the Young Generation People for the last years, due to the need of information motivated by the huge fusion projects on-going in the world (ITER, NIF, etc.).

2. The Motivation

The goal of the Seminar was to give an overview of the nuclear fusion fundamentals and technology, introducing the audience to the research projects in nuclear. That was a great driver of the course as the participants were able to see what challenges are being faced and how much effort is being made in the energy research field. Their feedback told that it was motivating experience for them.

After a great effort from JJNN with the support of the UPM, the Seminar took place in November 2011 at the Industrial Engineering School (ETSII). The lessons were conducted by expert researchers in the field, who belong to the Nuclear Fusion Institute at the UPM.
3. The Development of the Seminar

The Seminar was structured in four sessions: introduction to the nuclear fusion fundamentals, inertial confinement nuclear fusion, magnetic confinement nuclear fusion and overview of the projects in nuclear fusion.

In the first presentation, Alberto Fraile clearly explained the beginnings and foundations of fusion technology, not excluding the references to the non-civil origins. The presentation included several videos and stories, with many interventions of the public in the question time.

The next presentation was developed by Manuel Cotelo, which clearly reflected the theoretical foundations of inertial confinement fusion technology and hinted ongoing projects and future prospects of this technology.

Later, Antonio Rivera introduced to attendees in the complex technology of magnetic confinement fusion, addressing its strengths and challenges, as well as deepen the theoretical concepts of this technology.

Finally, in the last session, Jesus Alvarez made a broad perspective of past, present and future projects of both technologies, highlighting the projects in which there are Spanish participants.

In the 2012 edition, thanks to the kindness of Santiago Sánchez-Cervera, the seminar was finished with a very interesting visit to the TJ-II Stellarator at CIEMAT facilities. That is why, besides the gratitude to the Technical University of Madrid, and in particular to the Superior Technical School of Industrial Engineers for the assignment of space we extend the CIEMAT, who very kindly attended the visit.

4. Conclusions

The seminar was very popular, with nearly 80 attendees each day, from the university, nuclear companies and research centers. After each session there were very interesting and animated discussions between the presenters and the public that demonstrated the interest of the attendees for the subjects taught.

Both, the UPM and the SNE, supported strongly the seminar: the opening session was conducted by the member of to board of directors of the Spanish Nuclear Society and Nuclear Engineering professor of the UPM, Emilio Mínguez and the closing session was conducted by the director of the Nuclear Fusion Institute (UPM).

The assistants were asked for a highly detailed feedback of each one of the lessons and those opinions have helped to review the program for the 2012 and 2013 Seminars, which took place also in November at UPM as well.
Figure 1. Public at the Nuclear Fusion Seminar

Figure 2. Attendees to the TJ-II visit in 2012
Seminarios de Fusión Nuclear

Universidad Politécnica de Madrid - ETSII
José Gutiérrez Abascal 2, Madrid
Noviembre 2011

**Día 21** Antecedentes históricos y fundamentos de la fusión
17:30-19:30
Aula C
Fusión en las estrellas, Reacciones fusión (D-D, D-T, otros...), Recursos y sostenibilidad: autoproducción de tritio, Necesidad y tipos de un confinamiento.

**Día 23** Fusión por confinamiento inercial
17:30-19:30
Aula C
Descripción del confinamiento inercial, Requisitos para ignición, Etapas, Targets (capsulas, Hohlraum), Tipos de iluminación(directa/indirecta).

**Día 28** Fusión por confinamiento magnético
17:30-19:30
Aula C
Descripción del confinamiento magnético, Tokamak vs Stellarator, Componentes reactor, Desafíos y dificultades por resolver

**Día 30** Proyectos en curso y retos futuros
17:30-19:30
Aula C
Perspectivas de futuro, Proyectos conf. Magnético (ITER), Proyectos conf. Inercial (HIPER)

Inscripción y consultas en www.jovenesnucleares.org
Inscripción gratuita. Aforo limitado por orden de inscripción.
INFORMING THE YOUNG GENERATION AND THEIR TEACHERS ABOUT THE CONCEPTS OF NUCLEAR ENERGY AND RESEARCH

Michèle COECK, Tom CLARIJS

SCK•CEN Academy for Nuclear Science and Technology
Boeretang 200, 2400 Mol - BELGIUM

ABSTRACT

Preserving and extending nuclear knowledge, skills and competences at the service of society is a key function of the Belgian Nuclear Research Centre SCK•CEN. Extensive experience in nuclear science and technology, performing innovative research and the availability of large and unique nuclear facilities make our renowned nuclear research centre also an important partner for nuclear education and training.

In the interests of maintaining a competent workforce in industry, healthcare, research and policy, and of transferring nuclear knowledge to the next generations, the SCK•CEN Academy takes it as its mission to provide guidance for young researchers, to organise academic courses and customised training for professionals, to offer policy support with regard to education and training matters and to care for critical-intellectual capacities for society.

This paper focusses on our activities for final-year high school pupils and their teachers. These involve thematic educational tours that provide insights into its many applications in today’s society, and a view of the daily practices in a research centre. On a monthly basis, final-year pupils and their teachers can participate in guided tours covering various nuclear themes such as research on radiation protection in space, the history and future of nuclear reactors, and the research concerned with finding solutions for the disposal of nuclear waste. The SCK•CEN Academy also provides supporting educational material and organises workshops for teachers. These workshops discuss the state of the art of nuclear research and share insights on the what, why and how of teaching a complex subject such as nuclear science and technology in class.

1. Introduction

Pupils have a wide attention span and are eager to learn. In our complex society, they should be able to develop an open and critical mind in order to gain more insight into the multifaceted issues such as the risks and benefits of radioactivity and nuclear technology, and their possible applications. In this sense, the SCK•CEN Academy (http://academy.sckcen.be) interacts with high-school pupils and teachers in order to (i) explain the basics of radioactivity and discuss several nuclear applications in, for example, industry and medical, (ii) give an overview of the status of nuclear research and a flavour of what the daily life in a nuclear research centre comprises, and (iii) discuss with teachers how the standard education programme can integrate a pluralistic approach to complex technical issues such as the applications of radioactivity.

The tools used to support this aim are a dedicated website (http://jongeren.sckcen.be) in the two national languages French and Dutch with general information on nuclear science and technology, the organisation of guided thematic tours at SCK•CEN laboratories, and topical discussion sessions with high-school teachers.

2. A dedicated website
In addition to the general SCK•CEN website, the Academy developed a website which specifically supports the high-school students and their teachers.

The site (http://jongeren.sckcen.be) is available in Dutch and French, and has specific sections for pupils and teachers. It contains general information about the R&D topics treated at our research centre, as well as basic information on nuclear science and technology. In addition, educational material (pictures, summaries, videos, animations, etc.) that can be used in the classroom to support teaching on nuclear can be found on this site. The pupils can also test their level of nuclear knowledge with a questionnaire. A "did-you-know" column refreshes with each new visit and aims at stimulating the curiosity of the visitor with daily-life facts and figures.

In case a visit to the SCK•CEN laboratories is considered, pupils and teachers can find all necessary practical information regarding the scientific themes, when and how these visits are organised, how to register, requirements to access the domain of SCK•CEN, checklist of practical arrangements, etc.

3. Thematic guided tours at the SCK•CEN laboratories

3.1 The different topics treated

On a monthly basis, eight times per year during the school season, the SCK•CEN Academy organises four different thematic visits. In general guidance is foreseen by SCK•CEN experts working in the relevant laboratories. The tour is given in the language of the visitors, and the level is adapted to the scientific background of the high-school pupils and is supported by posters and short power point presentations.

Thematic tour 1: four generations of nuclear reactors
This guided tour is focusing on how radioactivity is used to produce energy. The scientists of SCK•CEN guide the high-school pupils through the history of radioactivity, with the historical discoveries and applications in nuclear energy. The different characteristics of four generations of nuclear reactor are illustrated, together with the nuclear fuel cycle. The tour starts with a visit to the Belgian Reactor 1 (BR1), which is the oldest nuclear research reactor of Belgium, operational since 1956. This 4 MWth reactor is air-cooled and moderated with graphite with natural uranium as fuel. During the guided tour, the graphite configuration is shown, together with the control room. By demonstrating the advantages of this research reactor, insight is gained on the importance of nuclear research reactors for current applications in society, such as the production of medical isotopes, the irradiation of silicon and material testing. The tour continues with an explanation of the characteristics of the actual generations II and III, and ends with a description of the possibilities of future generation IV reactors. The SCK•CEN experimental facility VENUS and the GUINEVERE project are illustrated and the MYRRHA project, an accelerator driven fast spectrum research reactor with MOX fuel and liquid lead-bismuth cooling, is explained.

**Thematic tour 2: radiation in space**

Radiation protection is a major challenge in the industrial applications of ionising radiation, both nuclear and non-nuclear, as well as in other areas such as the medical and research area. To highlight the importance of protection of man and environment from potential hazards from ionising radiation, and the relevant research in this field, our research project regarding space applications is put forward as case study. The visitors are invited to reflect on the extreme conditions outside the atmosphere. A demonstration is given on how radiation is measured, with a link to the exposure to cosmic radiation of a spacecraft with astronauts. The radiobiological effects on different tissues are explained, with an insight into the human immune system and the impact of radiation on fertility and the foetus. The pupils are guided through the laboratory of our radiobiology unit, and experience the different techniques to detect genome expressions. With longer space journeys in mind, the visitor is stimulated to discuss the implications of space travel. Our microbiology research group focuses on the presence and consequences of bacteria in space. In the laboratory of microbiology, culture and detection of bacteria is demonstrated, with a simulation of space conditions. In addition, one of the projects of the European Space Agency (ESA) is demonstrated where organic waste is recycled in a bioreactor into oxygen and food (MELiSSA, Micro-Ecological Life Support System Alternative). Although this guided tour does not contain a visit to a large nuclear infrastructure, these research topics surely trigger the imagination of this young audience.

**Thematic tour 3: radioactive waste disposal**

This tour focusses on the treatment and geological disposal of nuclear waste, a topic with an important socio-political, ethical and trans-generational dimension. The economic interest group EIG EURIDICE (European Underground Research Infrastructure for Disposal of nuclear waste In Clay Environment), a collaboration between SCK•CEN and NIRAS/ONDRAF, possesses of a demonstration hall at the domain of SCK•CEN with interactive screens, videos, graphic representations and real scale demonstration models. It is at the disposal for these group visits and pupils can learn all about the safe containment and isolation of radioactive waste. When possible, a visit is made to the underground laboratory HADES, where research is done on a multibarrier system for geological disposal of highly active and long-lived radioactive waste. Experiments on waste form behaviour, container corrosion, radionuclide chemistry and migration, are highlighted and a first-hand experience on the excavation of Boom Clay is encountered. Also, a demonstration experiment is shown which examines the behaviour of the geological disposal system on a true operational scale. Since this guided tour involves visiting a research lab which is located 225 meters below the ground, this theme is quite popular for the high-school audience.
Thematic tour 4: reactor technology – from idea to reality

This topic was added recently and the tour was especially developed to show the importance of high-level and precise technical work, complementary to the scientific research needed to conceive and implement innovative nuclear applications. It specifically addresses students with a technical background, and focuses on the engineering aspects of reactor technology, with a visit to the technology building of SCK•CEN. In this tour, the pupils learn all about the different phases which are typical for research and development in the industry, going from the conceptual idea to the actual commissioning. In the technology building of SCK•CEN, new and innovative laboratory experiments are built on a semi-industrial scale. Currently, visitors can see an experimental loop for corrosion testing, experience ultrasonic visualisations and see several chemical behaviour experiments on liquid lead-bismuth. Most of these experiments are set up in the framework of research programme MYRRHA. In the same building, all instruments are built for irradiation experiments in the Belgian Reactor 2. The variety of experiments and the different profiles of scientists and engineers encountered during this visit, make the young visitor enthusiastic about the technical aspects of nuclear applications.

3.2 Participation and feedback

The SCK•CEN Academy started with the organisation of the first three thematic tours for pupils and their teachers in 2009; recently the fourth theme was added. From 2009 until November 2013, more than 500 high-school pupils have visited SCK•CEN, coming from more than 20 different schools. Most schools are located in the vicinity of Mol; about 30% comes from a place located more than 50km from our research centre.

Figure 1: number of high schools visiting SCK•CEN

In 2012, extra sessions were organised prior to the open doors which was held on the occasion of the 60th anniversary of our research centre. These are not taken up in the graph shown below; 108 visitors coming from 10 different schools paid a visit to SCK•CEN on that occasion.

Figure 2 shows the participation per theme visit.
In order to improve the overall quality of the scientific visits, the SCK•CEN Academy asked for feedback by means of a short questionnaire treating different aspects of the scientific visit. Of all questionnaires sent out since 2012, 81% response was received. Table 1 gives the summary of the feedback forms, indicating the satisfaction of the majority of the visitors.

**Table 1: Summary of the feedback of the school visits**

<table>
<thead>
<tr>
<th>Feedback item</th>
<th>very satisfied</th>
<th>satisfied</th>
<th>less satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td>53%</td>
<td>47%</td>
<td>0%</td>
</tr>
<tr>
<td>Documentation</td>
<td>42%</td>
<td>58%</td>
<td>0%</td>
</tr>
<tr>
<td>Tour guides</td>
<td>58%</td>
<td>42%</td>
<td>0%</td>
</tr>
<tr>
<td>Organisation</td>
<td>20%</td>
<td>77%</td>
<td>3%</td>
</tr>
<tr>
<td>Overall feedback of the visit</td>
<td>70%</td>
<td>30%</td>
<td>0%</td>
</tr>
</tbody>
</table>

In addition to filling out standardised scoring questions, the visitors were also invited to answer some open questions regarding their reason for visiting SCK•CEN, if they would recommend the visits to colleagues, if there were interesting topics not treated during their scientific visits, etc. From these open questions, some critical remarks were made towards the possibility to visit nuclear installations where access was restricted due to the safety and security policy. As a large nuclear infrastructure, it remains a challenge to be transparent in all research activities towards the public and at the same time deal with all necessary safety and security rules imposed by the authorities.

In general, we can state that these scientific 'field trips' are highly appreciated by the visiting high schools. The high-school teachers indicate that the treated topics are complementary to the regional imposed learning objectives, and welcome the demonstration of nuclear applications outside a classroom environment.

# 4. Workshops for high-school teachers

Complementary to the provision of educational material to be used in the classroom, the SCK•CEN Academy for Nuclear Science and Technology also discusses with teachers how the standard high-school education programmes can integrate a pluralistic approach to complex technical issues such as the applications of radioactivity, and what the most recent developments in nuclear research represent. During so-called "teachers' days", teachers visit SCK•CEN outside school hours, and discuss these topics with their peers and our experts. These workshops also aim to facilitate exchange of experiences related to perception of nuclear application, job opportunities, etc. by themselves and their pupils and how this potentially influences the choice of the pupil with regard to post-high-school studies.
The Academy also participates in workshops organised by regional associations of high school teachers in science. These events can be embedded into regional symposia, or exist as stand-alone continuous professional development initiatives for high-school teachers.

With these initiatives, the Academy aims to meet the requests of teachers who often express their lack of up-to-date information on nuclear science and technological evolution in different fields like industry and medicine. This additional information helps them to transfer correct information to the next generations.

5. Summary and conclusions

The SCK•CEN Academy for Nuclear Science and Technology highly values the young generation. By means of various initiatives for high-school pupils and their teachers, the current nuclear research and technology is brought into the classroom in an interactive way.

Educational material like illustrations, pictures, animations etc. are provided through our website.

In addition, visits to our research centre's facilities and discussions with our experts provide insights into the many nuclear applications in today's society, and give a view on the daily practices in a research centre.

While the science itself may not be controversial, its application often is. There is a growing awareness of the importance of being able to consider this wider context. The SCK•CEN Academy is unique in addressing this challenge by developing educational content and methods to raise awareness and stimulate thinking and discussion. This is also applied in these initiatives for high-school pupils and their teachers.

Through this mixture of theoretical approaches, on-site demonstrations, qualitative educational resources and an introduction of transdisciplinary aspects in the education at the undergraduate level, the SCK•CEN Academy stimulates an optimized knowledge transfer of nuclear science and technology to the young generation and contributes to development of critical-intellectual capacities for future society.
What are the interactions between nuclear education and civil society?
EMOTIONAL ASPECTS OF NUCLEAR CONFRONTATIONS:
CAN STUDENTS LEARN FROM PAST SITUATIONS?

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ABSTRACT

No one in the nuclear sector can expect to avoid confrontation with people who do not appreciate the development of nuclear activities. Luckily young “nuclearists” are seldom confronted with demonstrators at the door of their plant or office, but quite often early in their careers, they may be asked to participate in hearings, or encouraged to give talks to local schools or cultural associations. Confrontation can also happen within the family or during dinner parties with friends.

This means that nuclear students should learn about the emotional aspects of nuclear evaluation, about the fact that people’s “values” may be different and how this influences the interpretation of facts and figures. They should examine opponents’ arguments and the way they are presented in the media or during demonstrations. They should also be shown fiction in films and literature that, like the Simpson, are often accepted by the lay-man as an objective source of information.

The paper includes a selection of past events, documents, films and literature that could serve as case studies in a workshop/seminar within nuclear related studies.

1. Introduction

During the question time of a recent conference I gave in Namur (Belgium), I was asked why nuclear communicators or engineers willing to communicate with the public, are always taking a top-down attitude and not trying to listen to bottom-up information. This remark is probably not totally fair but it contains some truth. In most circumstances, we consider we should give information, make it understandable for the lay-people, answer his questions if any and if they make sense according to our criteria. Although we are aware our activities generate emotions, we consider our efforts should tend to alleviate them because for most of us, these scares are not justified.

“Communicating about the environment [ and this is also true for nuclear ] may have been seen in the not-so-distant past as mainly a matter of making the public understand the science and scientific evidence behind controversial environmental issues. Some of the most controversial environmental issues and debates of the recent period show a very different picture. Whether looking at the ozone layer, climate change, whaling, hunting, animal experimentation or the multiple issues relating to rapid advances in genetic modification and the bio-genetic sciences, it is clear that the battles over these issues are now much more to do with persuasive communication, with ‘winning hearts and minds’ than they are to do with understanding the ‘science’ behind these issues.”(1).

Presently, decision making by governments and parliaments is strongly influenced by what has been called by Louis Michel, a Belgian minister, “emocracy”. Politicians have been elected and they give some importance to their electors’ opinion. This is normal. But this opinion does not only rely on scientific or technological truth, it is influenced by the way the public perceives the situation and the emotions it creates. And emotions mark the human memories much more than technical facts.

Thus if we want to progress with our technical projects, we must listen to the emotions they create. We must listen to the opposition, be it rational or not. Opposition might accept a dialogue, as long as it feels it can influence decisions. But if it considers the circumstances
are such – e.g. the pressure of powerful political or financial interests - that there is a low probably that the discussion will lead to some changes, “disruptive actions” as Yves Citton (2) calls them, will take place and are justified.

Thus I think there is a lot to learn from past confrontations, be it dialogues or demonstrations, contradictory reports or slogans and banners in the streets. Analyzing the documents we can access on such situations in the past, the students shall try to discriminate between arguments coming from trained opposition and locals NIMBY rejections. They shall evaluate what their own reactions would have been in these situations ...

2. Some typical examples that could be used

Historical examples of movements against civil nuclear plants or transport of wastes and used fuels are so numerous that the main problem will not be to find one but to select among the best documented. The arguments pro and con have not changed very much with time so old situations can still be useful to study the respective positions. I tried to summarize some in my book “Dompter le dragon nucléaire ?”(3). It seems that disruptive demonstrations started in the USA at the end of the seventies by local opponents but also by hard activists who knew how to organize such actions, following their participation in movements against the Vietnam war.

Actions took place through demonstrations but also by conferences and publications of scientific papers e.g. those of Gofman and Tamplin, who received a large audience in university campuses and media. Similar developments happened in Europe. In France, in April 1971,1500 persons, Frenchs but also Germans, marched against the construction of a PWR at Fessenheim on the Rhine. The same year they were 15.000 against the Bugey power plant on the Rhone.

In Germany at the site of the future Wyhl plant, locals organised themselves in so-called Bürgerinitiativen, reacting against the “intrusion” of federal initiatives with pamphlets and demonstrations. In many places, site occupation turned into violent confrontation. In France, the “battle” of Creys - Malville against the construction of Superphenix in July 1977 was a violent confrontation with the CRS 1. Being fully involved in fast breeder designs, and my niece having been part in a prior more pacific demonstration on the same site in 1976, I collected heaps of press cuttings and pamphlets from both sides. The lack of dialogue between the two parties is flagrant. The objections of the locals grouped in diverse associations are well documented; the attempts to reach a consensus by the Conseil général and other authorities have been published e.g. in (4).

One of the situations in France that has lead to the most accessible documentation – very few cases have been studied in such details during so many years after the events – is the fight of the local population supported by numerous associations and scientists against the construction of a nuclear plant in Plogoff (Bretagne). It started in 1976 when the Conseil regional and the Conseil économique et social accepted the project. In 1978, the Conseil général du Finistère also approved the plant: 10.000 people and later 15.000 marched against this decision.

In 1980, the situation became a source of conflict; people opposed the installation of a “mairie annexe” to submit the public inquiry dossiers, protected by the CRS. Fights started early February and lasted five nights. Some were arrested and this lead to thousands of demonstrators in the streets of Quimper. Finally the objectors benefitted from the presidential election in May 1981: the project was cancelled when Mitterand was elected.

1 Compagnie Républicaine de Sécurité, heavily protected and armed police forces.
To analyse this case, there is first a book of photographs and comments published immediately after the events (5). At the same time, two persons who initially came just to support the locals, filmed the events. Nicole and Felix Le Garrec (6) received no financial support from film producers or other sources of finance but could present the resulting film in public places, totalling 250,000 visits in the cinemas. Twenty years later, Brigitte Chevet (7) decided to interview those who participated in 1980: she interviewed villagers, the mayor, EDF engineers, antinuclear activists, officials and politicians. She added images from archives and the result is an exceptional document. One of the participants in this fight wrote a book in 2004 (8) but the most extensive study was done by Gilles Simon and published in 2010 (9). This doctor in political science analyzes in the more than 400 pages of this study, the motivations of the participants and how they learned to be efficient through 7 years of social, political and physical fights. Finally very recently, two authors revived the memories with a spectacular “bande dessinée” (10).

Nuclear wastes treatments and transports of used fuels and wastes have always raised a lot of opposition in Europe. Efforts have been made by the organisations responsible for these tasks to obtain some acceptance. Nevertheless, these programs often lead to strong opposition, one of the most recent situation being the boycott of the public inquiry in Lorraine, on the Bure site for geological storage. These follow previous actions since years such as street sit-in.
The situation of waste management in Belgium remains quieter until now. Perhaps due to very progressive approach to formulate proposals to the government, and the concentration since the fifties of nuclear activities in a single area of nuclear research, fuel fabrication, wastes treatment and storage. The organisation responsible for the waste management, ONDRAF, obtained agreements for the storage of low level wastes in that part of country after a lengthy – many years - but successful consultation process between ONDRAF, local authorities, experts, environmental groups, locals, ...

In the same area, ONDRAF would like to store category B and C wastes. Since 1974, the experimental study of geological storage in clay below 200 meters is underway. Galleries with all types of experiments are operated. In 2006, the Belgian government asked ONDRAF to prepare a Strategic Environmental Assessment for the application of this solution. This evaluation has to include financial, economical, scientific and technical data but also societal and ethical aspects, probably essential to obtain public acceptance. In 2009, ONDRAF organised a number of consultations : the Dialogues to identify the various questions that worry the public, the Conférence Interdisciplinaire to collect advices from experts of different domains. But a most interesting approach was the Conference citoyenne (11) : organised by the Fondation Roi Baudouin, which has no connection with nuclear activities, but is expert in organising such meetings. They selected 32 citizens, representing different social and cultural positions. They declared : “none of us were experts on nuclear wastes but we took the challenge seriously and with enthusiasm, conscious of the societal importance of the subject”. They worked three week-ends, identifying the particular themes they would like to investigate, questioning the experts, defining their positions and summarizing them in a remarkable short report that was presented without delay after the last session. This process lead to an interesting conclusion : acceptance of the geological solution as long as it could be re-evaluated every ten years during the first 100 years.

If the ONDRAF actions lead to a report to the government in October 2011, decisions by the authorities are not yet taken. A similar process, with an even larger public consultation, was launched in November 2012 by the French government to define with the public, the future “energy transition”. The objective was to propose a plan to the parliament in autumn but the project was so ambitious with such a large number of meetings and consultations - 170.000 participants in about 1000 meetings - that the synthesis will be a hard job and the conclusions might frustrate a large part of the participants. The Mouvement des Entreprises de France (MEDEF) already considered that the debate was inconclusive . Nuclear was somehow pushed aside from the start due to the President’s statements : early closing of Fessenheim plant and a reduction of nuclear electricity with a target of 50 %.

These are just a few examples. They show that depending on the time that can be devoted to the studies, the case must be carefully chosen, avoiding those that are insufficiently documented but also the situations that would be too wide to be interestingly analysed in the time allowed.

I took the examples above among the ones I knew best, mostly in France and Belgium, to show the sort of information that can be examined. But the interesting cases are many; In Great-Britain a well documented case is the controversy around THORP reprocessing plant with a basic book to start from : The politics of anxiety (13). The author was helped among others by two scientists deeply involved in the debate: F.G Berkhout and G.P. Walker from SPRU. The discussions around the PWR in Sizewell is also a well documented case starting with the Greenhalgh paper (14). Its summary gives a good overview already:

“The author sees the Inquiry as the latest in a line arising from government’s wish to achieve greater public participation in controversial decisions. He believes that the Sizewell Inquiry is unlikely to shake the public out of its apathy; while a decision that goes against them will not satisfy the objectors. The concept of the Inquiry is based on the belief that the legal process will unearth objective truth, while most of the issues are matters of opinion and judgment. The wide-ranging terms of reference are leading to constitutional anomalies and attempts to
take on Herculean tasks in the search for objective truth. However, while concluding that an Inquiry Commission adopting a legal approach and following courtroom procedures is not a satisfactory way of dealing with large-scale technological projects, the author finds it hard to suggest alternatives short of more direct parliamentary control.

A quick look on the internet or any history of nuclear opposition, will also immediately give examples in Germany, Spain, Switzerland and many other countries like China where people demonstrations forced the government to cancel a uranium processing project out of respect for public opinion (15). A starting point can be the sites of the opponents organisations e.g. Greenpeace, Friends of the Earth, Sortir du Nucléaire (France, but also Switzerland).

3. What did we learn in a previous analysis of opponents actions?

Years ago, we were confronted in Belgium with an organised opposition to the recycling of plutonium in Belgian reactors and the extension of the MOX fabrication plant. It lead to two years of demonstrations in front of the plants and in the streets and debates in the Parliament. It was a sort of companion campaign to the well-known - at the time,- anti-THORP campaign conducted by the international anti-nuclear lobby (12).

The main lesson we learned during this period, was that creating confidence is the major factor of success. This can only be the outcome of a long term in-depth action. Meanwhile, you cannot avoid a campaign against your nuclear projects. Thus when you plan a new activity, you must evaluate potential scenarios of the opposition and define your position towards the various pressure groups that might interfere in a possible debate. It must take into account that such a situation may last years on a single project and during this period to win a battle does never mean the end of the war. As the boy scouts are supposed to be, be prepared!

You have to devote as much time to the local context as to scientific or technical facts. Approach of objections in the last ten years were very different near Mol, a nuclear area in Belgium, from what it was in Plogoff in the eighties. In some circumstances, Industries tend to offer information prepared in layman’s terms, as most people have no time nor the adequate background to study technical or economical documents. But does the climate of confidence exist so that people do not simply reject this information, calling it intox ? Greenpeace among others is well known for its “never compromise” attitude so that it will reject the nuclear experts and bring forward its own that the public will believe more easily, suspecting the others of being “thick as thieves” with the nuclear business.

The role of the media is essential. Unluckily, in most cases in does not support nuclear activities. In Belgium, this is no surprise as a recent study by the Association des journalistes professionnels in April 2013 found that 45% of them, would vote green. Nevertheless, if well prepared in advance with interesting and attractive data, contact can be established, sometimes with the help of professional intermediates, obtaining more objective presentations in the media. A typical example during the MOX campaign was to provide a film of the complete process in the factory, without comments, only industrial noises, so that the televisions could illustrate their reports on plutonium activities with realistic images instead of atomic bombs explosions...

We concluded the PIME presentation saying that it is time for industrial professional associations to ring the alarm bell and not simply wait until each of us is being challenged in his daily activities and has to fight for himself. Since 1994, nuclear industry did react and the professional associations worked to find democratic ways of developing nuclear activities with the population’s consent. Nevertheless, each of us is still subject to nuclear objections in our daily life, objections coming from nearby friends or local movements. Sometimes it is not easy to reply calmly. But we must learn, otherwise the result can be disastrous. During the
Fondation Roi Baudouin working week-ends I mentioned above, one of the experts lost his temper while defending the fact that his private company would manage the funds necessary to maintain the geological storage. The result was that the group recommended to transfer this task to a public institution...

4. Practically, how could we proceed?

When selecting the case, consideration of the time allowed will be essential. I do not propose to analyze the consequence on the public opinion after Three Mile Island, Chernobyl or Fukushima, although it is documented in a large number of publications: books and films, internet sites, facts and fictions. For those interested, I give a first approach of these situations in my book (3) and I will not develop it here.

Rather, I would recommend to select a real situation that concerned the students as much as possible. If they are all from the same country, the last local opposition, which is sufficiently documented, would be the best. This condition could not apply to an international group of course but I would nevertheless chose a real case and not build an artificial situation.

If the teaching staff would not devote more than a day with no advance preparation by the students, they would have to collect the documents, possibly even summarize or translate some of them. To do the search, they might call for help from people who have been working on such subject like I did! If I look at my own archives, I can find a number of cases where I have piles of press cuttings, books and films.

For courses that extend over longer periods like a year, with courses a few days every month or week, students may be asked to do their own research, to propose the event to be studied, select one and form small working groups. Another organisation would be required when students come from all places for residential courses lasting a few weeks, like the World Nuclear University in Oxford. Usually, they have to register a long time ahead and thus can be asked to propose cases. The teaching staff would select among them to form small groups; the students would be offered to chose among these, be confirmed in their choice by the staff so that they can collect information before they arrive. Thus the working groups during their residence could devote the time allowed for this subject, mostly to the analysis, the discussions between them and the presentations of their findings.

The objective is that students realize that opposition is a mix of rational argumentation and emotional objections, that bringing information is not sufficient. Opponents expect us to listen to their arguments, even if we consider them out of place. When people think that discussion will not drive changes, they will often consider that disruptive actions are justified. Then we are confronted with demonstrations and sometimes violent actions. It is better that students become conscious of this before they are involved personally.

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12. Ph. Massart, P. Verbeek et A. Michel – *Two years debating MOX in Belgium, A case study* – PIME Conference 1994
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More references – also in English and German - on these subjects in my book (3). For those interested but who do not read French, I am willing to simply send copies by email of the reference list (167 references). Email your request to am462568@scarlet.be.
THE project started from the consideration that the subjective perception (sensation) of the risk doesn’t correspond very often to the objective and real risk of human activity. In particular, our perception of radioactivity is often misleading because of the lack of accurate information. A way to approach this theme, to make the public more trusting of nuclear issues related also to medical applications is to discuss radioactivity and ionizing radiation starting from young students. An experimental activity that involves secondary school students has been developed. It allows them to provide basic and correct information with the added benefit of being able to an experimental approach. On this basis was developed a project concerning the Italian secondary school, whose core idea is: (i) to provide the students a furnished laboratory at their school so that they can measure the radioactivity starting from the natural components that is a part of our environment. In this exercise, the measurement of the $^{222}$Rn concentration is particularly well suited; (ii) to show the different types of radiations including ionizing radiations and how they are related each to the other; (iii) to demonstrate how ionizing radiations can be measured; (iv) to prove the fun a student can derive from discovery and detection of ionizing radiation.

1. Introduction

Usually the lack of information cause to be afraid about what we don’t know, imputing to it a greater hazard. On the contrary we face up, without fear, activities that have a high level of riskiness, but for which we have direct experience. In other worlds the subjective perception of the risk very often doesn’t correspond to the objective and real risk of an activity. In particular the radioactivity theme is misled because it is almost unknown and a reason for general heightened sense of concern about radiation may be the lack of reliable and accessible information for not expert people [1].

A way to make the public more trusting, to help to build up a personal understanding to have a more rationally reactions, is to open a discussion about these themes, starting from young generations [2].

On this basis in Italy, with the aim to disseminate the scientific culture, several University Physics Departments with Lauree Scientifiche Project, funded by Italian Minister of the University (MIUR), and sections of the National Institute of Nuclear Physics (INFN) with ENVIRAD-SPLASH Project start, few years ago, an activity especially devoted to students and teachers of the Italian secondary school system, that would give them the opportunity to
discuss and to experiment with nuclear related experiences [3]. The students were provided basic but correct information with the added benefit of being able to make experiments by themselves. Moreover, this program offers the students an opportunity to understand the meaning of a research activity [4].

The core idea is to assist the students to understand that radiation sources produced by man and in particular after the Chernobyl severe accident [5] contribute with negligible exposure if compared with the natural sources from cosmic and terrestrial radiation [6]. The best way is that they by themselves measure the natural component of radioactivity to realize that radiation is a natural component of the air we breathe, of the earth we walk on, of the homes we live in, of the food we eat and of human tissues and bones. In this exercise the measurement of the $^{222}$Rn concentration that alone – according to ICRP – contributes with the 55 % of the total exposure which an individual receives annually is particularly well suited. This specific topic induces students to be confident with nuclear science, introduces in correct way the problem of the radioactivity, involves students in physics measurements, in handling equipment, in data analysis, in result report, stimulates students to know environment where they live or study linking also radioactivity knowledge with other disciplines as geophysics, biology, engineering.

2. Materials and Methods

The project has a national valence with the implication of many schools for each Italian region. At each school the students at their own set up a small-scale radiation laboratory, where are directly involved in indoor radon measurements. In order to can make an intercomparison between the different schools, to provide a scientific value to the activity and the results derived there from, so as to standardize the results and methodology, in all locations is adopted the same type of detectors. In particular at each school that participates to the project, nuclear training kits are distributed. The kits, composed of low cost instrumentation, include passive dosimeters CR39; small plastic boxes to be used as expansion chambers; a fryer to be used as thermostatic bath to develop the dosimeters; a cheap optical microscope with webcam interfaced to a PC. The detectors are prepared by students themselves, by cleaning in distilled water and treating with antistatic solution and, after drying the detectors are placed and packed in diffusion chambers. Afterwards students started the survey procedure positioning the dosimeters and filling data sheets with information on the sampling sites (address, building characteristics, room characteristics) and radon devices (device code, period and place of exposure, device position within the room, etc.). After the CR-39 dosimeters exposure for an integrate period of 6 or 12 months, the students are involved in etching procedure too, with a 6.25 M NaOH solution at 80°C for 6 hours, in order to enlarge the alpha tracks, and on the CR-39 reading at the optical microscope equipped with a web camera connected to a personal computer, for the track counting to determine density and then radon concentration values. Outputs were extracted as radon concentration in Bq m$^{-3}$, which represents integration over the entire exposure period of the solid state nuclear track detector.

In Fig. 1 is shown the exposure, development and track reading procedure. The instrumentation, even if not so sophisticated, is the same of the one required for the measurements of indoor radon concentration by the Italian Radioprotection Law (Dlgs 230/95, 241/2000 and 257/2001), that imposes in the underground working place concentrations that not exceed 500 Bq.m$^{-3}$. In Italy the guideline for radon concentration in homes recommended limits be lowered 400 Bq.m$^{-3}$ for the existing buildings and 200 Bq·m$^{-3}$
for the new ones: for higher Rn concentrations, measures, through suitable mitigation techniques, should be undertaken [7].

Fig. 1 – exposure, development and track reading of CR39 dosimeters

Each group of schools related to the different Italian Regions independently can complement with other methods of detection. In particular the students of Regione Lombardia compared the values measured with CR39 dosimeters with the results obtained with active portable radon monitor based on ZnS(Ag) solid scintillation chamber – or Lucas cell – (PRASSI, Silena, Italy) that can work in continuous and “grab sampling” way and by gamma spectrometry of $^{222}$Rn chain daughters ($^{214}$Pb, $^{214}$Bi), whose activity is accumulated in charcoal canisters (EG&G ORTEC, USA) exposed for some days. The scintillation chamber, the charcoal canisters and the gamma spectrometry system to analyze them are provided by our University research laboratory. Using different methods, students are challenged to reach a better understanding of the different measurements techniques and obtain more comprehensive data interpretation.

Finally with the help of their teachers, students prepare a report on the activity, like as a scientific publication and at the end of the year the students at the Physics Department of UNIMI and INFN during the “SPLASH Workshop” present, present, compare and discuss their results of the monitoring, the problems encountered, the future work in a really stimulating debate at the presence of other schools not jet involved, their teachers and University Professors.

3. Results and discussion

The measurements are done prevalently in the schools and in the houses of the students with the CR39 for periods of six months up to one year. The comparison with different measurement techniques prolonged up to some days, has given results in very good agreement, taking into account the errors present in these kinds of measures.
The students tried to find a correlation between the Rn concentration found in each measurement station with the year of building, the building materials, the floor and the soil composition. A group with the help of the Speleologist Group of the Club Alpino Italiano (CAI) of Saronno (VA), has exposed the dosimeters in some caves for three months. They could understand the problems related to make the measurements in this kind of environment, where the high humidity deforms the dosimeters and when radon concentration, ranging between 1 000 and 6 000 Bq m$^{-3}$ is so high to saturate them.

The project has achieved its goals. In particular it aims to promote a methodological approach in which the Physics (also the most attractive) is not only “introduced” to the students, but in which the Physics is “done” by the students; it is possible to underline to the students that the scientific method and the experimental approach is the same whether it is applied in the experiment smaller than in big experiments. This activity would like to contribute to underline to the young people that the real risk in the field involving ionizing radiations is related to the loss of expertise, aspect that only with education and training it is possible to try to stem, but in meanwhile the activities using ionizing radiation become each day more and more employed in every field of our life.

4. Conclusions

We retain that starting from the measure of natural radioactivity is the best way for the students to approach the theme related to the nuclear on a more rationale basis and that the effective experimental activity is the best way to provide for an adequate scientific background.

Trough this project, also the teachers can carry out training or refreshers the course on these subjects.

Moreover, recognizing the importance of the communication, many seminars and workshops are periodically organized specifically for the students or devoted to the population. Also it is important to discuss different possible energy production sources, compare the risks and benefits in order to provide unambiguous and comprehensive answers to a wide range of questions related to these subjects.

5. Acknowledgements

This project is funded in the mainframe of the experiments of the Commission V, Multidisciplinary and Applied Physics Research of National Institute of Nuclear Physics - INFN and the Italian Ministry of University and Scientific Research - MIUR, Italy. The contribution of all schools, students and teachers involved is fundamental.

6. References


Spanish Young Generation in Nuclear (Jóvenes Nucleares, JJNN) is a non-profit organization that depends on the Spanish Nuclear Society (Sociedad Nuclear Española, SNE). Since one of its main goals is to spread the knowledge about nuclear power, several technical tours to facilities with an important role in the nuclear fuel cycle have been organized for the purpose of learning about the different stages of the Spanish fuel cycle.

Spanish Young Generation in Nuclear had the opportunity to visit ENUSA Fuel Assembly Factory in Juzbado (Salamanca, Spain), where it could be understood the front-end cycle which involves the uranium supply and storage, design and manufacturing of fuel bundles for European nuclear power plants. Afterwards, due to the tour of Almaraz NPP (PWR) and Santa María de Garoña NPP (BWR), it could be comprehended how to obtain energy from this fuel in two different types of reactors. Furthermore, in these two plants, the facilities related to the back-end cycle could be toured. It was possible to watch the Spent Fuel Pools, where the fuel bundles are stored under water until their activity is reduced enough to transport them to an Individual Temporary Storage Facility or to the Centralized Temporary Storage. Finally, a technical tour to ENSA Heavy Components Factory (ENSA) was accomplished, where it could be experienced at first hand how different Nuclear Steam Supply System (NSSS) components and other nuclear elements, such as racks or shipping and storage casks for spent nuclear fuel, are manufactured.

All these performed technical tours were a complete success thanks to a generous care and know-how of the workers in charge of leading the technical tours. The unanimous opinion of the participants was that taking part in this kind of activities is a worthwhile experience which has exceeded their expectations.

1. Introduction

Spanish Young Generation in Nuclear (Jóvenes Nucleares, JJNN) is a non-profit organization that depends on the Spanish Nuclear Society (Sociedad Nuclear Española, SNE). Since one of its main goals is to spread the knowledge about nuclear power, several technical tours to facilities with an important role in the nuclear fuel cycle have been organized for the purpose of learning about the different stages of the Spanish fuel cycle.

2. The Spanish Nuclear Fuel Cycle

The nuclear fuel cycle includes all processes and operations involved in manufacturing nuclear fuel, its irradiation in nuclear power reactors, as well as spent fuel reprocessing, recycling or disposing of the fission product waste produced during irradiation.

Depending on the management of the irradiated nuclear fuel, two cycle options may be considered:

- Open or once-through fuel cycle, without reuse of nuclear materials.
- Closed fuel cycle, with reuse of nuclear materials extracted from irradiated fuel.

In Spain, the closed fuel cycle was chosen for the reprocessing of irradiated nuclear fuel from the longest-serving nuclear power plants (Vandellós I NPP, José Cabrera NPP and Santa
María de Garoña NPP). This practice was interrupted in 1982, except for Vandellós I NPP. This plant was shut down in 1989, due to a turbine fire, and its fuel had to be reprocessed in its entirety. As a result of the commitments acquired from the different reprocessing contracts, several medium and high activity wastes should be returned to Spain from foreign fuel reprocessing facilities.

Nowadays the fuel cycle strategy adopted by Spain is the open or once-through cycle (see figure 1), mode of operation in which the nuclear material passes through the reactor just once. After irradiation, the fuel is stored in reactor spent fuel pools until it is sent to a storage facility, as it is done in Spanish nuclear power plants in operation (Almaraz NPP, Ascó I&II NPP, Vandellós II NPP, Cofrentes NPP and Trillo NPP).

All the activities involved in the fuel cycle may be divided into three categories:

- **First category** involves activities that take place prior to fuel irradiation, when fuel radioactivity levels are relatively low. These activities include milling, refining, conversion to uranium hexafluoride, enrichment in the fissile isotope $^{235}$U and fuel assembly manufacturing.

- **Second category** of activities consists of fuel cycle design and irradiation of the fuel elements and assemblies in the reactor.

- **Third category** of fuel management activities includes operations on the highly radioactive spent fuel storage, shipping and disposal.

### 3. Spanish Fuel Cycle Facilities

Taking into account that the open or once-through cycle is the strategy adopted by Spain, it is important to make an overview about the current situation of the Spanish facilities belonging to each category of the cycle.

- **First category:**

All the facilities existing in Spain for the extraction of uranium ore have now ceased to operate. Certain of the mining sites have now been restored, while others are in the rehabilitation phase or are scheduled to be restored in the near future.

In addition to extraction and treatment of the ore, the first part of the cycle also involves the manufacturing of uranium concentrates. At present, the Quercus Plant, an uranium concentrates manufacturing facility, is shut down and no longer produces. Other disused concentrates manufacturing facilities, such as the Lobo G Plant, have been decommissioned or are in the final phases of dismantling and decommissioning, for example the Elefante Plant and the AUM (Andújar Uranium Mill).

The final stage of the first category of the cycle is the manufacturing of the fuel assemblies. In Spain, there is a fuel cycle facility in operation for the manufacturing of pellets, rods and fuel assemblies, located in Juzbado (Salamanca).
- **Second category:**

The second category of activities of the fuel cycle is the irradiation of the fuel in the reactor. Spain has eight nuclear power reactors in operation located at six sites, two power reactors closed down, in different steps of the decommissioning process, and a power reactor temporarily shut down.

- **Third category:**

After passing through the reactors, the irradiated fuel contains high levels of activity due to fission products and small amounts of plutonium. The last part of the cycle encompasses the management of the waste generated throughout the process. This waste may have low and intermediate or high levels of activity. The low and intermediate level waste is taken to the El Cabril disposal facility, called ‘El Cabril’ and located in the South of Spain. The irradiated fuel assemblies are stored in each nuclear power plant pool. However, due to the lack of capacity in reactor pools or to decommissioning, three temporary individual storage facilities have been built in three nuclear power plants sites, where the irradiated fuel assemblies are stored in dry casks. Nowadays, a centralized temporary storage facility is projected. The planned facility is designed to receive and store for decades all the spent fuel resulting from Spanish nuclear power reactors, the high-level vitrified waste and long-lived intermediate level waste generated abroad in the reprocessing of Spanish fuel and the intermediate level radioactive waste from nuclear power plants decommissioning, those with activity levels higher than ‘El Cabril’ low and intermediate level waste disposal facility acceptance criteria.

Besides, in figure 1, in light-red colour, it is represented an additional facility located in Spain, with an important role in the fuel cycle, which supports the second and final categories of the nuclear fuel cycle. It is the heavy components factory, which supplies Nuclear Steam Supply System (NSSS) components and other nuclear elements such as racks and shipping and storage cask for spent nuclear fuel.

### 4. Technical Tours

Several technical tours have been organized to comprehend the different stages of the Spanish open fuel cycle. These tours have provided an excellent opportunity for young professionals to increase their understanding of the technical process accomplished at the different Spanish fuel cycle facilities.

Spanish Young Generation in Nuclear had visited three fuel cycle facilities and the heavy components factory, which supports the second and final categories of the cycle. All of them are listed below and are located in the map of Spain shown in figure 2:

![Figure 2.- Location of the nuclear facilities toured](image-url)
• ENUSA Fuel Assembly Factory in Juzbado (Salamanca).
• Almaraz Nuclear Power Plant (PWR) in Almaraz (Cáceres).
• Santa María de Garoña Nuclear Power Plant (BWR) in Santa María de Garoña (Burgos).
• ENSA Heavy Components Factory in Maliaño (Santander).

The tours have allowed the participants to experience at first hand how the different activities of the fuel cycle are performed and to broaden their knowledge about the front-end cycle. As it is shown in figure 3, a wide part of the different categories of the cycle have been covered: fuel assembly factory, power stations (BWR&PWR), spent nuclear fuel pools and heavy components factory.

![Figure 3.- Nuclear fuel cycle facilities toured](image)

4.1. ENUSA Fuel Assembly Factory

Enusa Industrias Avanzadas, S.A. is focused on the design, manufacture and supply of fuel assemblies to Spanish and international power plants. Enusa core business is the front end of the nuclear cycle, which includes everything from the management and supply of enriched uranium to fuel manufacturing, as well as provision of engineering and fuel services to the nuclear power plants.

Present in the town of Juzbado, in the province of Salamanca, since 1985, the Enusa fuel assembly factory is one of the most innovative in Europe, as it incorporates latest generation technology that optimizes resources and protects the environment. This centre has a specialized, highly qualified team that covers the entire fuel production cycle: uranium supply and storage, and logistics of the components required for manufacturing, fuel production, product quality control, development of equipment for PWR, BWR and VVER product manufacturing and management of logistics and distribution to the plants throughout Europe.

The group of young participants could visit the main areas of Enusa fuel assembly factory:

• Ceramic area where it could be observed how the powder of uranium oxide and/or uranium oxide plus gadolinium is turned into high density sintered pellets.
• Mechanical area where ranges from the loading of the pellets in the rods to the manufacturing of the fuel assembly, including all the required inspections to ensure the final product quality.
4.2. Almaraz Nuclear Power Plant

Almaraz Nuclear Power Plant is located in the province of Cáceres, in the area known as Campo Arañuelo, cooled by water from the Arrocampo reservoir on the Tajo River.

There are two Westinghouse three-loop pressurized water reactors (PWR) operating on the site with an electric power of around 1000 MWe each one. Unit I was connected to the national grid in 1981 and the Unit II was connected two years later, in 1983.

As introduction, the visitors entered to the Information Centre, where there is a mockup of the plant and, basing on it, the improvements required from post-Fukushima nuclear stress tests were commented.

Inside the plant the group of young people could visit the turbine building, the electrical building, the control room, the technical support centre and one of the five emergency diesel generators. Subsequently, the visitors gained access to the controlled area, in particular, to the safeguard building, the auxiliary building and the fuel building where the Cherenkov effect could be seen glowing in the spent nuclear fuel pool.

4.3. Santa María de Garoña Nuclear Power Plant

The Santa María de Garoña Nuclear Power Plant is located in the meander formed by the Ebro River in the surroundings of the town that gave its name to the site, in the Tobalina valley in the province of Burgos.

In 1971, Santa María de Garoña was connected to the national electricity grid, achieving full power 27 days later, with 460 gross electric megawatts, which correspond to 1,381 thermal megawatts, the greatest amount installed in Europe at that date.
The nuclear power plant has a Series 3 Boiling Water Reactor and Mark I type containment, which produces 466 MW of electric power and was supplied by General Electric Company.

Upon arrival the group was conducted to the Information Centre, receiving an explanation about the main characteristics of Series 3 BWR and an outline of how Fukushima accident happened, due to both plants are twin plants. Once it was understood how a BWR reactor works, the young people had the opportunity to visit the secondary containment, the pressure suppression pool torus and the spent fuel pool, as well as the emergency diesel generator building, the control room and the simulator.

4.4. ENSA Heavy Components Factory

ENSA is a worldwide leader in the supply of manufactured equipment and services for the civil nuclear industry.

ENSA factory is located in the north of Spain, in Maliaño (Cantabria), 9 km from Santander city. ENSA manufactures components in compliance with the most exigent standards, regulations and customer requirements. They are world leaders in supplying steam generators for nuclear power plants. They also supply reactor vessels, reactor vessel cover heads, reactor vessel internals, reactor vessel supports, casks for fuel storage and/or transportation, racks for fuel, nozzles for fuel and heat exchangers.

Tour participants visited the Advanced Technology Centre (CTA), where the materials and process performed during the manufacturing and test of the heavy components are developed, proved and qualified. The centre comprises four working units: metrology and materials testing laboratories, welding development, robotic applications and defectology. Finally they traversed the heavy nuclear components factory, being able to see casks for fuel storage and shipping up close, reactor vessel cover heads and to compare the steam generator from conventional PWR reactors with ones from AP1000 reactors.
5. Conclusions
The unanimous opinion of the participants was that taking part in technical tours is a worthwhile experience which has exceeded their expectations. Taking into account the interest wakened in the young participants, it can be concluded that visiting technical facilities is an overwhelming teaching practice which provides an excellent opportunity to experience at first hand the whole process of electricity production in nuclear power reactors.

All the performed technical tours were a complete success thanks to a generous care and know-how of the workers in charge of leading the technical tours.

Spanish Young Generation in Nuclear is extremely grateful to the Spanish Nuclear Society for the support for all the activities accomplished.

6. References
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- Centrales Nucleares Almaraz – Trillo http://www.cnat.es/
- Central Nuclear Santa María de Garoña – NUCLENOR http://www.nuclenor.org/
- ENSA http://www.ensa.es/
Jóvenes Nucleares, the Spanish Young Generation Network, has organized five lectures explaining the evolution of the Spanish nuclear power program, milestones, and achievements for today involving 20% of the energy consumed in Spain.

In the first lecture in the series titled "The Rise of Spanish nuclear program", Mr. Agustín Alonso spoke of the actions carried out by the Spanish Government and the Utilities, in the development stage euphoria of Spanish nuclear. The second lecture of the series, "José Cabrera Nuclear Power Plant", by Mr. Jesus Fornieles, talked about the characteristics of the plant, the most important milestones in its construction and investments implemented.

In the third lecture, "Almaraz Nuclear Power Plant", Mr. José María Zamarrón spoke about the most representative landmarks of the plant construction and improvements implemented. The fourth conference, "Santa María de Garoña Nuclear Power Plant", by Mr. Elias Fernandez Centellas, talked about the milestones most representative of the construction of the plant, difficulties and lessons learned.

In the fifth lecture, "Trillo Nuclear Power Plant", by Victor Sola, was talk of energy, political and economic environment in which the project was initiated and developed, representing milestones in the construction and the contribution of nuclear generation to development of Spain.

1. Introduction

Spanish Young Generation in Nuclear (Jóvenes Nucleares) is a commission of the Spanish Nuclear Society (SNE), whose main goals are to promote the transfer of knowledge and experience between mature and young generations of nuclear professionals and encourage communication and discussion among these professionals.

The objective of the cycle of conferences is to present to young nuclear professionals the experiences and knowledge of professionals who have worked in the industry since its inception and have made it an industry leading.

In the first lecture "The Rise of Spanish nuclear program" was shown to the audience the Spanish nuclear program origins, the development, resources, training people, site selection.

The following conferences related with the construction of nuclear power plants in Spain, served to show to the attendees the design phase, construction phase, commissioning phase and operation phase; particularized to each of the plants.
2. Lectures Development

The introductory lecture "The Rise of Spanish nuclear program" was conducted by Dr. Agustín Alonso, Professor Emeritus at the UPM who has worked in the nuclear industry development. The young and experienced attendees learned about positive and negative milestones that changed the history of the world nuclear development, the milestones of the nuclear development in Spain, the origins of the Regulatory Body, the different national energy plans, the motivation of the antinuclear movement and the origins of the Spanish nuclear moratorium in the 80’s.

![Lecture "The Rise of Spanish nuclear program"](image)

The second conference called "José Cabrera Nuclear Power Plant", was given by Mr. Jesús Fornieles, who has worked at this plant from the 70’s, having different responsibility positions. The lecture showed the different stages through which it has passed the plant: preliminary design phase, design phase (site selection, business owners, economic data), construction (Spanish and local participation, programming and planning, purchasing, quality, engineering), operation, post-operation and decommissioning.

The conference "Almaraz Nuclear Power Plant", was given by Mr José María Zamarrón who worked for 30 years in all phases of project Almaraz Nuclear Power Plant: site selection, construction, testing, commissioning and operation, occupying multiple positions technical and management. Attendees learned the facts most representative of the construction of the plant, from the "Prior authorization" to "First criticality", through the "Building permit" and "Cold hydrostatic test" and the recents improvements.
The conference "Santa Maria de Garona Nuclear Power Plant" was given by Mr. Elias Fernandez Centellas that is working for this plant since its construction phase. In this conference was presented the most important milestones from the construction to commissioning and various curiosities such as difficulties in transporting large equipment on the roads of that time. The presentation was accompanied by a video made by the Spanish Public Television during the first years of plant operation to publicize the work done there.

The conference "Trillo Nuclear Power Plant", was done by Mr. Victor Sola, responsible for the commissioning of this plant. The young participants learned more about energy, political and economic environment in which the project was initiated and developed, as well as details specific to implementation: project phase, authorization, construction and operation. The conference also discussed nuclear generation contribution to the development of Spain and future prospects of the nuclear sector.
3. Conclusions

All conferences were a large number of attendees, young professionals and mature professionals, some of whom lived the reality exposed at conferences.

Young professionals attended these conferences motivated to know more about the origins of the sector for which they work and the mature generation of professionals attending in order to transfer their experience and knowledge to younger generations.

These experience is quite valuable for those young workers that may participate in a NPP construction in the next years, being in Europe, Asia or America.
ABSTRACT

Due to Austrian legislation it was never easy to train and educate people in Austria about nuclear issues. The Institute of Atomic and Subatomic Physics (ATI) in Vienna together with the Austrian Nuclear Society (ÖKTG) has taken, several steps to bring the subject of nuclear topics closer to the public. This was especially important as the TRIGA reactor at the institute was in the phase of negotiations for a new core, just during the crisis caused by the Fukushima accident. Without the good education program of the institute, that enabled an information centre of students and professionals for the public and media during the Fukushima crisis, the reactor would now be shut down. This paper will show the latest education efforts at the institute, together with the ÖKTG. It will be shown how information and training at the secondary education level is essential for the civil society. School classes have different possibilities of requiring nuclear training at the ATI Vienna: They can either choose a simple visit to the institute and reactor, a presentation in class by a member of the Young Generation, or full-day training at the reactor (which includes a start of the reactor for each student). Further, a project was started in 2011 to train high school teachers at the institute for a longer period so that their knowledge stays up to the current research level and they can give their students up to date and interesting lectures. The last point will be a showcase of public information. A book aimed for a general audience was written just after the Fukushima accident, with the goal to inform the public about all relevant nuclear topics. This book was recently translated into English and shall be available for all training and education purposes at undergraduate levels. Additionally, in mid-2012 a project was started together with a private company and EHRO-N investigating how the Fukushima nuclear accident affected enrollment numbers at a University level. A paper with the first results of this study is currently on its way to publication and a second one focusing on the European status in education after Fukushima is under work, and should provide results in July 2013.

1. Introduction

Due to the Austrian legislation it was never easy to train and educate people in Austria about nuclear issues. The Atom institute in Vienna has taken, together with the Austrian Nuclear Society (ÖKTG) several steps to bring the subject of nuclear topics closer to the public. This was especially important as the TRIGA reactor at the institute was under negotiations for a new core. These negotiations took place in 2011, when the Tsunami hit Japan and caused severe crises in the nuclear industry. Without the good education program of the institute,
that enabled an information centre of students and professionals for the public and media during the Fukushima crisis, the reactor would now be shut down. This paper will state the current status of courses at the Institute of Atomic and Subatomic Physics, discuss the initiatives driven together with the Austrian Nuclear society (ÖKTG) for schools and teachers. It will furthermore describe a showcase of how a simple book can be used for educational purposes. The last part of this paper is dedicated to a study carried out of a private company together with EHRO-N determining the changes of university education programs after the Fukushima crises.

2. University Level Courses at the Institute of Atomic and Subatomic Physics (ATI)

The ATI offers courses for national students and for students of foreign universities. The most important international courses are listed and described below. This is an important part of knowledge management and is very well perceived from European Countries.

2.1 Eugene Wigner Course
The Eugene Wigner Course was established in 2005 in cooperation between TU Bratislava, TU Budapest, TU Prague and the Vienna University of Technology (VUT). A group of about 15 students was subdivided into four groups, started together in Bratislava, and then rotated among the involved Technical Universities. At this course they carried out practical work at three different research reactors including theoretical lectures, and a final examination which was accredited by their home university with 6 ECTS. During the last two years, financing of this course became very difficult and the course was terminated in 2009 due to lack of financial support from external sources although the feedback from all participants was very positive.

2.2 Training Course for the MTR+3I EU project
The ATI took part in the above mentioned EU project together with about 25 other European research centers. The contribution of the ATI was to prepare a practical demonstration training course for future reactor operators. This course took place in March 2009 with five international participants and was successfully accepted as a demo course by the EU.

2.3 Nuclear Technology Education Consortium NTEC, UK
In 2007, the NTEC, coordinated by the University of Manchester, contacted the ATI if it could offer a one week academic reactor course for NTEC students. The contract was signed and since this time a total of twelve courses (two per year) were carried out, each course with six NTEC students. The course is credited by NTEC with six ECTS.

2.4 NPP Staff from Slovakia
For several years, the Technical University of Bratislava is involved in the re-training of the NPP staff of the NPP Bohunice and NPP Mochovce. Since Slovakia does not operate a research reactor and Bratislava is very close to Vienna, the ATI was asked to take over the practical part of the training course which has been performed 11 times since 2002.

2.5 MOL Courses
The Belgian research centre MOL is requested by the regulatory body to offer a re-training programme for their operators. In view of this task, the ATI was asked to host a total of 36 operators divided into six groups of six participants each to perform a course using experiments both from the standard reactor physics and kinetics course as well as from the reactor instrumentation and control course.

2.6 IAEA Junior Safeguards Traineeship Program
To fulfill the IAEA requirements for an application as Safeguard Inspector, the ATI offers, together with the IAEA a specific training for applicants from emerging countries. Since 1984 every two years a 9 month training course is held for up to 6 technicians from emerging countries. The first part of the course takes place at the ATI and covers practical training at
the TRIGA reactor Vienna as well as basic nuclear- and reactor physics, reactor safety and fuel cycle. Since 1984 totally 114 trainees passed the course at the ATI.

2.7 Eastern European Research Reactor Coalition (EERRI)
In 2008, the IAEA initiated several research reactor coalition programs to increase cooperation and utilization of research reactors in various regions. One region is Central and Eastern Europe and therefore the Eastern European Research Reactor Initiative (EERRI) was created. The ATI is part of this coalition and one target of this initiative is to offer practical training to young professionals. Since the formation of EERRI two different types of courses were carried out, the first course coordinated by the ATI in cooperation with the Institute Josef Stefan in Ljubljana/Slovenia, the KFKI and Technical University in Budapest/Hungary, and the second course was coordinated by TU Prague in cooperation with the ATI and the Institute Josef Stefan in Ljubljana/Slovenia. A total of 8 courses have been carried out since September 2013 with more than 50 trainees from 30 nuclear emerging countries. Two more courses are already planned for 2014. Participants are accepted either through IAEA Technical Cooperation projects from all over the world or by direct contract between the ATI and the requesting countries.

2.8 Selected Courses for IAEA Technical Cooperation projects
The ATI hosts IAEA fellows for periods of one month to one year through IAEA Technical Cooperation projects. Since 1983, more than 130 fellows participated at highly specialized training project from all over the world, and fellows are attached according to their interest in one of the working groups. Experience shows that after their return to their home institute long term relation and cooperation between the two institutes result as a positive outcome from these fellowships.

2.9 Master of Nuclear Security Course
The Master in Nuclear Security Programme is based on the IAEA publication NSS 12 and was established as a cooperation of the Delft University of Technology, VUT, Brandenburg University, University of Manchester, University of Oslo and the National centre for Scientific Research DEMOKRITOS (Greece). The programme is financed by the Lifelong Learning Programme of the EU. The ATI with its close relation to the IAEA plays an important part in this course, providing lecturers on nuclear physics, physical protection as well as detection of criminal or unauthorized acts involving nuclear and other radioactive material out of regulatory control. The pilot course started in March 2013, and 4 lectures were given at the ATI. The course is planned to continue as a regular course in the next years.

2.10 Conclusion
It has been shown that even a small university research reactor can be efficiently used, not only for standard training course within the academic field, but can also be used commercially by offering education and training experiences to other groups as mentioned above.

3. Initiatives for High Schools and Teachers
Driven by the initiative of a high school physics teacher the ÖKTG – YGN started an educational program in 2010. Several ideas were put together, which are described in the next points.

3.1 High School Initiatives
To introduce the topic of radioactivity and nuclear technologies to interested high school students the ÖKTG – YGN proposed two different options: They could either “book” a day at the ATI or could be visited by a member of the YGN. The first option included a three point program with the first part being an introduction to radioactivity, the second part a guided tour through the ATI and the last part a start up by every pupil of the reactor.
The introduction to radioactivity was carried out by members of the YGN, who also talked about their personal experience of working in NPPs or their interest in the studies of technical subjects. The pupils were given radiation pagers, and searched for hidden radioactive objects (NORM material).

The tour through the ATI showed them the different options the subject “Physics” provides, the highlight was the train driven by superconductivity in the basement of the ATI.

As the TRIGA reactor is very easy to handle, and especially made for training, the ATI was also able to let all visiting pupils start the reactor up. A certification was given to the pupils, after successfully carrying out this task.

The second option was a visit of an YGN member to the school class. This included a presentation about the basics of radiation, the basic working principles of a reactor and applied radiation in different fields. In the end was time for a discussion.

### 3.2 Teachers Initiatives

To achieve a longer lasting effect, the Austrian Nuclear Society started together with the club A.L.F (Up-to-date Teacher’s education) an initiative to show physics high school teachers the up-to-date research in several institutes of the VUT. Teachers visited the institute for a day, got insight knowledge of the current research at the institute and had to choose a topic for an essay. In the beginning teachers were interested, as it was also part of their on-going and mandatory training, but the initiative came to a halt. It was planned to have a training of teachers every 18 month.

### 4. Educational Showcase

During the Fukushima Crises, the ÖKTG-YGN was managing an information centre [1]. This lead to the idea of writing a book [2] which can be used as background and basic knowledge information. This book was published in October 2011, translated into English in 2012 and is now available for everyone. It is a useful tool to inform and educate the broad public. Without the help of this book the TRIGA reactor would now be shut down [3].

### 5. Nuclear knowledge Management after the Fukushima Accident

Nuclear education has seen many ups and down since the birth of nuclear technology. Due to the highest prior support from all stakeholders during 1960s, nuclear education, along with its technology, has witnessed its peak time. In the 1970s, the development of nuclear power technology was severely damaged by some local and global nuclear accidents. The Chernobyl nuclear disaster in 1986 further deteriorated nuclear education, especially in industrialized countries. Many local, regional, and international efforts were put together to restore a system of nuclear education. These painstaking efforts started the nuclear education system growing again, but the Fukushima nuclear disaster in 2011 seems to be creating serious obstacles in the restoration of nuclear education in many counties. This study shows light on the influence of the Fukushima nuclear accident on nuclear education. For this purpose, a worldwide survey has been conducted through a well-designed questionnaire, seeking the most information possible about the trends of nuclear education. This questionnaire collects student enrollment data from 2007 to 2012. It was distributed to about 210 different institutions in 57 countries with nuclear power programs, or intentions to develop a nuclear program. Out of these 210 institutions, a total of 69 institutions responded the questionnaire. This survey covered the continents of Europe, Asia, and The Americas. Based on these international survey results, this research highlights the impacts of the Fukushima nuclear accident on nuclear education programs in European, Asian, and American countries individually. Due to great interest this study lead to a second study together with EHRO-N taking a closer and more detailed look at European student enrollment numbers.

#### 5.1. The questionnaire
The questionnaire was designed to be answerable in 5-10 minutes and still collect as much information as possible. It included answers about:

- Name and country of the institution
- Nature and length of nuclear education program
- Special academic/training program (if any)
- Total number of applications per year
- Student enrollment data of the current year (2012)
- Enrollment data of last six years (from 2007 to 2012)
- Main employer of the graduates
- Inclusion of Fukushima accident in the course
- Student interests in response to Fukushima accident
- Impact of Fukushima accident in the funding
- Institution is interested in the final report
- Rating the questionnaire
- Confidentiality of data

After collecting the data from 29 different countries in Europe, Asia, and The Americas, the trends in nuclear education have been seen in different regions, reflecting the nature and size of their respective nuclear programs. It has only been one and half years since the Fukushima accident, which is not enough to predict the visible influence of the accident. The visibility of trends in nuclear education may take some more time. The Fukushima accident affected the nuclear environment in some developed countries like Germany, Italy, Austria, Switzerland, and Japan, while in India, Pakistan, and China, the public perception is still pro-nuclear and there have been increasing trends in nuclear education. This section is divided into three subsections: Europe, The Americas, and Asia. Out of the 69 received responses, 48 have shown complete enrollment records, 12 presented incomplete records, and 9 were unable to provide any enrollment data. It is safe to say that many universities did not respond to the questionnaire because of their own reasons, and possibly due to lack of data. 85% of Universities did not record a change in their budgets, 5% reported an increase and 10% reported a decrease directly linked to Fukushima which is problematic since nuclear education would need more money to train better professionals.

Figure 1 depicts the overall state of nuclear education around the globe. After the Fukushima nuclear accident, Germany shut down half of their nuclear power plants, Italy held a referendum which cancelled their plans for new build, Switzerland put their nuclear plans on hold, and other European countries also didn’t show much enthusiasm for nuclear development. It is not surprising that European universities show the biggest decline in student numbers. American universities show almost no impact from Fukushima.
Before the Fukushima nuclear accident, the nuclear knowledge management landscape in Europe (EU-27) has been observed as growing in variety, as well as in number of instruments and initiatives [4]. The effects of the Fukushima Daiichi accident on the workforce situation are significant in some countries. For example, the main changes that affect the supply of/demand for nuclear experts, at least at a national level, occurred in Germany (where 8 nuclear power reactors were taken off the grid, and the rest will be closed by 2022.

The overall picture is changeable, and a clear judgment of the consequences is considerably challenging at this moment. It is, however, clear that there is still the need for highly competent experts on nuclear safety in the EU-27, which should provide a drive for good job opportunities in the region for decades to come [4].

To show the real influence of the Fukushima accident, the responses on the above-described questionnaire were received from 24 different institutions of nuclear education, located in 18 European countries.

Europe is quite important for the nuclear future, since many countries have their own programs, but do not coordinate much with one another. EHRO-N has already started to find out how flexible nuclear experts in Europe are, and how much they are willing to travel or resettle in a new location.
The results of the new survey carried out together with EHRO-N are still incomplete and not enough data was received to make a reliable conclusion but preliminary results show mostly increased or steady student numbers.

4. References

RISKY KNOWLEDGE : E-LEARNING METHOD AND TOOL FOR SECURITY AND SAFETY DOMAINS

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Risky Knowledge is a European Transfer of Innovation project. The aim is to develop an innovative e-learning tool and a specific training approach for professionals, focusing on Security and Safety topics. Funded by the Leonardo da Vinci Programme, the RISKY project sets a collaborative network to promote experience exchange between trainers, learners, industrial experts and professional associations. The RISKY project will result in an online, competence- and Work-Based-Learning vocational training approach for Security and Safety professionals.

Nowadays, there is a lack of Security and Safety skills in SMEs and large companies. Enterprises do not have enough experienced people able to provide efficient judgement and workforce.

Thanks to this collaborative project we are implementing an e-learning platform to address Security and Safety specific training needs by providing pragmatic content created by professionals and experts, available in different languages. The first outcome of this innovation project is a training catalogue of innovative e-learning courses on security and safety, created by professionals of the sector.

Moreover, our tool is designed according to job requirements and trainee profile, thus giving the opportunity to have a very personalized training course. The second outcome of this project is a specific pattern of Security and Safety knowledge in order to follow-up the progress and paths to develop the appropriate competencies. Our ambition is to give trainees the opportunity to adjust their skills and competencies to cover professional profile requirements by following a specific learning path for attendee or managing profiles for Human resources or head of security and safety.

The long-term ambition is to offer to future client companies the opportunity to use this platform to capitalize on their own proper knowledge: our platform will be used as a staff management tool regarding competence and training needs.

Feedback continuously provided to RISKY partners by European industrials (like Euro Nuclear Society, French Space Agency or IK4-IKERLAN) and professional associations (like ISACA) helps to tune the training approach, adapting it to the appropriate competences.

To put it in a nutshell, the e-learning tool we are developing is much more than mere online learning. It is job-oriented (i.e. dedicated to Security and Safety professionals), with a focus on competences (i.e. what are you able to do with your knowledge) and uses an innovative methodology called work-based learning, thus enabling the learner to quickly apply his knowledge to practical working situations.
Centres of excellence - academia and their master programmes
1. Introduction

One of the main objectives of the Master on Nuclear Science and Technology implemented in the Department of Nuclear Engineering (DIN) is the training for the development of methodologies of simulation, design and advanced analysis necessary in research and in professional work in the nuclear field, for Fission Reactors and Nuclear Fusion, including fuel cycle and safety aspects. The programme also includes other basic disciplinary contents such as Quantum Mechanics and Atomic & Nuclear Physics, Non-Energy uses of Radiation Sources and Nanotechnology.

The experience gained in the last years by our Department in the development of Codes for design and advanced analysis in Reactor Physics has been included in the programme, with the understanding of the current computational methodologies/codes from the nuclear data processing, then the lattice and core calculations codes, the 3D Core Physics simulations at static and dynamic conditions, and finally the power plant simulators. A large experience in Plasma Physics and Advance Materials under development and irradiation, including Reactor Systems, for Nuclear Fusion, is also in the program that includes multiscale simulation and availability to have access to experimental facilities for the students.

Our Department was provided in 2008 with the Interactive Graphical Simulator of the PWR nuclear power plant “José Cabrera”. The simulator is a state-of-the-art full-scope real-time simulator, that was used for training and qualification of the plant operators. Very illustrative screens show all the plant systems, and allow to act directly on the system components. Alarm control panels, similar to the ones existing in the control room of a nuclear power plant, are also available to alert users to potential equipment problems or unusual conditions. The Simulator plays an important role for education and training of our students, providing an attractive virtual space that allows to improve the understanding of the whole plant components and its safety systems, because of that the Consejo de Seguridad Nuclear grant each course several fellowships for training of students in this installation. Recently his TRACPWR software has been adapted to the new hardware base on PC’s with Windows. The SGI is now a more friendly tool, and easier to use by the students.

The Department participate in the international Sustainable Nuclear Fission Technology Platform (SNF-TP), and the European Nuclear Energy Network (ENEN), with the possibility for our students to obtain the “European Master of Science in Nuclear Engineering”. Participation in Erasmus-Mundus in Nuclear Fusion Science and Technology and a new Program of Erasmus Curricula in Plasma Physics and Fusion Technology is also an additional experience and attractive aspect for Master’s students.

Also there are several agreements with foreign universities and privates companies in the nuclear field, being some of them cooperative partners in the European research projects through the Euratom 7th Framework Programme, in which the Department is involved. Our Doctoral students may take advantage of that, doing the PhD research work in the projects, also the Department support the invitation of relevant foreign professors to teach advanced seminars to our students.
2. Master on Nuclear Science and Technology

The present Master/Doctorate in Nuclear Science and Technology programme implemented in the Department of Nuclear Engineering of the Universidad Politécnica de Madrid (NED-UPM) has the excellence qualification by the Spanish Ministry of Education. One of the main objectives of this programme is the training for the development of methodologies of simulation, design and advanced analysis, including experimental tools, necessary in research and in professional work in the nuclear field. This is, Fission and Fusion Reactors, including fuel cycle, waste management and safety aspects, and also non-energy uses of nuclear physics and technologies. The programme includes other basic disciplinary contents such as Quantum Mechanics and Atomic & Nuclear Physics, Non-Energy uses of Radiation Sources (such as Lasers and Accelerators) as well as, Nanotechnology.

In this context, based on the experience gained through research, significant efforts have been done to improve the following subjects in the curricula: Nuclear Power Plants (NPP), Nuclear Technology, Nuclear Safety, Nuclear Reactor Design, Radiation Sources for Diagnosis, Medical, Industrial Application, and Quantum Mechanics Applications such as nanoscience and Nanotechnology.

But more realistic studies are also required to complete the education & training objectives in the “Nuclear Safety” and “Nuclear Power Plants” programmes. For this purpose, we use a full scope Interactive Graphical Simulator (IGS) running in real-time, which was donated by the Spanish José Cabrera NPP, after its operation ceased in 2006. The simulator was used during the commercial exploitation of the plant for training of the main control room personnel, technical support engineers, and for operations management. It was commissioned on NED-UPM in 2008.

On the experimental side, NED-UPM has a neutron measurements laboratory with a calibration bench, and presently a new facility based on sputtering techniques is being commissioned in order to support training and research on development and testing of new high radiation-resistant materials.

3. Codes for design and advanced analysis in Nuclear Engineering.

The experience gained in the last years by NED-UPM in the development of Codes for design and advanced analysis in Reactor Physics has been included in the Master Programme, with the understanding of the current computational methodologies/codes from the nuclear data processing, the lattice and core calculations codes, the 3D Core Physics simulations at static and dynamic conditions, and finally the power plant simulators.

A large experience in Plasma Physics and Advanced Materials development, characterization and testing under irradiation, together with Reactor Systems for Nuclear Fusion, is also incorporated in the Programme. This includes the development of codes for High Energy Density Matter studies, which is key for inertial fusion energy (both Radiation Hydrodynamics and Atomic Physics), but also original codes in atomic quantum and classical dynamics and defects diffusion for Materials Research in a scheme of multiscale simulation, with new developments in Fluid dynamics and Basic Physics for Liquid Metals behaviour, important in new generation of Fission and Fusion Reactors, and accessibility to experimental facilities for the students.

The “Nuclear Reactor Design” programme has been focused on the understanding of the computational codes for nuclear reactor design, starting with the nuclear data processing codes, the core calculations codes, and finally the plant simulators codes (JANIS, NJOY, WIMSD, ORIGEN/ACAB, MCNP, COBAYA/SIMULA, COBRA, SIMTRAN, RELAP).

Some of these codes have been developed in our NED-UPM for many years including the generation of the necessary cross-section libraries for accurate use of the codes. First, visualizing with JANIS code, and checking nuclear data from Evaluated Nuclear Data Files (ENDF), with ENDF Utility Codes. Different lattice codes have been developed to solve the neutron transport equation to model
pin-cells and clusters taking part of the SEANAP system developed by NED-UPM for NPP design. Deterministic computational methods are complemented with Monte Carlo calculations. Students are introduced in this methodology and several examples for shielding and criticality systems are simulated with MCNP4.

For activation and burn-up calculations ACAB and ORIGEN2.2 codes are used. ACAB code (partially developed by NED-UPM) is designed to perform activation and transmutation calculations for nuclear applications. ACAB is used to simulate realistic operational scenarios of very different nuclear systems: inertial fusion, magnetic fusion, accelerator driven systems, and fission reactors.

Neutronic calculations for core design in 2D and 3D are introduced with COBAYA and SIMULA codes, respectively. These codes also are part of SEANAP system. For core design and operational monitoring we use our SIMTRAN code, SIMTRAN is a 3D-PWR core dynamics code, under development and validation for 20 years. It was developed as a single code merge, with data sharing through the 3D neutron-kinetics nodal code (SIMULA) and the multichannel, with cross flows, thermal-hydraulics code COBRA IIIC/MIT2. COBAYA3 is also now integrated in the NURESIM European platform for best-estimate reactors simulation.

For Multiscale Simulation of Materials, a significant number of developments have been performed with original development or co-development of Molecular Dynamics codes such as MDCASK, and Kinetic MonteCarlo (modified BIGMAC). In general, the full scale is covered from First Principles (SIESTA, VASP), Molecular Dynamics (MDCASK and LAMMPS), Defects Diffusion by MonteCarlo, Dislocation Dynamics, and Structural Codes such as ANSYS, but also with a large modification and adaptation to our problems of free codes such as CODEASTER.

Fluid dynamics problems in nuclear facilities (both reactors or research in New Sources) is covered by implementing and using popular CFD codes such as ANSYS-FLUENT or STAR-CD, extensively modified in some cases for specific problems. In particular, a large modification includes new data generated by using Quantum and Classical Molecular Dynamics, to study liquid metals such as LiPb or others, and get responses to problems of heat transport, corrosion or phase transition. Safety aspects for new Nuclear Systems are considered by using a special version of the MELCOR code for liquid metals, which is being implemented. Also in the safety area, and for fusion reactors, the diffusion and transport of tritium inventory has been originally implemented with new data in codes such as TMAP in order to estimate the final T inventory.

A key aspect developed is the computational coupling of those codes; from the 3D CAD/CAM description of the system to be studied, the particle transport, the heat deposition and particle irradiation, the generation of the basic numbers of material damage and activation, the fluid dynamics of the heat extraction (coolant), the tritium breeding in case of fusion, and the thermo-mechanical effects up to the Power Plant Thermodynamics cycle.

Atmospheric dispersion of radioactive elements in case of accidents are modelled with available codes but also with some new including new chemistry and physics such as Tritium analysis. A new battery of data has been included for components different of HTO, HT and organic bound tritium (OBT), with new models in NORMTRI, UFOTRI and the weather ECMWF/FLEXPART dispersion model, to incorporate the sequential chain of elements after deposition and through the organic systems with evaluation to the environment.

4. Facilities

4.1 Interactive Graphical Simulator

NED-UPM was provided in 2008 with the Interactive Graphical Simulator of the PWR nuclear power plant “José Cabrera”, whose operation ceased definitively in 2006. The simulator is a state-of-the-art full-scope real-time simulator, which was used for training and qualification of the plant operators. The Simulator plays an important role for education and training of our students, providing an
attractive virtual space that allows to improve the understanding of the whole plant components and its safety systems. The Consejo de Seguridad Nuclear grants each course several fellowships for training of students in this installation.

The Interactive Graphical Simulator is a full scope PWR nuclear Power plant engineering simulator that is especially useful for didactic purposes, as it is an interactive tool that allows the student to complete the teaching-learning methodology in nuclear science and technology as is recommended in the new engineering studies adapted to the Bologna rules. This simulator attracts, motivates and retains students within the nuclear science, and improves the quality of training, making students more active in their own learning and replacing simple memorization of the complex processes involved in the operation of a nuclear power plant by a more meaningful learning, involving interactive and team working experience.

The simulator provides the plant responses using TRAC as the software package. Very illustrative screens display all the plant systems, and allow to act directly on the system components. Alarm control panels, similar to the ones existing in the control room of a nuclear power plant, are also available to alert users to potential equipment problems or unusual conditions. The components and systems of the whole power plant are simulated, this includes the nuclear reactor, the pressurized vessel, the primary and secondary loops, the turbine, the condenser, the fluids systems, the instrumentation and control components, and the electrical systems, as well as the emergency systems that are automatic started when needed.

The simulator provides the real plant responses during normal operation, and simulates several maneuvers, a series of malfunctions, and operational transients, and it also allows the training in emergency operation procedures. With the simulation of these situations the student is trained in the plant behavior, and in the nuclear and thermohydraulics phenomenology in the nuclear reactor and in the components of the whole plant.

Standard operational situations to run by the students are: Normal operation in nominal power; Nuclear power variations and turbine demand follow; Plant start-up from Cold-Zero-Power to Full-Power; and Plant down from Full-Power to Cold-Zero-Power, and evolution during the Zero-Power period.

For the simulation of hypothetical accidents, best-estimate and realistic codes are used. The evolution is run in real time, and the students take conscience of the time and the risk of these potential situations, and the high reliability needed in order to limit the global risk. The accidental and complex situations run by the students are: Loss of coolant accident (LOCA), Steam generator tubes leakage or rupture, stop of the main pump rotor, transients with failure of the protection system and the reactor scram, Pressurizer fault, Main steam line break (MSLB) in/out the Containment building, Anticipated Transients without Scram (ATWS), etc.

4.2 Neutron dosimetry laboratory

The neutron measurements laboratory of NED-UPM has two neutron sources ($^{241}$Am-Be with 77 and 111 GBq), a cylindrical water cask (0.9m diameter) for irradiation with thermalized neutron, and a precision bench for irradiations in air by means of a fully automated pneumatic device for storage, transport and positioning of the source and measuring instruments. The installation has a Bonner spheres spectrometer with a small $^6$LiI(Eu) scintillation detector, four shadow cones (made of iron and polyethylene) and a Berthold LB6411 ambient dosimeter.

By using detailed Monte Carlo methods with MCNP code, several studies have been carried out to characterize the neutron fields in the laboratory in a set of reference points when the $^{241}$Am-Be source is situated in irradiation position 3 m over the floor and 4.5 m far from the nearest walls. It The ambient dose equivalent obtained by calculations has been also compared with that obtained from the spectrometric measurements and directly with the dosimeter measurements.
4.3 Experimental sputtering set-up for coating deposition.

The research company Nano4Energy is specialized on development, design and commissioning setups for sputtering deposition. In particular, this company develops coating solutions by using High Impulse Magnetron Sputtering (HIPIMS), DC and RF sputtering techniques. The company is commissioning a pre-industrial process at NED-UPM for the development of sputtering deposition of thin film for different purpose (photovoltaic cells, optical coatings, plasma facing components…).

That installation will be used with adequate modifications for diagnosis and irradiation of advanced materials in the same conditions that those at the first wall of the chamber of Laser Fusion Reactors. A similar facility already used at the Spanish Research Council CSIC will be now upgraded for higher voltage and stronger conditions. The installation will also be used for research activities for the Programme students. Moreover, because of the versatility of the facility and the experience in coating deposition of NED-UPM members, this setup is also intended to be used for the deposition of nanostructured-based materials (high radiation resistant).

4.4 Internet Reactor Laboratory

With the assistance and support of the IAEA, five reactors experiments on Reactor Physics will be incorporate in the Master curricula. These experiments will be follow online by the students through videoconference, with a connection with the control room of the ISIS experimental pool reactor in CEA- Saclay.

This five sessions will include:

Lab 1: Fuel loading
Lab 2: Approach to criticality; Reactor start up; Reactivity effect around criticality
Lab 3: Reactivity effect of devices (cylinders and box) placed in the core; Rod calibration curve; Global worth by the rod drop technique
Lab 4: Role of precursors; Temperature effect; Operating range of each detection system and associated OLC
Lab 5: Detection system in pulsed mode; Detection system in current mode; Neutron flux measurements with a micro fission chamber – Cartography

These sessions has special interest to understand the Reactor Physics concepts, and will be part of our advanced seminar program.

They will provide to the students, after the theoretical classes on Nuclear Technology, and before the Interactive Graphical Simulator sessions, this last installation is useful to understand the whole plant components, and the safety systems behavior.

5. International Masters Programs

NED-UPM is involved in several international programs:

- European Master of Science in Nuclear Engineering
- Erasmus-Mundus Nuclear Fusion Science and Technology
- Erasmus Curricula in Plasma Physics and Fusion Technology (PLAPA, New program)

Our University is involved and participates in several Education and Training Platforms, at national level is part of the CEIDEN technological Platform, at European level in the Sustainable Nuclear Energy Technology Platform (SNE-TP), and the European Nuclear Education Network (ENEN) association, both promoted by the European Commission. We also participate in the National Platform for Fusion Technology, and in the recently started National Ministerial Programme INDUCIENCIA that aims to join industry with universities and research institutions; in both cases the participation is not only for research and development, but also with intensive subprograms for education and training.
Also the University has participated in programs of the World Nuclear University (WNU), and the Frederic Joliot & Otto Hahn Summer School (UE).

6. Research Activities

NED-UPM has agreements with several foreign universities and companies in the nuclear field, being some of them cooperative partners in European research projects. Our Doctoral students may take advantage of that, doing the PhD research work in the projects, also NED-UPM supports the invitation of relevant foreign professors to teach advanced seminars to our students. New Programmes are also established with Institutions in Chile, Argentina, Japan and China.

The different research areas carried out in NED-UPM cover the main topics in Nuclear Engineering field, supported by the National Research Programs, the Nuclear Safety Council, the National Radioactive Waste Management Company ENRESA, the nuclear power plants, or international organizations as EURATOM, STFC RAL in the UK, CEA in France, CERN, LLNL and LANL in USA, Japanese Science and Technology through Bilateral Agreement (ILE Osaka and Graduate Photonic Institute).

- Fission Reactor Physics
  - SEANAP System for PWR reactor cores design and analysis with original methodology.
  - PWR operation surveillance.
  - Nuclear data needs, processing and development of tools
  - Burnup credit criticality safety
  - Sensitivity and uncertainty analysis for nuclear criticality safety and burnup calculations

- Nuclear Safety
  - Analysis of Severe Accidents in LWR
  - Integrated Safety Assessment and Probabilistic Safety Assessment for NPP

- Radiological protection
  - Dosimetry and neutron metrology
  - Environmental, radiological and economic impact of nuclear energy
  - Decision support systems for Nuclear Emergencies and post-accident management

- Nuclear Fusion
  - Development of computational models for target physics in Inertial Confinement Fusion
  - Design and analysis of experiments under the EU support, for X-ray lasers and for ICF.
  - Fusion reactors study and design (both engineering/experimental and Power Plants)
  - Development of computational models for the analysis of activation and material damage by irradiation.
  - Experiments in the area of Materials Irradiation and NanoMaterials development in collaboration with other research centers

- Fluid Dynamics
  - Development of a 2D fluid dynamic model with radiation transport using advanced techniques.
  - Development of new algorithms for considering in the state-of-art codes for engineering design new data bank and modifications to incorporate new fluids, key in new reactors.

- Materials
  - Development of New Advanced Materials with new nanostructures to support very high irradiation of Ions, X-rays, Gammas and Neutrons. Structural and Functional materials such as optical lenses using both Multiscale Modeling and Experiments.
  - Damage in nuclear reactors vessels
  - Separation and Transmutation of radioactive waste.
- New Sources of Radiation (by Lasers and Accelerators)
  - Design of New Facilities for very advanced Irradiation in extreme high fluxes of Particles and Radiation and potentially new methods for Medical and Industrial Applications, and Material and Biological Diagnosis.
  - Laser Generated Ions, Positron and Neutrons
  - Spallation Sources

7. Conclusions

The Master on Nuclear Science and Technology implemented in the Department of Nuclear Engineering (DIN) train students for the development of methodologies of simulation, design and advanced analysis necessary in research and in professional work in the nuclear field, for Fission Reactors and Nuclear Fusion, including fuel cycle and safety aspects.

The students are able to use the current computational methodologies/codes for nuclear engineering that covers a difficult gap between nuclear reactor theory and simulations. For students, the understanding in a comprehensive way of these codes is an important value in simulation, design and advanced analysis both in the research activities and in the professional work.

Also they are able to use the Interactive Graphical Simulator that has been proven to be an optimal tool to transfer the knowledge of the physical phenomena that are involved in the nuclear power plants, from the nuclear reactor to the whole set of systems and equipment on a nuclear power plant. As well as the new Internet reactor laboratory has interest to understand the Reactor Physics concepts.

The experimental set-ups for neutron research and for coating fabrication offer new opportunities for training and research activities. All of them are relevant tools for motivation of the students, and to complete the theoretical lessons. They also follow the tendency recommended for the European Space for higher Education (Bologna) adapted studies, help to increase the hands-on work of the student, and allows them to experience the work inside a team, in practical and real installations.
ABSTRACT

Knowledge Management in nuclear industry is indispensable to ensure excellence in performance and safety of nuclear installations. The Master on Nuclear Engineering and Applications (MINA) is a Spanish education venture which foundations and evolution have meant an adaptation to the European Education system and to the domestic and international changes occurred in the nuclear environment. This paper summarizes the most relevant aspects of such transformation, its motivation and the final outcome. Finally, it discusses the potential benefit of a closer collaboration among the existing national education ventures in the frame of Nuclear Engineering.

1. Introduction

Obtaining the necessary knowledge for the right people, at the time, manner and appropriate place, was defined by Ackermans et al. [1] as Knowledge Management (KM). Its ultimate goal is to ensure the closest approach between the speed of learning and the market exchange rate. To do this, it is essential to create an environment for sharing the acquired knowledge and its application, thus preventing recurrent learning processes that would make any system inefficient. The prominence achieved by the KM over the last decade has been led largely by the huge transformation of the information and communication technologies (ICT). These have involved radical structural changes in key aspects, such as: access to information, its immediacy and the new structures and sorting capabilities.

The importance of the knowledge management becomes even greater in the nuclear industry [2]. There is a direct relationship between the KM and the safety of the facilities. Design, licensing, construction, operation, maintenance and even dismantling activities must be risk-informed and based on knowledge. The abilities to make correct decisions and perform the necessary actions require achieve and preserve knowledge and experience [3]. Therefore, the KM in the nuclear industry has to respond to a clear challenge: providing human resources and training base necessary to successfully work in the applications arising from nuclear technology, either for energy production or for other uses demanded by society as medical, industrial, agricultural, etc.. For this, there are three fundamental pillars:

- Education and training initiatives. Their approach and interconnection are critical for their success. Exchange fore between nuclear teaching professionals and the mutual recognition of educational initiatives, are key tools for building a robust and efficient formative tissue.
• Storage and structuring of scientific and technical heritage from the development of existing nuclear programs. Databases set up to gather and preserve information in an ordered, easy to interpret, and open access way, is instrumental too.

• Mobility of students and professionals. The existence of the education and training international initiatives allows that students from countries with nuclear plans, under development, have the opportunity to learn from the experience in countries with consolidated programs. Furthermore, globalization has meant the growth of professionals in areas that even absent in their home country, are being developed beyond the borders.

The current development of ICT has undoubtedly led to innovative methodologies that enable and enhance each of these pillars.

The Master in Nuclear Engineering and Applications (MINA), title of the Autonomous University of Madrid (UAM), organized and managed jointly with CIEMAT, set one of the national nuclear education initiatives [4]. After five editions with nearly a hundred students in total, MINA is more aware than ever of its role in the KM of the Spanish nuclear sector. This article provides a reflection on the consistency of its approach with the fundamental objectives of the KM and it describes the major changes made along the years to continuously update it in a consistent way with the national and international nuclear sector.

2. Sectorial integration

The Master in Nuclear Engineering and Applications (MINA) was conceived with the ultimate goal of forming nuclear professionals. Therefore, every effort has been to introduce into the job market, graduates capable of performing the activities that the Spanish nuclear sector develops inside and outside our borders. To do this, it was imperative, from the beginning, to maintain a close cooperation with the industry in the many aspects of this master.

There are several elements that illustrate the sectorial integration of MINA:

- **Professional profile.** The subjects were set from the needs expressed by nuclear companies and institutions in the country, who also participated in articulating the detailed programs. A description of the classification procedure of the subjects (priority, fundamental and complementary subjects) and content development was detailed by Herranz et al. [4].

- **Teacher involvement.** MINA combines the teaching of the scientific basis for nuclear technology with its application in industry and engineering. The first is provided by teachers and researchers of high reputation. The application, which is more than 50% of teaching time, is largely responsible for industry professionals. This balance allows students to approach the experience of the industry, without neglecting the grounds on which it is based.

- **Project management.** The dimension of proposal and management of end of master projects has reached averaged values above 80% (Figure 1). These projects usually deal on the ongoing activities in industry, companies and institutions, a fact that underscores their interest in them. Not least, these projects allow direct contact of student and industry.
• Access to facilities and events. The students of MINA have access to different facilities during the master; examples are Juzbado nuclear fuel factory, CN Almaraz, the Cabril radioactive waste store for low and intermediate radioactive level, CN Jose Cabrera and others. Also, the Spanish Nuclear Society opens its doors in the Operating Experience Annual Conference for students of master's and postgraduate courses related to nuclear technology, including MINA.

• Financial support. The nuclear sector contributes to the economic viability of MINA through various mechanisms, such as grants for registration or financial assistance for the project development (Figure 2).

Fig 1. Management of end of master projects

Nuclear Sector
(41,5%)

Pupils
(45,0%)

CIEMAT
(13,5%)

From the beginning, MINA has maintained a constant contact with the Nuclear Fission Energy R & D Technology Platform (CEIDEN). Currently, one of the MINA team members is fully integrated into the education and training committee of the platform. Moreover, MINA distributes the students’ dossiers who have passed all the level tests into the industry and institutions.

In short, MINA acts as a vector of the experience accumulated by the industry to a new generation of professionals and it is able to assimilate them through the fundamental knowledge acquired.
3. Temporal progression

All the instruments of the any KM system have to be linked to a continuous assessment, aimed at optimizing its efficiency and adapting to changes in their environment. Thereby, MINA established a quality assurance system based on the analysis of: individual surveys of subjects, general surveys of the Master, self-assessments at the end of each academic year and, finally, a regular review of the nuclear sector development. Surveys are completed by students, the access is via Internet and are anonymous. The last two items are responsibility of the MINA team and the main difference between them is the temporal scope. Following the analysis of all of them MINA has undergone transformations that, according to their origin, can be divided into academic and sectorial.

3.1 Academic evolution

The academic evolution refers to those changes introduced for two fundamental purposes: accommodate MINA to the European Higher Education Area (Bologna Process) and provide students the achieving the maximum performance. Numerous changes have been implemented in this framework; just to mention some of the most representatives:

- Modular structure. Subjects have been grouped into eight modules, each one of 150 hours, of which at least 50% correspond to the individual student work. Each module is equivalent to six ECTS (European Credit Transfer System). A final module of 12 ECTS is devoted to develop the end master project (Figure 3).

![Fig 3. Modular structure of MINA](image)

The introductory aspects give way to three thematic lines: radiation protection, nuclear power plants and innovative systems. From the second one a broad spectrum of fundamental disciplines structured into four modules is covered: neutronics and thermohydraulics, nuclear safety, nuclear fuel, and materials and radiochemistry. As shown schematically in Figure 4, the project shows the learning outcomes acquired through the modules and it means the closest approximation of students to the reality of industry and institutions.
Emphasizing the practical aspects. Throughout the five performed editions of MINA some training elements, such as practical sessions, problem-solving sessions and assignments, have increased in number and importance. In this sense, special mention deserves the inclusion of two sessions in the Tecnatom PWR and BWR simulators.

Workshops. In the pursuit of know-how, learning spaces have been set in MINA where students have direct contact with analytical tools of interest in the nuclear sector. Currently there are four on-going workshops: MCNP (neutronics) FRAPCON-3 (nuclear fuel), Trace (thermohydraulics) and Melcor (severe accident).

Reduction and restructuring of school hours. Since the first edition of MINA the number of class hours has decreased more than 20%, and this fact, together with the continuous time setting, allows students to have more time for assimilation through the study, development of exercises and/or preparation of other academic activities.

Weighting the pressure of evaluations. Without limiting the level of demand, assessment processes are optimized. On the one hand, it has fostered among teachers that the elaboration of technical reports and the resolution of practical activities be considered as complementary when assessing students, without implying the renounce of a test in those subjects whose contents are determined as essential. On the other, the number of exams has decreased due to the realization of joint tests in subjects included in related fields, or by the use of alternative means of examination, in subjects with less than 10 teaching hours. However, in those cases where the failure is higher than 25% in testing, the obtainment of the master's degree will mean to pass these subjects by mean of a revalidation exercise at the end of the master.

To these and other more minor changes (such as progressive adaptation of the contents in subjects such as neutronics or thermohydraulics), the signature of a number of educational cooperation agreements with the majority of companies and institutions involved in MINA has to be added. This has facilitated the integration of students in companies and institutions during the master project.
Finally, the intensive and extensive use that MINA makes of computing resources, through the specific space created for the master in the CIEMAT Virtual Classroom (Figure 5) have to be emphasized. There, students can access all the contents of the master and their programming, in addition to exchange and discussion forums. In individual cases, no physical presence level tests have been made through the network.

![Fig 5. Web gate of the MINA 2012-2013 edition](image)

### 3.2 Sectorial evolution

Since 2008 several significant events have occurred in the nuclear environment, both domestically and internationally. MINA has maintained attention to them and has been adapted according to developments in the sector.

Beyond the necessary adaptation of MINA, one of the main objectives of the analysis made, was to assess the need for MINA as a tool within the nuclear KM in Spain. Among the main motivations of the origin of MINA, was the called nuclear renaissance. Following the slowdown in the world's nuclear plans, seemed legitimate, therefore rethink its meaning in the present context. The conclusion was clear: MINA initiative remains as a nuclear professional training relevant and capable.

The extraordinary dynamism and broad spectrum of nuclear technology makes that professionals of the sector in Spain ply their trade in remote locations such as Brazil, China and Korea, and not so far away as the United Kingdom; some MINA students, in fact, have found employment in companies based in France or Germany. Furthermore, the absence of construction activities of new Spanish nuclear power plants does not prevent to create needs in other areas such as design, construction and operation of other facilities (such as the Centralized Temporary Storage, CTS), or dismantling itself (as might be the case of Garoña NPP). As if these reasons were not enough, the generational change is a fact that is occurring in Spain and requires replace those people who have been protagonists of the national nuclear program until now by new experts that can absorb their experience and keep their good work. This fact is indisputable in a country with more than 7000 MW in
operation, that in 2012 were responsible for almost 21% of total electricity production in Spain, and whose operation is to continue at the highest levels of security for decades.

Finally, it is noteworthy that, despite the economic crisis, the average number of students in each MINA edition that has been incorporated into the institutions or companies, is around 60%. This fact is an additional indicator of the validity of the master for the labour market.

The context analysis also allowed the identification of significant events with potential impact on MINA. Below the facts and particular impacts on the master are extracted:

- The final decision on the location and commissioning of the Centralized Temporary Storage. The review of the contents of subjects as fuel cycle, nuclear fuel and radioactive waste indicated that the imparted knowledge is adapted to the capabilities that could be sued for the construction and operation of the CTS. Moreover, the fuel workshop will allow that students deepen even more into the evolution of the fuel during dry storage.

- The Fukushima-Daiichi accident. Subjects as Nuclear Safety and Environmental Impact have adapted their contents. The first emphasized, among others, the external events, the fuel storage pools, the filtered containment venting, the stress tests, and in general, everything related to severe accidents; in particular in the severe accident workshop, students will simulate the sequence of TMI -2 and Fukushima -Daiichi accidents. In the subject of Environmental Impact, monographic sessions exist about Fukushima, and the inclusion in the contents of the recovery techniques of soil and water, as well as organizing a new workshop on atmospheric dispersion of radioactivity are promoted. The chapters on boiling water reactors in the subject of Nuclear Power Plants, or the fuel cooling pools in the Fuel Cycle, have been reinforced.

- The nuclear rethinking. One of the immediate consequences of Fukushima has been the loss of the so-called nuclear renaissance, at least for some time. In the new situation takes even more strongly the possibility of plants life extension, even up to 80 years [5]. The teachers of Nuclear Materials subject are currently contemplating the possibility to accommodate the contents to explicitly include the NPP life extension. Also expected further underline the highlighted role of Asian and emerging countries in the nuclear development, within the subject of Generic Aspects of the Nuclear Energy. To these two changes must be added the introduction of the modular reactors within the subject of Fission Innovative Systems in future editions. Unlike the first two, this change has no connection with the accident in Japan in March 2011.

- The end of operation in the Garoña NPP. The dismantling of nuclear facilities is a MINA specific subject. The recent events around Garoña could highlight its importance and perhaps to promote some changes in the contents currently taught. Also, it will be possible to include the visit to Garoña in the visit plan that the students usually perform every year to some Spanish nuclear facilities.

The changes described in the preceding paragraphs have been the result of the analysis made by the management and coordination team of MINA to adapt the Master to the current nuclear context. Although some changes have been occurring gradually, as the directly derived in Nuclear Safety subject after Fukushima accident, others have been proposed from the teachers of the affected subjects and will be a reality in the next edition of MINA.

4. Final considerations

Knowledge management in the nuclear sector is essential to ensure a safe and optimum operation of facilities. The Master in Nuclear Engineering and Applications (MINA), has
managed to become a vehicle of knowledge and experience by incorporating the nuclear sector in the design and implementation of the Master. As a result, around 60% of MINA students are presently working as young professionals in nuclear industry and institutions.

MINA is a consolidated and mature project. However, it evolves to achieve a better adaptation to academia and industry environments. As a result, MINA is an education initiative well framed in the European Area of Education and which contents are updated and articulated through educational tools that promote learning and training of future professionals.

MINA coexists in Spain with two other education initiatives specifically addressing nuclear engineering. Each of the three masters has own characteristics that distinguish one from the others. In spite of it, it would be desirable that, without any harm to their individual identities, a stable framework to find synergies, creating feedbacks and achieving mutual academic recognition, was established. Far from weakening, this cooperation would enhance the nuclear option over other training options, optimizing teaching resources (such as Radioactive Waste Course, taught by the Autonomous University of Madrid, the Polytechnic University of Madrid and CIEMAT) and, possibly, it would result in a more homogeneous and attractive profile to the nuclear sector. The education and training platform, implemented within CEIDEN could be the appropriate environment to forge such collaboration.

5. References


ABSTRACT

The Master in Nuclear Engineering from BarcelonaTECH has started its third edition. The degree, completely taught in English, aims to produce competent nuclear engineers for the nuclear industry. Endesa participated actively in the definition of the syllabus. The Master's 90 credits are divided in required subjects (46.5), elective subjects (13.5), internship (15), and Master's Diploma Thesis (15). The subjects include activities based on active learning and team work: this way, evaluation system becomes an integral and inseparable part of the learning process. About one half of the classes have been delivered by lecturers external to BarcelonaTECH. Besides ENDESA, other companies (ANAV, AREVA, ENRESA, ENSA, ENUSA, Nuclenor, Tecnatom, Westinghouse) are collaborating in the Master with different degrees of involvement. CIEMAT (a major Spanish research centre) and the Spanish Regulatory Body (Consejo de Seguridad Nuclear, CSN) are participating in the Master, as well. In general, students are satisfied with the Master, which fulfils the expectations of the Industry and which, by producing professionals committed to safety culture, makes a significant contribution to society.

1. Introduction

In an international context in which World electricity demand grows rapidly, an important part of the new installed capacity worldwide will be made of renewable technologies and nuclear plants.

After Fukushima Daichi accident in March 2011 some European Union countries have made the decision of renouncing to nuclear energy, but other countries maintain a strong position in favour of this form of energy. Globalization of the economy and the increasing presence of European companies in international projects contribute noticeably to a growing need for hiring qualified professionals by companies around the world.

Endesa, which holds a large share (47%) of the Spanish nuclear capacity, is aware of these needs and it is interested in preparing professionals for the nuclear sector in Spain.

In Barcelona, Nuclear Engineering education has a history of more than forty years, always linked to the School of Industrial Engineering of Barcelona (ETSEIB) of the Universitat Politècnica de Catalunya (BarcelonaTECH).

In 2010, approach between Endesa’s professionals and BarcelonaTECH teaching staff started with the aim of defining the syllabus of a future Master in Nuclear Engineering. Endesa would contribute to the Master with its knowledge and operating experience in the nuclear field, BarcelonaTECH would provide its expertise in training engineers (among them
nuclear engineers) for the society. After several iterations the program was defined and was submitted to the National Agency for Quality Assessment and Accreditation of Spain (ANECA) for verification.

In March 2011, Antoni Giró, BarcelonaTECH’s president, and Andrea Brentan, the Chief Executive Officer of Endesa, signed a Memorandum of Understanding by which the Master was brought to live. The first edition started in October 2011. Since September 2013 the third edition is underway.

The master has the sponsorship of Endesa and the collaboration of most of the Spanish nuclear industries. The Spanish Nuclear Safety Council (CSN), the regulatory body, has been involved in the Master from the beginning and has collaborated actively in the development of the two editions of the Master done so far. Researchers from CIEMAT (the Spanish research centre for energy and environment) have participated as teachers in the Master as well.

Part of the academic offer of the Master in Nuclear Engineering from BarcelonaTECH [1] is offered as well in the framework of the European Master in Innovation in Nuclear Energy (EMINE) [2], launched in 2011 by KIC Innoenergy (European Institute of Innovation and Technology [3]). EMINE students can choose between BarcelonaTECH and KTH (Sweden) to get their first 60 ECTS credit points and then move to Grenoble INP or to ParisTech (France) to get other 60 credits (including internship and project). Electricité de France, AREVA, Vattenfall and Endesa are industrial partners of KIC.

2. Participant institutions

Endesa [4], the largest nuclear plant operator in Spain and the main private sponsor of the master, aims to use talent to help the company face its most important scientific and technological challenges for its business in the future. Seven years ago Endesa launched the Endesa Energy School, another step in Endesa’s pledge to manage its human and intellectual capital and focus on treating the Company’s intangible assets.

BarcelonaTECH [5] is a public higher education and research institution that specialises in architecture, sciences and engineering. The University is strongly committed to providing high quality technical education to timely attend the educational needs of traditional and emerging productive sectors. It is the leading Spanish university in terms of number of international students in master's and doctorate, and is the European university more involved in Erasmus Mundus (13 masters and 7 doctoral programs).

BarcelonaTECH has 23 different schools and faculties in 8 Catalan cities involved in teaching, research, development and technology transfer. One of these centres is the School of Industrial Engineering of Barcelona (ETSEIB) [6] which combines both a longstanding tradition (it was established in 1851) with a spirit of renewal and continuous improvement that have made it one of the best engineering schools in Spain and an internationally renowned educational centre. The School maintains strong ties with the local industrial, financial and social sectors and can boast significant international presence and recognition. Research and technology transfer have helped the ETSEIB to foster a strong presence and involvement in industry.

The Department of Physics and Nuclear Engineering (DFEN) [7], and specifically its Nuclear Engineering Section, is in charge of the education in Nuclear Engineering, always linked to the School of Industrial Engineering of Barcelona (ETSEIB). Together with the Institute of Energy Technologies (INTE), the DFEN offers a Doctorate Programme in Nuclear and Ionizing Radiation Engineering.
The Institute of Energy Technologies (INTE) [8] is one of the ten research institutes of BarcelonaTECH. It develops research activities in different fields: energy studies, ionising radiation, the physics and technology of detectors and particle accelerators.

Besides Endesa, other companies are collaborating in the Master with different degrees of involvement. The list of companies includes: ANAV [9] (the operator of Ascó-1, Ascó-2 and Vandellós-2 power plants, all of them PWR, in the vicinity of Barcelona), Nuclenor (a company participated by Endesa that operates a BWR plant in Santa Maria de Garoña), ENUSA [10] (publicly traded Spanish company for design, manufacture and supply of fuel), ENRESA [11] (public company in charge of the safe management, storage and disposal of the radioactive wastes produced in Spain), ENSA [12] (state owned company specialized in the manufacturing of heavy equipment), TECNATOM [13] (advanced engineering), IDOM (engineering company), Initec-Westinghouse and AREVA. These companies facilitate that their professionals participate in the Master, open internship positions, and/or offer guided visits to their facilities.

CIEMAT (a public Spanish research centre) [14] is participating in the Master, as well, mainly in the area of structural materials for nuclear plants and material degradation, but as well in other topics related with the activities of the centre.

Last but not least, the Master benefits from the collaboration of the Spanish Regulatory Body (Consejo de Seguridad Nuclear, CSN [15]), which contributes with lectures and offers grants to the students through the Argos Chair in Nuclear Safety (in the ETSEIB) sponsored by the CSN.

3. Aims and objectives

The Master in Nuclear Engineering from BarcelonaTECH aims to train competent nuclear engineers ready to assume managerial positions within the nuclear industry or research institutes in the nuclear field. It offers a high quality education for a strategic energy sector, needed of professionals able to work rigorously, accordingly to the Safety Culture and imbued of a high sense of responsibility.

The Master is oriented towards the preparation of qualified professionals, therefore the participation and opinion of the nuclear industry has been essential in the definition of the curriculum and syllabus. In this sense, the collaboration with Endesa has been a fundamental piece of the Master’s definition.

Other important strength of the master is the long-standing collaboration existing between the CSN (the regulatory authority in Spain) and BarcelonaTECH concerning nuclear safety. Since safety issues are of utmost importance in the exercise of the profession, this collaboration is deemed essential for the Nuclear Engineering education.

The connection of DFEN professors with engineers of the nuclear plants (active or retired) has contributed as well to the aim of forming well prepared professionals. After years of cooperation in research and technology transfer, and having a large part of the engineers in ANAV been educated at the School of Industrial Engineering of Barcelona, the personal links are strong. Senior engineers (former ANAV employees), with years of experience, have helped both to the development and teaching of part of the syllabus.

The courses are taught entirely in English with a dual aim; first, they can be taken by foreign students and, second, Spanish students will be fully prepared to participate in international projects.
The degree has been designed to help students:

- Achieve a deep understanding of the theoretical and practical fundamentals of nuclear engineering and the technology associated with power production via nuclear fission chain reactions.
- Have both a clear and broad vision of the energy transformation chain of nuclear fuel into its final useable form, from uranium mining to the management of used nuclear fuel.
- Learn the lifecycle of the different installations, from the initial construction to the decommissioning of a nuclear facility.
- Have a deep understanding of regulation and nuclear safety.
- Develop a strategic view of the sector and the ability to comprehend problems and to make decisions.

Students will acquire the competences needed to manage projects that are run within a company: material supply logistics, plant safety and technical management.

Nuclear industry is highly internationalized; with companies from different countries involved in the same project. The presence of students from different countries together with teaching methodologies based on team work, project based learning, etc. allow students to acquire the competences needed to work in a highly demanding field.

It is worth mentioning that, since this Master allows the access PhD degree studies, it will contribute to the formation not only of professionals but as well of qualified personnel able to exert research and teaching tasks.

4. Master’s programme and methodology

The Master in Nuclear Engineering form BarcelonaTECH is fully adapted to the European Higher Education Area (EHEA) standards, each credit implying 25 h of student work. The Master’s duration is 90 credits (European Credit Transfer System, ECTS). The syllabus is organized in required subjects (providing the necessary multidisciplinary training), elective subjects (which students can use to complement their training in different areas of interest), an obligatory internship (in the industry or in a research and development centre), and finally a Master’s Diploma Thesis, preferably in conjunction with the internship. Table 1 gives an overview of the distribution of the credits.

<table>
<thead>
<tr>
<th>TYPE OF SUBJECT</th>
<th>CREDITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required</td>
<td>46.5</td>
</tr>
<tr>
<td>Elective</td>
<td>13.5</td>
</tr>
<tr>
<td>Internship</td>
<td>15</td>
</tr>
<tr>
<td>Master’s Diploma Thesis</td>
<td>15</td>
</tr>
<tr>
<td>TOTAL</td>
<td>90</td>
</tr>
</tbody>
</table>

Table 1: Type of subject and distribution of credits.

The curriculum is organized on the basis of “subject areas”. A subject area is understood as the set of content and training activities aimed at the achievement of certain competences that can be conceived in an integrated manner. Table 2 shows the required subject areas and the credits planned for each of them.
The contents of the different subject areas can be summarized as follows:

- **Fundamentals of Nuclear Engineering and Radiological Protection**: this bloc includes contents in the areas of Nuclear Physics, Detection and Measurement of Radiation and Radiological Protection.
- **Nuclear Power Plants**: the main systems, components and materials of the nuclear and conventional islands of a nuclear power plant are described, with special focus on PWRs. Includes contents in the areas of Reactor Physics and Thermal-hydraulics.
- **Fuel Cycle and Environmental Impact**: description and justification of the different stages of the nuclear fuel cycle; quantification of the principal source terms of the environmental impact of a nuclear facility and potential doses.
- **Regulations and Safety**: Spanish regulatory framework; basic principles of nuclear safety and technologies and procedures developed to meet them.
- **Management of Nuclear Power Plants**: this module includes the operation and maintenance of a nuclear plant, along with design and construction procedures for new plants, the evaluation of costs and the life management.
- **Elective Block**: Every year a series of optional courses are offered. Students select 3 of them. During the academic year 2012-2013 the following elective subjects were offered:
  - Fusion technology
  - Instrumentation
  - Non-destructive testing methods
  - Monte-Carlo methods for radiation transport calculation
  - Core design
  - Seminars on management and safety.
- **Internship**: students are placed in real work situations in companies and thus will work with experts in the field who can offer them both their knowledge and experience. It should enable the development of high-level competences.
- **Master's Diploma Thesis**: This work should be a synthesis of skills acquired. It will be directed to the assessment of the competences associated to this master's degree.

All the subjects include a large fraction of active learning and team work. An important part of the learning process takes place in a Project Based Learning framework: students, grouped in small teams of 3 or 4 persons, develop two transversal course projects (one per semester) involving all the required subjects of the semester.

The list of subjects and their distribution in semesters is detailed in Table 3. Subject credits aren’t coincident with subject area credits because course projects are treated as transversal subjects encompassing different subject areas. Figure 1 shows the temporal sequence of the curriculum.
Subjects | Credits
---|---
First Semester
Fundamentals of Nuclear Engineering and Radiological Protection | 8
Reactor Physics and Thermal-Hydraulics | 7.5
Systems, Components and Materials | 6
Fuel Cycle and Environmental Impact | 5.5
Course Project 1 | 3

Second Semester
Regulations and Safety | 5
Management of Nuclear Power Plants | 8.5
Elective subjects | 3 x 4.5
Course Project 2 | 3

Table 3: Credits allocated for the different required subject areas.

The evaluation system is an integral and inseparable part of the process of learning. The assessment instruments or activities are integrated into the planning of learning activities, are appropriate to the level of complexity of the learning outcome, are diverse and frequent, and are intended to have immediate feedback.

To achieve meaningful learning, students have to apply their knowledge to realistic situations, in contexts close to the workplace, facing problems whose solution requires making decisions. So, for each subject the dedication of the student (25 hours per credit, 40% contact, 60% autonomous) is planned based on activities using varied teaching methods, coherent with the learning objectives and in line with the evaluation mechanisms so as to achieve high quality learning outcomes.

The courses combine theoretical and practice-based activities (demonstration classes, self-guided studies, use of calculation codes and laboratory) with guided visits to different nuclear installations. The project-based learning ("learning by doing") greatly facilitates the acquisition of generic competences and motivates future engineers by enabling them to apply the knowledge they acquire to solve realistic problems.

Figure 1: Distribution of the curriculum in semesters.
As mentioned in the previous section, one of the goals of the master is to facilitate the students’ transition from university to industry. The internship is part of this strategy, but it is not the only one. About one half of the classes are delivered by lecturers external to BarcelonaTECH (half of them from the industry); this participation is more relevant in subjects like “Management of Nuclear Power Plants” and “Regulations and Safety”. In the first two editions of the Master, the list of lecturers has included professionals and researchers from: ANAV, AREVA, Endesa, ENRESA, ENSA, ENUSA, IDOM, Nuclenor, Tecnatom and Westinghouse (all of them from the industry side), the regulatory body (CSN), CIEMAT, F4E, the Spanish National Fusion Laboratory, JRC Petten, Penn State University, Pisa University, Madrid Polytechnic University etc. In total, some seventy people have participated as lecturers in the Master.

Another important activity regarding the adaptation of students to the industry is the participation in a seminar that every year organizes the Spanish Nuclear Society in Madrid. In this seminar the Directors of the Spanish NPP expose their operating experiences during the previous year. This seminar represents the students’ immersion in the real industrial world. Endesa sponsors the simultaneous translation to English. Within the Master, this seminar is programmed as an activity of the subject Management of Nuclear Power Plants.

Finally, guided visits to industrial facilities contribute as well to the students’ approach to industrial reality. Visits include and one of the power plants near Barcelona, the ENUSA’s fuel factory in Juzbado, Tecnatom’s headquarters in Madrid, ITER site in Cadarache, three days of practices at the full scope simulator of Tecnatom in Vandellòs and the factory of ENSA in Santander.

5. Balance of the first and second editions

In its first edition 15 students followed the masters and, in general, finished their studies with good academic records.

Eight of these students, of different origins, arrived at BarcelonaTECH through the EMINE program with scholarship awarded by KIC Innoenergy. These students followed, in equal number, the second year of the EMINE in ParisTech and Grenoble INP. The other seven students were Spanish. One of them incorporated into the second year of EMINE. According to the available information, all the students of the first edition (2011/2012) have completed internships at European reference institutions such as CERN, CEA, PSI (Paul Scherrer Institut) in Switzerland, Pisa University (GRNSPG), KIT or the NPL at United Kingdom, and at companies such as AREVA, ANAV and Westinghouse.

Students of the first edition have got their degrees between May and September 2013. Presently they are in remunerated pre-doctoral positions (~15%), seeking for a PhD student position (~35%) or looking for a job (~10%); some have obtained a job in the nuclear industry or institutions of the nuclear sector (~20%): Westinghouse, Electricité de France, IAEA; data are missing for the others (~20%).

During the first year valuable information was gathered by means of surveys, personal interviews and meetings with groups of students, which allowed detecting improvement opportunities.

The following important aspects were detected:
- The feedback resulting from the assessment of planned activities not always arrived to the students in time. This probably made their learning process more difficult.
- In some subjects, the students’ evaluation system was not clear enough beforehand.
In some subjects, the workload was not evenly distributed during the semester. It was concentrated towards the end of the term.

In general, lecturers external to the University should receive an academic orientation regarding the clarity of objectives assessment methods, etc.

A greater coordination was necessary among the teachers responsible of the different subjects regarding the overall workload distribution and the exams scheduling.

A great deal of the students’ suggestions were taken into account immediately and implemented on the go during the first edition of the master. All of them have been introduced in the second edition (2012-2013).

Seventeen students participated in the second edition, thirteen of them of diverse origin came through the EMINE programme, the other four were Spanish. Although in the second edition academic results have been also good in general, not all the students validated all the credits.

EMINE students are now in Paris or Grenoble to take their second year of courses. Spanish students are now in internships at ANAV, BarcelonaTECH (linked to the DFEN PhD program), IDOM and ENDESA.

In general, the students that have followed the first two editions of the Master are satisfied. Students identified, among the most satisfactory activities, the guided visits to industrial facilities.

The students of the two first editions come from worldwide: India (9 students), Ethiopia (2 students), United States, Argentina, France, Italy, Bangladesh, Lebanon, Egypt, Indonesia, China, and Republic of Mauritius. This master is particularly attractive for those students coming from countries with plans to build new nuclear power plants, since the subject “Management of Nuclear Power Plants” covers the most important keypoints of the life of a nuclear power plant, from the beginning of the process till its dismantling.

6. Conclusions

The Master in Nuclear Engineering from BarcelonaTECH has started its third edition. It is foreseen that within few years the demand of highly skilled nuclear engineers will increase.

The degree, born from the synergies of different institutions at the Universitat Politècnica de Catalunya (BarcelonaTECH) and Endesa, aims to produce these competent professionals,

The Master’s 90 credits (each credit implies 25 hour of student’s work) are divided in required subjects (46.5), elective subjects (13.5), internship in a company or research centre (15), and Master’s Diploma Thesis (15). The subjects include activities based on active learning and team work. Evaluation system is an integral and inseparable part of the learning process. The Master in Nuclear Engineering is completely taught in English.

The following strengths are identified:

- The focus of the curriculum and syllabus
- The external participation in its definition
- The learning methodology
- The experience of BarceloneTECH in the field of Nuclear Engineering education
- The implication of the Spanish nuclear industry in the Master, that provides an applied approach.
- The implication of the regulatory body
- The high fraction of sessions lectured by external experts.
- The practical visits to sites and installations of interest.
In general, students are satisfied with the Master, which fulfils the expectations of the Industry and which, by producing professionals committed to safety culture, makes a significant contribution to society.

Finally, all the companies and institutions implied in the Master have expressed their intention to keep collaborating in it, specially Endesa, in its clear pursuit of training professionals.

7. References

EUROPEAN MASTER IN INNOVATION IN NUCLEAR ENERGY (EMINE), THIRD EDITION ON PROGRESS.

E. FERRIE\(^{1}\); M. CARREIRA\(^{1}\); W. GUDOWSKI\(^{2}\); F. GARRIDO\(^{3}\); J. DIES\(^{4}\); LL. BATET\(^{4}\); I. OTIC\(^{5}\); C. PATTE\(^{6}\); P.P. PETIOT\(^{6}\); L. DEL VAL\(^{7}\); P. FERNANDEZ-OLANO\(^{7}\); P. JARAS\(^{8}\); Y. FANJAS\(^{9}\); J. BLOMGREN\(^{10}\)

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\(^{8}\)INSTN, CEA, Paris (France)
\(^{9}\)AREVA, Paris (France)
\(^{10}\)Vattenfall, Stockholm, (Sweden)
1. Introduction

The 3rd Edition of European Master in Innovation in Nuclear Energy (EMINE) in the framework of the European Institute of Innovation and Technology – KIC InnoEnergy is on progress.

The experience achieved with master EMINE is presented.

MSc EMINE helps tomorrow’s nuclear engineers take up the challenges that the nuclear energy industry faces in terms of safety, social acceptability and waste management. By offering outstanding technical training and addressing the economic, social and political issues of nuclear energy, the programme broadens the scope of traditional nuclear education.

2. Programme Description

As a significant contributor to energy supply security and diversity, the nuclear industry is a key component of EU energy policy. For example, the price of nuclear electricity is competitive and predictable, and carbon emissions are low and comparable with the best renewable. Nuclear energy is also a potential low-carbon substitute for fossil-fuel-based combined heat and power production.

MSc EMINE will help provide the industry, which already employs around 400,000 people in Europe, with the highly-qualified engineers required to meet the ambitious nuclear expansion plans that many countries are now drawing up. Its students receive the high-level technical education they need to master the engineering complexities of nuclear power generation, as well as business training related to innovation issues and energy management.

The programme thus helps students integrate the technical aspects of the nuclear industry with key political, economic and social issues.

3. Industrial Partners

The uniqueness of EMINE lies in the involvement of its industrial partners. Four major players of nuclear energy, AREVA, EDF, ENDESA and Vattenfall take active part in the master.

The CEA is also actively involved in EMINE, bringing thus its expertise as one of the most important research centres in Nuclear energy in Europe.
4. Programme content

The two-year (120 ECTS) MSc EMINE programme teaches students about energy management issues and gives them in-depth knowledge of the nuclear industry. The first year is spent learning the fundamentals of nuclear engineering plus safety and radiation protection as well as the design and management of power plants, all mandatory for any nuclear engineer, at either of the following locations:

- Royal Institute of Technology (KTH), Stockholm, Sweden
- Technical University of Catalonia (UPC), Barcelona, Spain

MSc EMINE also includes mandatory international mobility among recognized universities in Europe. A second year is spent at either of the following:

- Grenoble Institute of Technology (Grenoble INP), France
- ParisTech, France

Grenoble INP offers specialization in Materials Science for Nuclear Energy with two options: Fuel or Components.

At ParisTech, five options are available:

- Nuclear Reactor Physics and Engineering
- Nuclear Plant Design
- Operations
• Fuel Cycle
• Decommissioning and Waste Management

At the end of the first year, students from both UPC and KTH gather at a summer school at Grenoble Ecole de Management (Grenoble, France) to discuss and dissect innovation issues in energy markets in general and nuclear in particular.

During their second specialization year, students have the opportunity to gain a closer insight into innovation issues through a live case study where they apply a methodological ‘learning-by-doing’ approach in projects coached by KIC InnoEnergy. After completing their second year, students perform a master thesis at an industrial group or research laboratory.

As a result of this approach, MSc EMINE students gain a deep knowledge of what innovation is all about and acquire the soft skills very much appreciated by employers e.g. creating problem-solving solutions or developing fresh initiatives.

Figure 1: EMINE track programme.

Furthermore, the involvement of leading actors from the European nuclear industry helps EMINE’s students benefit from professional conferences and lectures as well as in-house training at key research centres.
5. Career opportunities

The EMINE programme leads to a comprehensive understanding of the stakes of the nuclear business. It opens a path towards a wide range of positions in the industry, from design and construction, to operation and maintenance, decommissioning and waste management.

As MSc EMINE engineers are trained in soft skills, they are also able to evolve in management positions. In addition to a career in industry, EMINE students can also pursue a research career leading to a PhD degree.

6. Requirements

Applicants must have completed a Bachelor of Science or Bachelor of Engineering or equivalent degree that provides a solid background in electrical engineering and/or Physics and/or Chemistry and/or Mechanics and/or Materials Science.

7. Conditional acceptance

Students in their final year of undergraduate education may also apply and if qualified, receive a conditional offer. If you have not completed your studies, please include a written statement from the degree administration office (or equivalent department), confirming that you are enrolled on the final year of your education and giving your expected completion date. If you receive a conditional offer, you should present your degree certificate to the InnoEnergy Admissions Office before your admission in a specific programme can be formalized. The InnoEnergy Admission Office will forward this to your programme, and appointed Year 1 university, such that your admission can be completed.

8. English proficiency

All the programme is in English.

All applicants must provide proof of their English language proficiency, which is most commonly established through an internationally recognized test such as TOEFL, IELTS or University of Cambridge/ University of
Oxford Certificates.

9. Funding details

KIC InnoEnergy grants scholarships to selected students. Scholarships include a monthly allowance during the 24 months of the training, as well as travel and installation costs in the case of non-European students. Students awarded a scholarship will have their tuition fees covered.

10. Accreditation

On completion of the EMINE programme, a Master of Science degree will be awarded from the universities where studies were performed during year one and year two, i.e. a double-degree. A diploma from KIC InnoEnergy related to innovation and entrepreneurship will also be presented.

11. Students:

The students in the three first editions are from:

France, Spain, USA, India, Lebanon, Argentina, China, Egypt, Indonesia, Italy, Mauritius, Ethiopia, Bangladesh, Montenegro, Germany, Poland.
Figure 3: EMINE students in several activities.
For more information:
http://www.kic-innoenergy.com/ emine/home/
THE "DECOMMISSIONING AND WASTE MANAGEMENT SUMMER SCHOOL" AT THE JOINT RESEARCH CENTRE IN ISPRA, ITALY

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ABSTRACT
The Joint Research Centre of Ispra, one of the research sites belonging to the European Commission, Directorate General JRC, was created in the late '50s, in order to support European research related to the civil use of nuclear energy, focussing on safety, safeguards and security aspects. It currently hosts a number of nuclear facilities, some of which are maintained in operation, while others were shutdown in past years or are currently being decommissioned. The Ispra site hosts almost 2500 workers, among which around 400 internal and external workers, operate daily in radiologically designated areas, performing activities related to decommissioning, nuclear waste management, nuclear security research and radioisotope production.

The JRC-ISPRA has been the organiser for many years of the ESARDA courses on nuclear safeguards and non-proliferation, which enjoys academic recognition through the ENEN. The Nuclear Security unit also provides a large set of training courses to nuclear safeguards inspectors and to border security personnel. At the local site level, a radiation protection training programme (based on classical conference teaching and OTJ training) was launched in 2009 by the Radiation Protection Sector of the Nuclear Decommissioning Unit, covering general and specific training on radiological risks and on JRC-ISPRA facilities, and more general conferences are offered on radioactivity and radiation for visitors, schools and the public visiting the site during "open days".

A specific need has emerged in recent years for education and training (E&T) in the field of decommissioning and radioactive waste management (D&WM) field: according to international institutions, it will become increasingly necessary, in the future, to address this need, also taking into account the global reduction in the number of competent persons in the nuclear workforce.

The E&T need in decommissioning and radioactive waste management has been recognized and addressed via a specific training action: the "Summer School on Decommissioning and Waste Management", a joint initiative of the University of Milano, the IAEA, the Joint Research Centre of Ispra and the Italian Society for Radiation Protection (AIRP).

The School targets both internal JRC professionals, who already daily operate in the field of D&WM, and external students/professionals. During the Summer School, site visits and hands-on training take place in the JRC-ISPRA waste management facilities, which provides a unique opportunity for students and professionals to become familiar and gain experience in the field by receiving both theoretical lectures and direct practical application. Moreover, lecturers from many European companies and institutions present state of the art of specific developments in characterisation, clearance procedures, decontamination, dismantling, waste storage, etc. The paper will describe the history, content and organisation of the D&WM Summer School.
1. Introduction

A joint education and training initiative between the IAEA, the Joint Research Centre of the European Commission, the University of Milano and the Italian Radiation Protection Society (AIRP) was started in 2009: the “Summer School on Nuclear Decommissioning and Radioactive Waste Management”. This event contributed, during its five editions, to the training of more than 300 professionals in D&WM from more than 100 Institutions/Companies.

After two initial years in which the Summer School (DSS) was held in the University of Milano buildings, with a single-day visit to the Joint Research Centre in Ispra (JRC-ISPRA), since 2011 the DSS has been entirely held in the JRC-ISPRA site, profiting both from its nuclear facilities in the process of decommissioning, and of the availability of various radiological facilities for radioactive waste management and for demonstration purposes.

Although the training format chosen (frontal lessons + visits and demonstrations) has proved to be very successful throughout the five initial years, also confirmed by participants' feedback, an evolution of the DSS is foreseen in the next years. It will in the future also involve the development of a real case-study, and a more active participation of the attendees in the preparation of safety case for decommissioning and waste management as the collection of arguments that contribute to demonstrate the safety of facilities and activities.

With this new format, The Organising Committee foresees that the DSS will more effectively help students and young professionals in the field of decommissioning and radioactive waste management (D&WM) (the attendee target group) to actively develop their personal skills and competences.

2. Emergence of D&WM training needs

D&WM is an important emerging subject for the nuclear industry, and will become more and more important during the next years, also considering the ageing of existing nuclear power plants and of radiological installations, and the projected gradual reduction in use of nuclear power in some countries.

According to the NEA [1] "in some countries, such as the United Kingdom - in recent years, the decommissioning sector has formed the largest part of the civil nuclear workforce".

However, D&WM has only since recent years been covered in some university courses, and only recently some specific modules have been made available in masters programmes.

An important training need in this field does in fact exist, according to some evaluations [1], and will even increase in the coming years with the emerging D&WM market, which adds to the well-known European and world-wide concern over competent workforce reduction, caused by departures to pension of many experienced persons [2, 3, 4, 5].

The availability of the DSS, an event open without any fee or limitation in the number of participants, is addressing some of these concerns, and following recommendations of the international nuclear E&T market, as reported by the NEA [1]:

- (Recommendation 4) Access to research facilities suitable for education and training purposes should be widened and international co-ordination for such uses should be enhanced. Efforts should be made by governments to financially support existing infrastructure
- (Recommendation 6) Research facilities should work with industry and academia to create opportunities for more effective use of research facilities so as to enhance education and training

The European Commission JRC-ISPRA, recognizing the necessity of a proper evaluation of training needs in D&WM, intends to organize a technical seminar, aimed at identifying stakeholders in the field, and at collecting the views of professionals and universities and...
requests and suggestions.

Moreover, as the DSS can be considered part of the "vocational training pipeline", efforts are underway to validate and accredit its E&T value, via formal university procedures.

In this sense, the DSS Organising Committee is well aware of the recommendations of the European Council and of the European Parliament ([6], [7]) and of the work being done at the level of ECVET for the preparation of an ECVET-oriented taxonomy of nuclear jobs [8], also considering D&WM jobs, and is actively participating in its development.

3. Training facilities and education and training experience at the JRC-ISPRA

The European Commission JRC-ISPRA is a Directorate-General of the Commission, providing independent scientific and technological support for EU policy-making. The JRC-ISPRA site was founded in 1958, after signature of the EURATOM Treaty of Rome, in order to foster research on nuclear applications and technologies: its mission and roles evolved throughout the years and presently nuclear research is only a limited part of its various activities.

The JRC-ISPRA site is the third largest Commission site after Brussels and Luxembourg. It covers an area of 167 hectares and has 36 km of roads and 6 km of perimeter fencing. There are around 250 buildings hosting some 1 800 site staff plus typically 500 staff of external companies and up to 200 daily visitors. The JRC-ISPRA hosts nuclear facilities awaiting decommissioning (two research reactors, three hot cells laboratories, a radioactive liquids treatment station, etc.), facilities already in the decommissioning process (a radiochemistry laboratory, old deposits for radioactive waste, etc.), waste management facilities in operation (a solid waste characterization, treatment and management station, a new radioactive liquids treatment station, a new interim storage facility, RW characterisation facilities, two decontamination facilities, etc.), and research facilities which are in operation (the Cyclotron Laboratory, the Performance Laboratory (PERLA), the PUNITA, EUSecTRA and ITRAP Laboratories, etc.).

Since 1999, with the adoption of the "Nuclear Decommissioning and Waste Management Programme" -a process which will span over a few decades-, JRC-ISPRA is committed to progressively reducing its nuclear liabilities, releasing from regulatory control all classified areas which were accommodated nuclear activities in the past, and eventually assigning them to conventional research activities, without any radiological constraints.

JRC-ISPRA accounts for more than 20 classified zones for radiation protection purposes, and the number of occupationally exposed workers operating in JRC-ISPRA is around 180 internal staff and around 180-200 external staff (depending on specific projects), employed by 25-30 specialised external companies.

A long experience in E&T exists since many years at the JRC-ISPRA: this is linked to the original mission of the JRC-ISPRA, to disseminate knowledge on nuclear topics and harmonize nuclear culture in Europe, but was enormously developed throughout the years, especially in the fields of nuclear safeguards, nuclear materials' management, and nuclear security [9], e.g. the ESARDA workshops.

From a local point of view, some E&T experience also exists in the field of radiation protection, partly due to obligations regarding continuous training to internal and external occupationally exposed workers in the field. In 2009 a new training course catalogue was been established featuring around 40 courses, which are continuously given to occupationally exposed workers throughout the year, alternatively in Italian and in English, and are regrouped in a one-week session once per year [10].

The JRC-ISPRA site is therefore an excellent environment for E&T given the possibility to offer to students both training experience and modern infrastructures for event management and frontal lessons; and the possibility to actively visit site works and laboratories in which decommissioning and radioactive waste management operations are undertaken on a daily
Moreover, many training activities, including the DSS, fall under the dedicated nuclear training and education programmes in the frame of the European Nuclear Safety and Security School (EN3S) of JRC’s Institute for Transuranium Elements.

4. The original concept of the "Summer School" and the organizing Institutions

The first edition of the DSS was a concept developed by some professionals of D&WM and of the radiation protection fields, who agreed to start that event based on their perception of a specific training need.

The original concept of the DSS, which has been basically conserved up the most recent editions, was to combine frontal lessons with practical demonstrations.

It was originally a three-days event whose sessions were mostly addressed to radioactive waste management and also presented an overview on European experience and a visit to some RWM facilities in JRC-ISPRA.

The sessions in the three-days first edition (DSS2009) were:

1. Radioactive waste and risk associated
2. Principles in waste management
3. European Experiences
4. Practice in waste management and research
5. Visit to the JRC-ISPRA Decommissioning project

The Organisations sharing the first DSS2009 were: the University of Milano (Marie-Claire CANTONE), the IAEA (Phil METCALF), and the JRC-ISPRA (Celso OSIMANI): Marie-Claire and Celso also represented, and in fact involved, the Italian Radiation Protection Society (AIRP).

The second edition, DSS2010, featured three sessions, and spanned over four days:

1. Radioactive waste and risk associated
2. Radiation protection and policy issues
3. Principles and experience in decommissioning and waste management

It comprised a more detailed visit to the facilities at JRC-ISPRA, allowing students to appreciate the complex infrastructure needed for waste characterisation and treatment.

In 2011, the 3rd edition of the DSS was entirely held at the JRC-ISPRA: its duration was maintained to four days, but the number of sessions and topics available were significantly increased. The change in the DSS’s format addressed more operational aspects in D&WM, as recalled in the title of the DSS itself, which was modified from the original "Criteria and approaches for radioactive waste management and nuclear decommissioning " to: "Operational issues in radioactive waste management and nuclear decommissioning".
Sessions available in DSS2011 were:

1. Initial characterization, dismantling and demolition
2. Stakeholders’ Involvement
3. Hands-on Visit to JRC-ISPRA’s WM Facilities
4. Seminar: Final Radiological Survey
5. Operational Decommissioning Experience in Europe
6. Radiation Protection
7. Waste Management

For the first time a demonstration in the waste management facilities allowed students not only to follow explanations of measurement techniques but to perform themselves some basic, a priori selected, operations on the JRC-ISPRA installations.

Moreover, recognizing the opportunity to focus every year on a more specific subject, a half-day seminar on the issues regarding "Final radiological survey" after decommissioning was proposed to the attendees.

In 2011, it was considered that the DSS format had reached a good level of maturity, and was replicated in 2012 and 2013 with minor changes in a more consolidated form.

5. The consolidated format of the "Summer School"
   In 2012 and 2013 the DSS spanned over five days offering in both editions six topical sessions:
   1. SESSION 1 – Involvement with society and stakeholders
   2. SESSION 2 – Radiological characterization and facility release; regulatory issues
   3. SESSION 3 - Hands-on visit to JRC-ISPRA WM facilities
   4. SESSION 4 - Radiation protection
   5. SESSION 5 - Operational decommissioning experience in Europe
   6. SESSION 6 - Waste management
   Every session was preceded by an opening lecture offering more insight in its specific field.

For DSS2013 additional Laboratory visits were foreseen: not only to the JRC-ISPRA waste management facilities, as in previous editions, but also on specific facilities belonging to the Institute for Transuranium Elements (ITU) i.e. the PUNITA Laboratory (detection of small amounts of nuclear materials and characterization); to the 3D Laser Laboratory.
(reconstruction of images and detection of change); and an introduction to the use of the NUCLEONICA software in D&WM with interactive exercises jointly developed online by the lecturer and the participants.

6. Participation and feedback to the "Summer School"

Participation to the DSS events has always been very rewarding for the Organizing Committee: number of attendees, in fact, were:

• 2009 edition: limited to 30 participants, 30 registrations
• 2010 edition: limited to 30 participants, 30 registrations
• 2011 edition: limited to 100 participants, 100 registrations
• 2012 edition: limited to 100 participants, 87 registrations
• 2013 edition: limited to 100 participants, 71 registrations

An important number of institutions/companies were sending representatives to the DSS: 12 for the 2009 edition, 16 for 2010, 51 for 2011, 34 for 2012 and 25 for 2013.

The DSS lecturers came from 14 different institutions/companies in 2009, from 13 in 2010, 16 in 2011, 19 in 2012 and in 2013.

According to the evaluation sheets distributed and collected feedback from participants was very positive encouraging further developments of the DSS in the same directions. In previous editions they helped to focus possible improvements and additions to the programme, namely on economic aspects and on informatics applications/demonstrations.

Figure 2, Examples of evaluations sheets
The following picture shows the average appreciation mark (on a range 1 (low) to 5 (maximum) for different DSS2013 lectures: it is interesting and a positive information that the appreciation of attendees rises as the DSS is unfolding.

![Bar chart showing average appreciation marks for different lectures]

Figure 3, Average lectures’ appreciation (1 to 5)

“Difficulty evaluation” is another interesting indicator, showing how the level of every single presentation (from the technical point of view) is perceived by participants, and if it suits their expectations and competences: the following table contains average participant evaluations, and is evaluated on a different range: 1 being “too simple”, and 5 being “too complicated”.

<table>
<thead>
<tr>
<th>Day</th>
<th>Session</th>
<th>Average indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday 9th</td>
<td>Involvement with society and stakeholders</td>
<td>3,15</td>
</tr>
<tr>
<td>Tuesday 10th</td>
<td>Radiation Protection</td>
<td>3,12</td>
</tr>
<tr>
<td>Wednesday 11th</td>
<td>Clearance, characterization and Release</td>
<td>3,32</td>
</tr>
<tr>
<td>Thursday 12th</td>
<td>Decommissioning</td>
<td>3,12</td>
</tr>
<tr>
<td>Friday 13th</td>
<td>Waste Management</td>
<td>3,11</td>
</tr>
</tbody>
</table>

Table 1, Participant evaluations of lecture “difficulty”

Again, the positive indication coming from this evaluation is that lecture levels were not beyond the average level of expectation and of competence of participants.
7. Future evolution of the "Summer School"

Possible evolution options for the DSS format are under study: this will imply an important change in future DSS duration and structure, and a considerable additional amount of preparatory work for lecturers and tutors.

A possible evolution of the DSS may consider a more direct and active involvement of participants in the development of a (previously prepared) "Case Study". The case study could possibly be chosen from amongst the JRC-ISPRA nuclear and radiological facilities. The facilities would be visited in the previous days and the basic radiological and engineering data would be made available to the participants (after proper security clearance!). During the DSS week, after morning lessons participants would be divided in groups and requested to develop the safety case, with the help of tutors. This will consider different aspects namely: decommissioning activities, waste management, clearance and site release, and stakeholder involvement. For each topic both safety demonstration and technological aspects will be taken into account. Finally, a public presentation to the participants of the work developed by each single group would allow a deeper discussion with tutors and a larger involvement of the students in the safety case.

Another development under consideration is the possibility to increase the duration of the DSS to 8 working days, including a weekend, and separating more basic lectures in radiation protection, decommissioning, and waste pre-disposal and disposal (a sort of refresher courses for more experienced participants and an introduction for those with less experience. This new organisation hence, will better specify the DSS target group, "young professionals in the D&WM field", and help in setting the scene for the safety case development in the following week.

This possible new format would entail a large amount of preparatory work and is still under discussion.

Figure 4. Some Participants and Lecturers in DSS2010
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Poster
TRIGA REACTOR PC-BASED SIMULATORS FOR TRAINING AND EDUCATION

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ABSTRACT

The IPR-R1 TRIGA nuclear reactor at Nuclear Technology Development Centre (CDTN) is used for education, particularly for the needs of the Brazilian Nuclear Power Plants operators’ training. Thus, a digital system was developed that simulates the behaviour of the main variables related to the routine start-up of the reactor in order to assist in the training conducted in this reactor. Students of physics and postgraduate students of nuclear engineering can carry out practical exercises on this reactor simulator system. The variables derived from the neutron multiplication that can be simulated are: the inhour curve (relationship between the reactivity and the stable period T); the control rods worth; the neutron multiplication (power). The control panel shows the reactor power in Linear and Logarithmic Channels. With the simulator, several exercises can be performed by simulating various operation scenarios, such as neutron multiplication as a function of the rod position or as a function of a given period. The program can evaluate the effect of extreme values of several variables, allowing understanding the process behaviour and its implications. This is of extreme importance for the safe operation of nuclear reactors. The use of video screens for monitoring the operational parameters is important in the normal operation and to perform basic operator training. Advanced human-system interface technology is being integrated into existing nuclear plants as part of plant modification and upgrades.

1. Introduction

The most important variable in the nuclear reactors control is the power released by fission of the fuel in the core, which is directly proportional to neutron flux [1]. It was developed a digital system to simulate the neutron evolution flux and monitor their interaction on the other operational parameters. The control objective is to bring the reactor power from its source level (mW) to a few W. It is intended for education of basic reactor neutronic principles such as the multiplication factor, criticality, reactivity, period, delayed neutron and control by rods.

The 250 kW IPR-R1 TRIGA research reactor at Nuclear Technology Development Center - CDTN (Belo Horizonte/Brazil) was used as reference. TRIGA reactors, developed by General Atomics (GA), are the most widely used research reactor in the world. They are cooled by light water under natural convection and are characterized by being inherently safe.

The simulation system was developed using the LabVIEW® (Laboratory Virtual Instruments Engineering Workbench) software developed by National Instruments, considering the modern concept of virtual instruments (VI’s) [2]. This system use electronic processor and visual interface in video monitor, as shown in Fig. 1. The main purpose of the system is to provide training tools for students and reactor operator, allowing to study, to observe, and to analyze the behavior, and the tendency of some processes that occur in the reactor using a user-
friendly operator interface. Some scenarios are presented to demonstrate that it is possible to know the behavior of some variables from knowledge of input parameters. The TRIGA simulator system will allow the study of parameters, which affect the reactor operation. Nuclear reactor instrumentation is designed so as to emphasize the reliability, redundancy and diversity of control systems. Power monitoring in nuclear reactors is of crucial importance with respect to safety and efficient operation. Since the first criticality of a nuclear reactor carried out by Fermi and collaborators on December 2, 1942, at the Chicago University, there has been concern about safely monitoring the parameters involved in the chain reaction. Nuclear reactor simulation involves mainly neutronic (neutron physic) and thermal hydraulic (fluid and heat transfer). The dynamic behavior of a reactor is associated with an important property known as its reactivity. This property changes when the fuel temperatures are changed. The changes of reactivity occasioned by fuel changes of temperatures form the effect that is called the "temperature coefficient of reactivity". For the IPR-R1 TRIGA reactor, this effect appears when the reactor operates in power above nearly 1 kW. For low operating power level, there is not the influence of temperature.

Fig. 1. Digital control system simulation for nuclear reactor parameters

2. The IPR-R1 TRIGA Reactor

The IPR-R1 TRIGA (Instituto de Pesquisas Radiativas - Reactor 1, Training Research Isotope General Atomic) reactor is a typical TRIGA Mark I light-water and open-pool type reactor. The fuel elements in the reactor core are cooled by water natural circulation. The heat removal capability of this process is great enough for safety reasons at the current maximum 250 kW power level configuration. However, a heat removal system is provided for removing heat from the reactor pool water. The water is pumped through a heat exchanger, where the heat is transferred from the primary to the secondary loop. The secondary loop water is cooled in an external cooling tower.

TRIGA reactors are the most widely used research reactor in the world. There is an installed base of over sixty-five facilities in twenty-four countries on five continents. General Atomics (GA), the supplier of TRIGA research reactors, since the late 1950s, continues to design and install TRIGA reactors around the world and has built TRIGA reactors in a variety of configurations and capabilities, with steady state thermal power levels ranging from 100 kW to 16 MW. TRIGA reactors are used in many diverse applications, including production of radioisotopes for medicine and industry, treatment of tumors, nondestructive testing, basic research on the properties of matter, and for education and training. The TRIGA reactor is the only nuclear reactor in this category that offers true "inherent safety," rather than relying on "engineered safety." It is possible due to the unique properties of General Atomic’s uranium-
zirconium hydride fuel, which provides unrivaled safety characteristics, which also permit flexibility in siting, with minimal environmental effects [3]. The prototypical cylindrical fuel elements are a homogeneous alloy of zirconium hydride (neutron moderator) and uranium enriched at 20% in $^{235}$U. The reactor core has 58 aluminum-clad fuel elements and five stainless steel-clad fuel elements. One of these steel-clad fuel elements is instrumented with three thermocouples along its centerline. This instrumented fuel element was inserted in the reactor core in order to evaluate the thermal hydraulic performance of the IPR-R1 reactor [4]. The fuel rod has about 3.5 cm diameter; the active length is about 37 cm closed by graphite slugs at the top and bottom ends, which act as axial reflector. The moderating effects are carried out mainly by the zirconium hydride in the mixture and on a smaller scale by light water coolant. The characteristic of the fuel elements gives a very high negative prompt temperature coefficient and is the main reason of the high inherent safety behavior of the TRIGA reactors. The power level of the reactor is controlled with three independent control rods: a Regulating rod, a Shim rod, and a Safety rod.

3 Digital Instrumentation for Nuclear Reactors

Control and instrumentation of nuclear power plants has improved rapidly and significantly in recent years as demands for reactor safety, availability, and reliability increased. Development and design of modern, highly automated systems have become possible as new measurement and control methods were introduced together with new data processing techniques based on recent advances in electronic components, transducers, and computers. There is now a new generation of computerized nuclear power plant control systems that meet the high demands for reactor safety and decrease the risk of accidents. The experience gained using computers in reactor-control systems and in monitoring the status of safety systems has shown the benefits that can be gained from fully computerized shut-down systems. They are reliable, flexible in design, and give a better man-machine interface. Microcomputers and their software will dominate future systems. Computers and their peripherals, e.g., graphical color screens, will become the major source of information for the reactor operator. The new digital control includes automatic start-up and shut-down procedures to reduce risks for potential errors and to improve operational management. The control methods employed are mainly supervisory computer control and direct digital control [5].

4 Virtual Instruments

The rapid adoption of the PC in the last 20 years catalyzed a revolution in instrumentation for test, measurement, and automation. One major development resulting from the ubiquity of the PC is the concept of virtual instrumentation, which offers several benefits to engineers and scientists who require increased productivity, accuracy, and performance. A virtual instrument (VI) consists of an industry-standard computer or workstation equipped with powerful application software, cost-effective hardware such as plug-in boards, and driver software, which together perform the functions of traditional instruments. The VI appearance and operation imitate physical instruments. Traditional hardware instrumentation systems are made up of pre-defined hardware components, such as digital multimeters and oscilloscopes. These systems are more limited in their versatility than virtual instrumentation systems. The primary difference between hardware instrumentation and virtual instrumentation is that software is used to replace a large amount of hardware. Virtual instruments are computer programs that interact with real world objects by means of sensors and that implement functions of real or imaginary instruments. They can acquire, simulate and analyze data. Virtual instruments represent a fundamental shift from traditional hardware-centered instrumentation systems to software-centered systems that exploit the computing power, productivity, display, and connectivity capabilities of popular desktop computers and workstations. Although the PC and integrated circuit technology have experienced significant advances in the last two decades, it is software that truly provides the advantage to build on this powerful hardware foundation to create virtual instruments, providing better ways to innovate and significantly
reduce cost. With virtual instruments, engineers and scientists build measurement and automation systems that suit their needs exactly (user defined) instead of being limited by traditional fixed-function instruments (vendor defined). The synergy between them offers advantages that cannot be matched by traditional instrumentation [2].

LabVIEW® (Laboratory Virtual Instruments Engineering Workbench) contains a comprehensive set of tools for acquiring analyzing, displaying, and storing data. This software is used in conventional plants and in some nuclear reactors, replacing the analog control system with modern, user-friendly digital control [6]. LabVIEW® is an amazingly intuitive software which allows to create programs using a graphics-based programming language called G. This means there are no longer lines upon lines of text-based code with hard-to-remember syntax (e.g., C++, Fortran). You just drag the functions onto the screen and wire them together. Also, LabVIEW® is equipped with some very easy-to-use functions that take care of the dirty low-level work of configuring the computer hardware to establish communication between the computer and the instrument. LabVIEW® software was used, in the work present here, to simulate the neutronic parameter evolution of nuclear reactor. LabVIEW® VIs contain three components: the front panel, the block diagram, and the icon and connector panel. In LabVIEW®, the user builds an interface, or front panel, with controls and indicators. Controls are knobs, switches, push buttons, dials, and other input devices. Indicators are graphs, meters, and other displays that simulate the front panel of a real instrument. The code and structures to control the front panel objects are added to the user interface. The block diagram contains this code. The block diagram resembles a flowchart [7]. Their most recognizable feature is user friendly human–machine interfaces (HMIs) with graphical [8].

5 Simulated Parameters

The neutronic parameters to be simulated are those that appear in the reactor startup caused by the control rods' movement, leading to neutron flux multiplication. As mentioned, the reactor reference is the IPR-R1 TRIGA research reactor. In this reactor, the reactivity control, and consequently the power level, is done by three control rods that can be inserted into or withdrawn from the core. They are: a Safety Rod, a Shim Rod and a Regulating Rod.

The front panel of the simulator system displays the responses of the two main power measure channels, the Linear Channel and the Logarithmic Channel. The reactivity (ρ) the period (T) and the inhour equation are variables derived from these two channels. The boundary conditions are:

- The inhour equation is only valid for stable period.
- The Safety Rod can be moved from position 150 (fully inserted) to position 890 (totally removed). During reactor operation, this rod is completely out.
- The Shim Rod, during the reactor operation, normally works in an intermediate position. It can be moved from position 161 (fully inserted) to position 890 (totally removed).
- The Regulation Rod also works in an intermediate position. It can be moved from position 171 (fully inserted) to position 900 (totally removed).

The simulation is valid for operations up to a maximum of 1 kW. For higher power, the fuel temperature increase causes the appearance of a negative reactivity in the core (temperature coefficient of reactivity), not simulated by this program version.

The main VIs developed for the simulator were: the VI that relates the control rod position with the reactivity inserted in the core (calibration rod equation), the VI that relates reactor period with reactivity (inhour curve) and the VI that relates the neutron multiplication in the Linear Channel and Logarithmic Channel. Some VIs were developed to manage the program. These instruments were called "structure events."

6 Routine Startup and Shutdown of the TRIGA Reactor

The steps that are followed for the routine startup and shutdown the TRIGA reactor are described here. With the control rods of the reactor calibrated and a neutron source provided, the reactor might be taken up to power from its shutdown condition by slowly withdrawing the
Safety rod to its ready position, followed by small stepwise withdrawal of the Shim rod and the Regulating rod, maintaining approximately symmetrical positions for this two rods. The multiplication of the neutrons is followed with the period meter, the fission chamber (Startup Channel) and the ionization chamber (Logarithmic Channel), while the reactor is still subcritical. If the motion of the shim or regulation rod under withdrawal is stopped while the reactor is in this condition, the meters will come to rest and the period meter will return to the infinite period position [9].

The slow adjustment of the shim rod and the regulating rod by the operator is continued. There will come a time when, with the rods stationary, the period meter not indicate an infinite period but some finite, large value. This indicates that the reactor is slightly supercritical. The shim rod positions should then be left as they are, and the regulating rod adjusted slightly to set the period to a moderate value. In this state, the reactor power is slowly rising and may be followed by the meter of the logarithmic channel and later by the linear channel. When the desired power level is obtained, the regulating rod should be slightly inserted until the power level remains constant and the period meter returns to the infinite-period position. The reactor may be shut down by one or more methods. To shutdown the reactor, the “scram” button is pressed, thereby releasing the control rods. They will then quickly insert the rods by gravity and shut the reactor down [9].

7 The Control Rods Worth VI

It was created several virtual instruments (VIs) and for each VI, had developed a LabVIEW® block diagram. The determination of the reactivity worth of individual control elements and the effects of such elements on the power distribution in the core is important to the safe and efficient operation of a nuclear reactor. Once a control rod is calibrated, it is possible to evaluate the magnitude of other reactivity changes by comparing the critical rod positions before and after the change. All three-control rods are calibrated by the positive period method. The method consists of withdrawing the control rod from a known critical position through a small distance. This adds a positive reactivity to the system, and the reactor power increases in an exponential manner with time and establishes a stable period that is measured using the doubling time, that is the time required for the power to increase by a factor of two. Each successive step is compensated by lowering the other control rod just enough to reestablish criticality. The reactivity associated with the measurement is gotten from the graphical form of the inhour equation that gives the relationship between reactivity and the stable reactor period.

The experimental data obtained in the control rods’ calibration and the integral fitted worth curves of the Regulating, Shim and Safety control rods as a function of their positions are shown graphically in Figure 2, Figure 3 and Figure 4, respectively. The equations representing the fitted model, and the coefficients of determination $R^2$, that confirm the goodness of the fit are also shown in the figures. The integral control rod worth curve is particularly important in research reactor operation. The experimental values of the Regulating, Shim and Safety control rod worth for the IPR-R1 TRIGA reactor were 0.5, 3.1 and 2.8 cents, respectively [10].
Fig. 2. Reactivity as function of insertion of Regulation control rod

Regulating Rod

\[ y = -2.07 \times 10^{-6} x^3 + 3.21 \times 10^{-3} x^2 - 8.39 \times 10^{-1} x + 7.81 \times 10^1 \]

\[ R^2 = 0.999 \times 10^{-1} \]

Fig. 3. Reactivity as function of insertion of Shim control rod

Shim Rod

\[ y = -1.23 \times 10^{-5} x^3 + 1.87 \times 10^{-2} x^2 - 4.62 \times 10^{-1} x - 2.82 \times 10^2 \]

\[ R^2 = 1.00 \]

Fig. 4. Reactivity as function of insertion of the Safety control rod

Safety Rod

\[ y = -1.22 \times 10^{-5} x^3 + 1.83 \times 10^{-2} x^2 - 4.47 \times 10^{-1} x - 1.02 \times 10^2 \]

\[ R^2 = 0.999 \times 10^{-1} \]
It was building the VI named “Control Rods Worth” and the control rods worth curves were added to the block diagram of LabVIEW® program. In this VI there are switches and indicators that allow the user to simulate the reactivity inserted into the core as a function of the rods positions. Figure 5 shown the graphic interface for Regulating Rod and places where the user enters with the variables “delta reactivity” and “rod position step”

![Fig. 5. Reactivity versus Regulating rod position](image)

7.1 The Inhour Equation VI

The relationship between the reactivity ($\rho$) and period ($T$) for the IPR-R1 TRIGA reactor, which is not far above the critical condition of operation, is given by the inhour equation. This equation was inserted into the LabVIEW® simulator program. For IPR-R1 TRIGA reactor: the neutron generation average lifetime ($\lambda$ =100µs), the delayed neutron fraction and its decay constant, and the multiplication factor ($k \approx 1$ and $\lambda k \approx 0.001$) is known so the period can be determined when the reactivity is known and vice versa. It was considered the properties of the six known groups of delayed neutrons emitted during the fission of $^{235}$U. Figure 6 shows the graphic interface of the program.

![Fig. 6. Inhour equation curve](image)
7.2 The Neutron Multiplication VI

It was developed the VI named “Neutron Multiplication”. In the graphical interface the user inserts the initial power and the period (T). Graphic presentation of the power may be in linear or logarithmic scales and other resources can also be simulated. Figures 7 and Figure 8 show the graphical interfaces available for the user.

7.3 The Control Panel VI

On the VI "Control Panel" the user must enter the following variables concerning the inhour equation which is specific for the IPR-R1 TRIGA reactor:
- The excess of the multiplication factor “Delta K” which is used in the inhour equation. The default value for the IPR-R1 reactor is 0.001s.
- The neutron average lifetime “L” [s], for IPR-R1 TRIGA is 100µs or 0.0001s.

The block diagram of the control panel is shown in Fig. 9. In all other VI's of the program were developed block diagrams similar to this.
In the VI "Control Panel" is also available the button named "Help" (Fig. 10), which when clicked, presents to the user the recommendations, tips and logical sequence for using the simulator system.

7.4 The Rods Control VI
The operator performs, the control rods movement using the keys "Up" and "Down" on the VI "Control Rods". The rods position is shown on the screen. There are buttons to cause the scram of each rod "SCRAM" or for all rods simultaneously "Emergency". This is the main program screen where the operator starts the reactor operation and visualizes the rod movement in a scheme of the TRIGA core as shown in Fig 11.
8 Conclusion

The IPR-R1 TRIGA nuclear reactor at Nuclear Technology Development Center (CDTN) is used for education, particularly for the needs of the Brazilian Nuclear Power Plants operators' training. Thus, a digital system was developed that simulates the behavior of the main variables related to the routine startup of the reactor in order to assist in the training conducted in this reactor. Students of physics and postgraduate students of nuclear engineering can carry out practical exercises on this reactor simulator system.

The variables derived from the neutron multiplication that can be simulated are: the inhour curve (relationship between the reactivity and the stable period); the control rods worth; the neutron multiplication (power). The control panel shows the reactor power in Linear and Logarithmic Channels. With the simulator, several exercises can be performed by simulating various operation scenarios, such as neutron multiplication as a function of the rod position or as a function of a given period.

The program can evaluate the effect of extreme values of several variables, allowing understanding the process behavior and its implications. This is of extreme importance for the safe operation of nuclear reactors. The use of video screens for monitoring the operational parameters is important in the normal operation and to perform basic operator training. Advanced human-system interface technology is being integrated into existing nuclear plants as part of plant modification and upgrades.

The system simulator was developed using the LabVIEW® software that is the most commonly program used for monitoring, control, simulation and data acquisition. In LabVIEW®, the user builds an interface, or front panel, with controls and indicators. The use of customizable software and modular measurement hardware to create user-defined measurement systems is called virtual instruments (VIs).

Their appearance and operation imitate physical instruments. The resulting system has a user-friendly operator interface. Advanced human-system interface technology is being integrated into existing nuclear plants as part of plant modification and upgrades. A new version of the simulator is being developed to simulate the entire power range of the IPR-R1 TRIGA reactor (until 250 kW). For this upgrade a mathematical expression must be inserted that takes into account the temperature coefficient of reactivity that occurs in operation powers above about 1 kW.
9 Acknowledgments

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10 References


AUGMENTED NUCLEAR EDUCATION

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ABSTRACT

An important duty for a scientist is to correctly inform and educate people on scientific topics. In these regards several studies have shown that acceptance of Nuclear Energy strongly depends by coherent and unbiased information.

In the framework of creating a multimedia tool for Education and Training a new innovative concept was applied. The project is about explaining how a Nuclear Power Plant (NPP) works and solving some of the most Frequently Asked Questions (FAQ) that the user might have. The innovative approach consists in enhancing the end-user experience and attracting his interest through the implementation of an Augmented Reality (AR) environment hence the name “Augmented Nuclear Education”. Augmented Reality is a technology that blends digital objects with reality, so that they appear in the user’s real-world environment.

The user activates the game waving at the screen and is welcome by Prof. Neutronix, the interaction happens in a gesture control environment, without the need of touching any component and/or device. The information are passed to the user through the animations of different components of the NPP and through small pop-up windows appearing once we select a component while Prof. Neutronix explains with a calm and warm voice the functioning of that equipment (see Fig. 1).

The tool was developed having in mind different types of audience and their requirements and hence the system asks to select a profile (i.e. “SIMPLE” or ”ADVANCED”) at the beginning of the “Game”. The simple profile addresses a general public audience explaining the NPP components with an everyday’s language and easily comprehensible examples. The advanced profile on the other hand is directed to an audience with some scientific knowledge but yet not technical that might be not used to terms and concepts of nuclear engineering (i.e. journalists, politicians, public with higher education...).

A second part of the tool is a kind of test that requires the user to answer some Frequently Asked Questions (FAQ) grouped in three subfields: Materials, Energy, and Radiations. The questions are presented with 3 multiple choice potential solutions. The user selects an answer and Prof. Neutronix interacts with her/him either approving the answer and giving some further technical details or encouraging the user to find a different solution. At the end of the 9 FAQs the user get the score of the total correct answers.
Figure 1 - Screen shot of the tool

The TURBINE converts the thermal energy of the steam into mechanical energy and drives the generator that generates electricity.
The Nuclear Fuels School of CEA Cadarache, an experimental and theoretical approach for education and training in the field of fuel study

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Abstract

The use of fuels, plutonium and actinides implies a knowledge of their physico-chemical characteristics, the technologies specifically related to plutonium and actinide facilities and the design and safety rules that must be observed. The Plutonium School was created in 1987 at Cadarache to meet the training needs of CEA agents working within the framework of fast reactor fuel and MOX fuel development, used in Pressurized Water Reactors. The different courses are designed for all personnel working in the field of nuclear research and energy: operators, technicians, engineers, manufacturers, the operation staff and project managers,....The Plutonium school was renamed “The Nuclear Fuels School” in 2012 in order to cover the entire scope of all fuel studies. The school is a part of the Fuel Studies Department and is associated with The National Institute for Nuclear Sciences and Techniques (INSTN).

1. Introduction

The use of fuels, plutonium and actinides implies a knowledge of their physico-chemical characteristics, the technologies specifically related to plutonium and actinide facilities and the design and safety rules that must be observed. The Plutonium School was created in 1987 at Cadarache to meet the training needs of CEA agents working within the framework of the development fast reactor fuel and MOX fuel, used in Pressurized Water Reactors. The Plutonium school was renamed “The Nuclear Fuels School” in 2012 in order to cover the entire scope of all fuel studies.

2. The training and the CEA facilities
The training is based on a mixture of conferences, practical work sessions and visits dealing with safety problems, legislative aspects and all the activities involving the fuel cycle. The topics of the conferences include reviews of nuclear physics, plutonium and actinide properties, metallurgy and chemistry, biological and medical aspects, plutonium metabolism, risk assessments (contamination, irradiation and criticality) and legislation (waste and facility management, safety). The school also offers handling exercises in both inactive and active glove boxes, an introduction to radiation measurements, gamma spectrometry, dosimetry and visits to nuclear reactors and laboratories working on fuel, reprocessing and waste. The CEA fuel facilities are shown in Figure 1 (hot labs).

Figure 1: CEA fuel facilities, hot labs

3. The training courses, trainees and trainers

The teaching levels vary according to the qualifications and profiles of the participants. Among the different training courses, the catalogue includes: “An Introduction to the Handling of Plutonium and Actinides”, “Fuels, A General Overview”, any tailor-made training course on plutonium and actinides according to specifications and courses for
foreign participants as well (AIEA, KIC InnoEnergy, ITU...). A new tool for fuel modelling is now available in a 3D movie. The teachers, mostly CEA and AREVA employees, are specialists in their fields. Engineers, technicians, project managers, all share their knowledge and pass on their expertise and professional feedback. The trainees come from the world of industry, the universities, and engineering schools.

Figure 2 gives the programme of the “Introduction to the Nuclear Fuels School” training session (5 days) carried out along with The National Institute for Nuclear Sciences and Techniques (INSTN) and Figure 3 shows the “nuclear fuels overview” training session (1 day) organized in collaboration with the CEA Professional Training Office.

NUCLEAR FUELS SCHOOL / INSTN

Introduction to the handling of plutonium and actinides
REF. 020

Objectives
-to be able to describe different radiation associated with plutonium and actinides and explain the differences.
-to know about the necessary equipment, its use as well as the risks associated with the implementation of the plutonium and actinides.
-to know how to explain and reproduce the gestures and necessary controls for manipulation of the plutonium and actinides.
-to be able to specify the nuclear fuel manufacturing conditions.
-to learn and describe rules for the management of waste and alpha effluents.

Public
Technicians or engineers working in facilities or on themes related to nuclear fuel manipulated in glove boxes and wishing to acquire a basic knowledge of plutonium and actinides, manipulation in a glove box and the associated risks.

Prerequisites: Interns must obtain medical clearance allowing them to stay and work in a controlled area for the duration of the session.

Content
-Review of nuclear physics.
-Characteristics of Pu and actinides.
-Medical aspects.
-The Pu and actinide risks: contamination, irradiation, criticality.
-Rules concerning the use of the Pu and actinides: facilities and waste management.
-Implementation of the Pu and actinides: premises, gloves boxes, the nuclearisation of equipment and the manufacturing of fuel elements.

Practical work
-Active and inactive glove boxes involving the manipulation of Pu and actinides.

Method
Lectures, practical work sessions including actual manipulation in a glove box.
Visits: facilities at CEA Cadarache.

Group limited to 14 participants.

Regulatory: Persons subject to dosimetric monitoring must make sure their dosimeter is regularly kept up to date for the duration of the session.
The GOALS of these sessions seek to:
- improve the knowledge of the various nuclear reactor types and their associated fuels,
- describe some fabrication processes for the more standard nuclear fuels,
- describe some characterization devices used for spent nuclear fuels.
- upgrade overall knowledge of in-pile nuclear oxide fuel behaviour and of its limits.

ATTENDANCE
Technicians and engineers intending to work on nuclear fuels or interested in this subject.
Students who wish to acquire an overall view of nuclear fuels and their performance.

COORDINATION
Collaboration: CEA/DEN/DEC/DIR
Pedagogical manager: Didier Paul

CONTENT
This training session is an introduction to an overall knowledge of nuclear fuels (mainly oxides). It is a full day lecture including discussion of the following items:
- The nuclear reactor types and their fuels,
- The design and fabrication of nuclear fuels,
- The post-irradiation examinations,
- The in-pile nuclear fuel behaviour and its limits.

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The Nuclear Fuels School
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Figure 3: Nuclear fuels overview training session

4. The training facilities, means

The training facilities, located in a building near the plutonium zone of the Cadarache Centre, include a conference room with modern communication means, an equipment demonstration room, a model cell designed for practical training sessions involving manipulations of matter in glove boxes, a library and a museum. The school is part of The Fuel Studies Department in The Plutonium, Uranium and Minor Actinides Service and is associated with The National Institute for Nuclear Sciences and Techniques (INSTN) operating within the framework of a convention.

Figure 4 shows the conference room and the practical work instructors in the model cell in front of one of the two glove boxes.

Figure 4: The conference room and the model cell (for practical work sessions) of The Nuclear Fuels School

Sometimes the training session takes place in the facility itself as seen in Figure 5 with the trainees enrolled in a KIC InnoEnergy session and working in the Bernard François Laboratory also called the UO₂ lab and training programme.
Figure 5: the KIC InnoEnergy training session (INEPT Project), CEA Bernard François (UO₂) lab

5. Conclusion

The Nuclear Fuels School now has new challenges facing it with a national and international outlook and new audiences. This facility of The Fuel Studies Department of the CEA has proven to be an excellent instrument in the monitoring of short, medium and long-term needs in the field of nuclear fuels and nuclear safety. Its goal is to establish links with the European Commission and the Joint Research Centre in order to reinforce the potential that the CEA’s expertise and unique facilities offer to graduate and post-graduate education and training, including a close collaboration with academic and other educational organisations acting as a new member of the GENTLE (Graduate and Executive Nuclear Training and Lifelong Education) Project (FP7).
Nuclear Chemistry and Radiochemistry play a fundamental role in sustainable production process of
energy through nuclear power plants and in new technological solutions development.
A crucial point is the cultural and operative preparation of new operators in these fields that implies the
necessity that courses like health physics and/or radiochemistry must be more present in the
university curricula.

1. Introduction

In 1896 Henry Becquerel discovered a related phenomenon, thanks to a well known
accidental event: some uranium salts put in contact onto a photographic film, closed in an
effective shield, blackened the film itself: he deduced that the U salts did produce unknown
rays more penetrating than light. At first, it seemed that the new radiation had the same
characteristics of the discovered Röntgen X rays just one year before.
Moreover, Marie Sklodowska and Pierre Curie in 1898 discovered that several other
chemical substances (or ores) presented the same properties of the uranium salts; thus they
invented the term radioactivity to describe this new phenomenon. They discovered that the
emitted rays presented different characteristics corresponding to three different types of
radiation: the 1-st with a positive electric charge called $\alpha$, the 2-nd with a negative electric
charge called $\beta$, and the 3-rd one without electric charge called $\gamma$. In 1919 Ernest Rutherford
became the first person that transmuted one element into another, when he converted
nitrogen into oxygen through the nuclear reaction $^{14}_{4}N(\alpha,p)^{17}_{7}O$.
In 1933 Frédéric Joliot e Irène Curie using the $\alpha$ particles discovered from Irène’s mother
Marie, discovered more deeply the artificial radioactivity: by bombarding with these particles
some light elements they observed that some elements like the natural ones but with
radioactive properties were produced. The new radioactive elements were not identical to the
knowing natural radioactive elements, as for their chemical properties, as for the type of the
emitted particles, as for half-lives as well; in other words they understood that it was possible,
by bombarding a nucleus, to transmute it in another one with particular nuclear characteristic
related to its decay mode.
At the beginning of 1934 at the Institute of via Panisperna in Roma, Italy, Enrico Fermi and
Co., after reading the discovery of the artificial radioactivity, by using a Ra-Be source,
discovered that also the neutrons (especially if thermalised) could transmute a stable nucleus
into a different radioactive one. Furthermore, become immediately evident that to produce a
large activity and a huge amount of radioactive elements it was necessary to use more intense neutron sources or intense sources of light ions (protons, deuterons, alpha) with high energy, suitable to penetrate the nucleus and produce, through a suitable nuclear reaction, the radionuclides of interest. As described by E. Fermi [1] the ways followed at that time were the use of nuclear reactors or particle accelerators like cyclotrons, Van de Graaf and/or linac. In a few months the Panisperna group was able to describe the properties of a great number of new artificial radionuclides. It was immediately clear that the application of artificial radioactivity could be a major outcome for research, industry and especially for medicine. In 1938 Fermi wrote that the main applications of artificial radioactive elements like the natural ones would be in the radiotherapeutic field. It would be possible to prepare a great number of different artificial radionuclides that could be produced in some particular chemical form, that permit to obtain specific effects. He stated also that he hoped that the huge amount of artificial radioactivity could allow experimental research in the field of biology and chemistry, using the radioelements like “indicators” (today they are called “radionuclides”). He knew very well the first experiments made in the ‘920 years by G. von Hévesy, Nobel Prize in 1943, about the dispensing of $^{32}$P, isotope of the phosphorus, that thanks to its radioactive properties, could be detected even if the amount given was so small that did not modify the biological behavior. This is the basis of the “radionuclide principle” for which the labeled compound doesn’t have a pharmacological effect on the patient due to the negligible mass or molar quantity administered (ng – nmol). At that time started what today we call radiodiagnostic and radiotherapy applications with the use of “unsealed radiopharmaceutical compounds”, chemical species labeled with suitable radionuclides. So it must be recognized that ionizing radiations play a fundamental rule in radiodiagnostics, where the radiations allow to “look” inside the human body and in metabolic radiotherapy, where the supplied energy of the radiations allow to kill the tumor cells [2]. The biodistribution of the radiopharmaceutical is related to the chemical – physical characteristics of the compound itself, the administration via to living organisms, the capability to cross the biological barriers and to the evaluated patient metabolic conditions. Moreover, induced fission promised suddenly to became a powerful and inexhaustible source of energy (both thermal and electrical) for industry, transportation and basic necessities of human life. In this scenario the novel disciplines namely Radiochemistry, Nuclear Chemistry, Radiation Chemistry (in short N&R) and Health Physics [3] started to develop quickly, up to the more update applications like: Radiopharmaceutical Chemistry (i.e. for both radiodiagnostics and metabolic radiotherapy) [4,5], curing of materials, protection of human heritage handicrafts and sterilization of different kinds of food, medical and surgical specimen as well [6], and last but not least the direct dissociation of water in gaseous H$_2$ (i.e. hydricity) and O$_2$, either pyrochemically in presence of a catalyst at temperatures much higher than 1000 °C in very high temperature nuclear reactor (VHTGR) or by thermochemical cycles at a bit lower temperatures (HTGR). The heat generated by Nuclear Power Plants - NPPs - can also solve the problem of lacking of potable water, by desalting the inexhaustible sea and ocean sources [3, 7-9].

2. Materials and Methods

The N&R and Health Physics play a crucial rule in many and different fields, related to:

- in the various steps of fuel cycle for energy production with NPPs, based on fission of either fissile (or fertile) materials, from ore mining, plant operation, decommissioning and radioactive waste disposal;
nuclear analytical techniques (NATs): Instrumental- and Radiochemical Separation Neutron Activation Analysis (INAA and RSNAA respectively) and others [1], applied to monitor environmental and biological matrices and to characterize the nuclear fuel;

radioanalytical techniques: use of High Specific Activity Radiotracers produced by cyclotron or nuclear reactor in no-carrier added (NCA) form [10], applied to the development and calibration of the radioanalytical and radiochemical processing procedures;

radiation protection techniques: alpha, beta and gamma spectrometries, applied to control the environmental contamination and to the health physics protection of general population and workers.

For each of these points a deeply dissertation could be reported. In this report we underline the contribution of N&R in the fields of research at LASA Laboratory, presenting some our results from which it can be understood the power of these kinds of techniques.

The INAA is a powerful multielemental technique that bombarding stable isotopes and with the successive gamma spectrometry of the activated samples reaches a high sensibility for many elements, high accuracy and precision and minimum effect of the matrix. It is excellent for environmental and biological matrices. In our laboratory we use the Research Nuclear reactor TRIGA MARC II – 250 kW (General Atomic – USA) of the Pavia University, that in the central thimble facility “Lazy Susan” can reach a neutron flux of $10^{13}$ cm$^{-2}$ s$^{-1}$. In Fig. 1 is reported, as an example, the results obtained analyzing the human blood [11].

Fig. 1 Analysis of the human blood by INAA and the determination at the same time of 30 different elements [11]. Inorganic Ion Exchangers: TDO tin dioxide, CUS copper sulfide, AAO acidic aluminum oxide; the DOWEX 1x8 is an anionic organic exchanger.

With the same technique we monitor the trace element (TE) content in the atmospheric particulate in order to control and evaluate the degree of the air pollution and furnish additional information for assessing the air quality of our environment. Many TE of anthropogenic origin may be considered dangerous to the human health and their presence in the air constitutes a potential risk for the population, not only at level of threshold concentrations, but also in terms of prolonged exposure to low levels. However, the
knowledge of the concentrations in the total suspended air particulate, which represents an important parameter, is nevertheless not sufficient for a more close evaluation of the possible impact onto the public health. The monitoring must be comprehensive of the concentrations in the fine particulate fractions involved in the respiratory system at alveolar and bronchial levels. By means of inertial multistage impactors, the air particulate can be collected in fractions, to distinguish among the deposition in the alveolar (particles from 0 to 1.1 mm nominal diameter), bronchial (from 1.1 to 4.6 mm) and tracheo-pharynx (from 4.6 to < 9 mm) areas of our respiratory system. After the sampling campaign consisting in the aspiration of dust upon filters, the INAA followed by high resolution gamma spectrometry measurements and the Electrothermal Atomic Absorption Spectrophotometry (ET-AAS) can be employed to evaluate the concentration in ng m^{-3} of many elements, of toxicological interest. The concentration of the TE in the corresponding total air particulate allows us to compare the state of the air quality among the different locations investigated. The knowledge of the TE distribution trends in the different size particle fractions furnishes information about their mobility and their paths followed in the different human respiratory areas [12, 13].

The High Specific Activity Radiotracers produced by cyclotron or by nuclear reactor in No Carrier Added (NCA) form is a long tradition at LASA [10, 14, 15]. Such radiotracers are a powerful tool to label a wide variety of chemical elements and compounds present in the biosphere in ultra-trace amounts. Medium and high Z radionuclides, can be produced by irradiation in light-ions accelerator and sometimes nuclear reactor. If the nuclear reaction product has atomic number different from irradiated target, it is possible separating the radioactive nuclide from irradiated target, without addition of isotopic carrier. These kinds of radionuclides are named No Carrier Added, NCA, and their specific activity is very high and can reach values close to the theoretical Carrier Free one. The true specific activity must be determined by use of very sensitive radioanalytical techniques. If a low isotopic dilution factor is obtained, these radiotracers are used to label inorganic species and complexes of elements, which are presently introduced into the echo-systems by human activities. The “accurate” knowledge of the behavior of thin-target excitation functions for nuclear reaction leading to cyclotron production of relevant RNs, allows increasing both radionuclidic purity and specific activity of RN itself, obviously by use of very selective radiochemical separations, without the addition of isotopic carrier.

In all these kinds of activities it is necessary to have a radioprotection system in order to guarantee the adequate protection of the personnel and of the public living outside the structure by the Qualified Expert, a professional figure with the responsibility to take under control all the aspects related to the usage of ionizing radiations.

3. Results and conclusions

Activities using ionizing radiation become each day more and more employed in every field of our life. It is very important to underline to the young people that the real risk, that only with education and training it is possible to try to stem, in the field involving ionizing radiations is related to the loss of expertise: the ageing of the workforce, limited prospects for new build and moratoria in a number of countries on the use of nuclear energy are all aspects that impact the level of skills and competence across the whole nuclear sector, particularly in the West Countries and dramatically in Italy. Emergency and post accident management is no exception to this trend. Key indicators of the nature of this problem are: declining university
enrolment, closure or dilution of university departments offering nuclear education and training, demographics of the workforce resulting from retirement over a relatively short period with little or no replacement planned, major reductions in research capacities as the industry matures, reducing funding for experimental research and closure of dedicated experimental facilities, which has been accelerated by growing social distrust of experiments involving radioactive materials.

On the contrary we can have a real “protection” if there are very well trained personnel that work in this field maintaining the competence, the expertise and the skill.

So it is clear the necessity to stress the great need of education and training of young scientists in the field of N&R techniques, in order to ensure sustainable supply of qualified nuclear chemists and health physicists. This goal could be reach (time goes on in the meantime) starting to re-enter in full into the university programs, the courses of health physics, nuclear chemistry, radiochemistry and related subjects.

It is important to take in mind that the subjects related to these fields require a constructive collaboration between Physics, Chemistry, Biology, Medicine that are only different chapters of the only one great book of the life science.

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5. References

THE POSSIBILITY OF UTILIZATION OF «CRYSTAL» AND «GIACINT» RESEARCH INSTALLATIONS FOR NUCLEAR EDUCATION AND TRAINING

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ABSTRACT

With the start of construction of a NPP in the Republic of Belarus, the work on the development of a national training system, necessary for the operation of the future NPP, is done. At present, the Belarusian universities are training specialists in the field of nuclear energy. The Joint Institute for Power and Nuclear Research-Sosny of the National Academy of Sciences of Belarus (JIPNR-Sosny of NAS of Belarus) has organized a branch of the Chair of Nuclear Physics of the Belarusian State University. The training strategy is to complete theoretical courses and training courses on simulators with the experimental work (laboratory work) carried out on research installations «Crystal» and «Giacint». The «Crystal» and «Giacint» installations can include uranium-containing critical assemblies with water and zirconium-hydride moderators, or without moderator. The specified installations can be used for education and training of university students. The education experiments can be combined into training courses attended by students according to their study specialization and knowledge level. Research project programs can be implemented in the postgraduate courses. The training program can be focused on neutron and reactor physics, nuclear safety, and control of nuclear installations. A proposal to expand the training activities at the «Crystal» and «Giacint» installations is presented here. The description of these research installations, which after modernization can be used in the educational purposes and some data about the experiments which can be carried out during training courses on these installations, is presented.

1. Introduction

In order to develop human resources for the NPP under construction in four leading universities of the Republic of Belarus, students in nuclear power engineering and physics are educated and trained. For involving leading scientists and experts in the use of nuclear power into the process of education of human resources and development of laboratory and educational books and manuals for university students, the Joint Institute for Power and Nuclear Research – Sosny of the National Academy of Sciences of Belarus (JIPNR-Sosny), which has a huge experience in theoretical and experimental research in nuclear power, has organized a branch of the Chair of Nuclear Physics of the Belarusian State University.

The JIPNR-Sosny has a training and computational centre and a classroom of physical protection of facilities using or storing nuclear materials. The training centre of the JIPNR-Sosny has an analytical NPP simulator with a VVER reactor facility. The computational centre has a modern supercomputer SKIF K-500 and data storage systems.

Since the JIPNR-Sosny has huge experience of making experiments at critical assemblies and nuclear reactors, it is expedient that the strategy of education in the branch of the Chair of Nuclear Physics should be aimed at supplementing theoretical and training courses on simulators by experimental research at nuclear research installations. The training courses at these installations are necessary to give to students and future operating personnel a comprehensive understanding of the nuclear physics and to illustrate the principles and the operation of the nuclear reactor. The research reactors installations critical «Crystal» and «Giacint» can be used for such purposes after the necessary modifications.

The research installations «Crystal» and «Giacint» are designed for investigations in physics and safety of neutrons of multiplication systems and for development of a new generation of nuclear reactors of various uses. These installations can be used to assemble uranium-containing critical assemblies with water and zirconium-hydride moderators or without moderator. Sets of fuel rods containing with different uranium-253 enrichments (10; 19,75; 462/506 18/11/2013
21; 36; 75 and 90%), cassettes of reflector units (based on zirconium hydride, beryllium, polyethylene, stainless steel, etc.) and controls (rods and plates) of the control and protection system (based on europium oxide, boron carbide, cadmium, etc.) are also available.

In order to use the described facilities for education and training, they should be appropriately upgraded, including reconstruction of the control and protection system and selecting the critical assembly types and configuration for experiments. It is also required to upgrade the system of collection, processing and storage of experimental data at research installations, organize a training classroom for students, provide the required equipment, including devices for experiment observations, and to develop and test at critical assemblies methods and manuals for education and training experiments (laboratory works). The education and training experiments can be included into training courses for students according to their study specialization and the level of knowledge. Research project programs can be organized for the postgraduate courses. The training program can be focused on neutron and reactor physics, nuclear safety, control of nuclear installations, etc.

A proposal to expand the training activities at the installations «Crystal» and «Giacint» is presented in this paper. It also includes some data on the experiments to be are carried out at the facilities in the course of training.

2. Research installation «Crystal»

The research installation «Crystal» includes: a critical assembly, a control and protection system (CPS), a radiation control system, an alert system, a temporary (operational) nuclear fuel storage, a physical protection system, etc. The research installation «Crystal» is used to assemble critical assemblies with zirconium-hydride moderator. Figures 1 and 2 show photos of the critical assembly and the loading chart for one of possible core configurations.

Fig 1. Critical assembly with zirconium-hydride moderator
Fig 2. Loading chart of critical assembly with zirconium-hydride moderator
The uranium-zirconium-hydride critical assembly (Fig. 2) represents a hexagonal grid of fuel assemblies of type 1, 2 and 3, channels of the CPS controls and side reflector cassettes spaces at 45 mm in the basket made from, stainless steel. The moderator and inner reflector’s layer are from zirconium-hydride. The critical assembly basket is surrounded by the side steel reflector. The upper end reflector units from stainless steel are put on top of the fuel assemblies and side reflector cassettes. Neutron detectors are fixed around the critical assembly.

The fuel assembly body, type 1, represents a thin-wall hexagonal stainless steel tube with the wall thickness 0.4 mm, for the 44 mm wrench. The hexagonal tube is connected to the shank, representing the mounting surface when the core is assembled. The hexagonal tube houses 12 hexagonal moderator units from zirconium-hydride ZrH$_{1.9}$, each 50 mm high, for the 42.85 mm wrench. The moderator units with the triangular grid pitch 14.5 mm, has seven holes 8.2 mm in diameter, housing the stainless steel channel tubes with the outer diameter 8 mm and the 0.25 mm walls. The fuel assembly houses one fuel rod, type 36 (in the center), and 6 fuel rods, type 21.

The fuel assembly, type 2, differs from the fuel assembly, type 1, in that three steel tapes alloyed with boron (boron-10 85% enrichment) are placed in the gaps between the hexagonal tube and the zirconium-hydride units. The tapes are arranged in the central part of the fuel assembly at the height 300 mm, on every second facet. The tape is 20 mm wide and 0.3 mm thick.

The fuel assembly, type 3, differs from the fuel assembly, type 1, in that the zirconium-hydride units arranged in the central part of these cassettes (at the height 300 mm) have recesses that increase the moderator content in this part of the fuel assembly by 17 volume percent, and the gaps between the hexagonal tube and the zirconium-hydride units include three steel tapes as in the fuel assembly type 2.

The fuel rod, type 36, includes a fuel core, its cladding and end parts. The fuel rod cladding is made from stainless steel with the 7 mm outer diameter and 0.35 mm wall. The fuel core is a fill of uranium dioxide with the density 5.2 g/cm$^3$. Enrichment by uranium-235 is 36%. The total core height is 500 mm. The upper and lower shanks of the fuel rod are made from stainless steel with the 60 mm length and 6.6 mm diameter. The total fuel rod length is 620 mm.

The fuel rod, type 21, includes a fuel core, its cladding and end parts, i.e., upper and lower plugs. The fuel rod cladding is made from stainless steel with the 6.2 mm outer diameter and 0.4 mm wall. The fuel core comprises tablets, 5.2-5.3 mm in diameter and 5-7 mm in height, made from uranium dioxide with the density 10.2 g/cm$^3$. Enrichment by uranium-235 is 21%. The total core height is 500 mm. The uranium-235 mass in the fuel rod is 20.5 g. The fuel rod has a stainless steel, 0.55 mm in diameter, wired on it with the 100 mm pitch.

The body of the side reflector cassette, type 1, is a hexagonal stainless steel tube, for the 44 mm wrench and the 0.4 mm wall thickness. The hexagonal tube is connected to the shank, representing the mounting surface when it is put into the basket. The hexagonal tube houses hexagonal zirconium-hydride ZrH$_{1.9}$ units, each 15 mm high, for the 43 mm wrench, arranged through the entire length of the cassette. These units have a 28 mm hole, with the 27 mm organic glass rod inserted through the entire length of the cassette. The zirconium-hydride reflector cassettes, type 2, are fuel rods, type 1, without fuel rods.

The critical assembly has 12 channels for the control and protection system’s controls, arranged uniformly along two belts, inner and outer. The CPS control moves inside the hood, representing a stainless steel tube 42 mm in diameter and the 3 mm wall. The CPS control comprises absorbing and dissipating links, connected by a swivel. The upper absorbing link includes an outer cladding (a steel tube with the 33x1.0 mm diameter) and an inner cladding
(a steel tube with the 17x0.5 mm diameter). The circular spacing between the outer and inner claddings is filled with Eu\textsubscript{2}O\textsubscript{3} neutron absorber with the density of fill 5.3 g/cm\textsuperscript{3}. The absorbing part is 400 mm long. The inner cladding includes powdered Al\textsubscript{2}O\textsubscript{3} with the density 2.1 g/cm\textsuperscript{3}. The lower dissipating link includes a cladding (a steel tube with the 33x1.0 mm diameter), filled with the powered Al\textsubscript{2}O\textsubscript{3} with the density 2.1 g/cm\textsuperscript{3} over the 410 mm length.

3. Research installation «Giacint»

The research installation «Giacint» is used for investigation of critical assemblies with water and zirconium-hydride moderators or without moderator. It includes: a critical assembly, a control and protection system (CPS), a hydraulic system, a radiation control system, an alert system, a temporary (operational) storage of nuclear fuel, radioactive substances and waste, a physical protection system, etc.

Figures 3 and 4 show photos of the critical assembly and the loading chart for one of possible uranium-water core configurations, which can be used for education and training purposes. The hydraulic system of the critical installation «Giacint» is designed to work only with uranium-water critical assemblies and is shown in Figure 5.

The uranium-water critical assembly (Fig. 4) represents a homogeneous hexagonal grid of fuel rods, type 20 and 20.1, arranged at 21 mm pitch in the water moderator. The fuel rods are arranged in the upper and lower aluminum spacer grids (the lower and upper edges of the lower grids match with the top and bottom of the core, respectively) and support on the steel bearing plate. The upper steel plate is installed above the fuel rods. The critical assembly is arranged in the stainless steel tank filled with water moderator and has physically “infinite” side and end water reflectors. Besides water, the core reflector includes steel shanks of fuel rods and elements of the critical assembly.

![Fig 3: Critical assembly with a water moderator](image1)

![Fig 4: Loading chart of critical assembly with a water moderator](image2)
The core of the uranium-water critical assembly comprises fuel rods of type 20 and 20.1. The fuel rod of type 20 (20.1) comprises a fuel core, cladding and end parts. The fuel rod core has the 12 mm outer diameter and the 0.6 mm wall thickness. The fuel core comprises tablets, 10.75 mm in diameter and 14.7 mm in height, from uranium-zirconium carbonitride $U_{0.9}Zr_{0.1}C_{0.5}N_{0.5}$. The core density is 12.0 g/cm$^3$, and the uranium-235 enrichment is 19.75%. The gaseous He medium at ~0.11 MPa is ensured in the gaps between the tablets of the fuel rod core and the fuel rod cladding. The total height of the core is 500 mm. The total length of the fuel rod is 620 mm. The cladding and end parts of the fuel rods (plugs) is stainless steel (fuel rod, type 20) or niobium alloy (fuel rod, type 20.1).

The CPS includes six controls (actuating elements): three controls are in the core and three in the moderator. The CPS control located in the core is a cluster of two composite rods representing an absorbing element and fuel rod, type 20, rigidly interconnected via an adaptor. The CPS control located in the moderator is also a cluster of two composite rods. The composite rod in this CPS control represents an absorbing element and an organic-glass rod rigidly interconnected between them.

The absorbing element is a cylindrical stainless steel cladding with the 12 mm diameter and 1 mm wall, filled with natural density (1.36 g/cm$^3$) boron carbide to the height of 500 mm. The total length of the absorbing element is 620 mm. The organic-glass rod is a 12 mm diameter cylinder.

Figures 6 and 7 show a photo of the critical assembly without moderator and the loading chart for one of possible core configurations without moderator that can be used for training.
The critical assembly without moderator (Fig. 7) is a core, assembled from fuel assemblies, surrounded by four rows of beryllium reflector units and two rows of steel reflector units. All fuel assemblies and reflector units are placed on the critical assembly support plate. The upper end reflector units are put on top of the fuel assemblies and side reflector of the fuel assemblies. Neutron detectors are fixed around the critical assembly on special racks (poles).

The fuel assembly of the critical assembly without a jacket comprises 19 fuel rods, including 16 fuel rods, type 36.1, and 3 fuel rods, type 90. The fuel rods are arranged with the 8-mm pitch over the hexagonal grid and are fixed by means of end parts (pieces). The fuel assembly size is for the 34.8 mm wrench, and the total assembly length is 1047 mm (the length of the core is 500 mm, the fuel rod shanks are 2x60 mm, the assembly upper end parts are 216 mm, and the assembly lower end parts are 211 mm). All upper and lower end parts of the fuel assemblies are made from stainless steel.

The fuel rod, type 90, comprises a fuel core, a cladding and end parts. The fuel rod cladding is made from stainless steel, with the 7 mm outer diameter and the 0.2 mm thick wall. The fuel core comprises tables of 6.4 mm diameter and 5 mm height, made from metal uranium. The uranium-235 enrichment is 90%. The total core height is 500 mm. The upper and lower shanks of the fuel rod are made from stainless steel, with the 60 mm length and the 6.6 mm diameter. The total fuel rod length is 620 mm.

The fuel rod, type 36.1, comprises a fuel core, a cladding and end parts. The fuel rod cladding is made from stainless steel, with the 7 mm outer diameter and the 0.2 mm thick wall. The fuel core comprises tables of 6.4 mm diameter and 4-7 mm height, made from uranium dioxide, 9.8 g/cm$^3$. The uranium-235 enrichment is 36%. The total core height is 500 mm.
mm. The upper and lower shanks of the fuel rod are made from stainless steel, with the 60 mm length and the 6.6 mm diameter. The total fuel rod length is 620 mm.

The critical assembly side reflector represents four rows of beryllium reflector units and two rows of steel reflector units.

The beryllium reflector unit is a hexagonal beryllium prism for the 34.8 mm wrench with the 972 mm length. The lower part of the unit has a stainless steel shank attached to it, this shank is the mounting surface when the critical assembly is loaded. The upper part of the unit has a hexagonal upper stainless steel reflector for the 34.8 mm wrench and the 40 mm length.

The steel reflector unit is made from stainless steel, representing a hexagonal prism for the 34.8 mm wrench, with the 1047 mm length. The lower part of the unit includes a shank being the mounting surface when the critical assembly is placed on the support plate.

The control and protection system included nine controls (actuating elements), arranged evenly on three belts (three controls on each): one belt in the core and two belts (inner and outer) in the beryllium reflector.

The CPS control in the core represents a fuel assembly and an absorbing element located in the core rigidly interconnected via an adaptor. The CPS control located in the beryllium reflector in the inner belt is a beryllium reflector unit and an absorbing element rigidly interconnected via an adaptor. The CPS control located in the beryllium reflector in the outer belt is a beryllium reflector.

The absorbing element is a stainless steel cylindrical cladding with the 26 mm diameter and the 1 mm wall, filled with boron carbide powder, with the mean density 1.38 g/cm$^3$, to the 500 mm height.

4. The system for collection, processing and storage of experimental data

The research installations «Crystal» and «Giacint» have a system of hardware and software designed for collection, processing and storage of experimental data on physical neutron characteristics of critical assemblies studied by these facilities.

The system for collection, processing and storage of experimental data can be used to make the following experiments:
- loading critical mass (plotting loading charts and inverse account curves);
- measuring efficiency of the control and safety rod of control and protection system;
- calibration the control and safety rod;
- determining the reactivity margin;
- measuring reactivity effects;
- measuring axial and radial distribution of power release in the core;
- measuring the critical assembly absolute power;
- measuring the ratio of the effective share of delayed neutrons to the lifetime of instantaneous neutrons (kinetic parameter $\beta_{\text{eff}}$);
- nondestructive control of fuel rods and fuel cassettes with fissile material, etc.

This system can be used to understand the role of the neutron instrumentation in nuclear reactors:
- study the neutron detection systems in real conditions,
- observe the signal coming from the detector at the different stages of the electronics system (pulse, current),
- study systems similar to that used to measure the neutron flux in a nuclear reactor.
The system was created on the basis of the local network of PCs, a subsystem for preliminary signal processing and data collection, experimental units and devices (for determining reactivity, distribution of the neutron flow density in the core, etc.) The said system, after its proper upgrading, can be used for education and training.

5. Experiments that can be performed for education and training

The training courses, involving experiments at the research installations «Crystal» and «Giacint», can be used by a broad range of participants, including students of universities, experts in area of physics and technique of reactors (researchers, engineers, operators, etc.) as well as university teachers. Such installations can also be used by international schools for training and retraining of experts in operation of research nuclear facilities. Depending on the trainees and related education and training goals, we propose courses on various aspects of nuclear reactors in order to ensure general understanding and demonstrating the reactor's operations as well as for detailed investigations of various aspects of reactor operations.

The educational activities using the research installations «Crystal» and «Giacint» after their upgrade can include experiments for determining a number of physical neutron characteristics of critical assemblies and studying neutron detection systems in nuclear reactors. We will review six experiments that can be carried out in the education and training activities.

**Critical mass measurement**

The approach to criticality is the most fundamental procedure in nuclear reactor experiments. Preparation and adjustment of the critical assembly as an experimental apparatus are completed by the approach to criticality. When a reactor is first loaded with fuel, the amount of fuel needed to make the reactor critical is usually not known very accurately. Therefore, prediction of the critical mass by neutronics calculations based on the reactor theory would be necessary for the safe loading of fuel. The physical characteristics of a nuclear reactor as well as the validity of computational methods and nuclear data used may also be well understood through comparison of the predicted and measured critical mass.

Experiments on determining critical load can be made on the above-described critical assemblies with water and zirconium-hydride moderators or without moderator. The above mentioned critical assemblies are controlled by control and safety rods. The neutron counters and the ionization chambers are used for nuclear instrumentation.

The approach to criticality is based on the inverse-multiplication method. Criticality is approached by adding the fuel elements (rods or assemblies) in the core periphery. The inverse-multiplication rate (when the neutron density is stable due to the neutron source) versus the fuel mass (the number of fuel elements) is plotted after each fuel loading step, and the critical mass is estimated by extrapolating the curve to zero. Comparison of the predicted and measured critical mass, the dependence of inverse-multiplication rate curves on the relative position of the detector and the source and other reactor physics problems are to be reported.

**Measurement of rod worth and control rod calibration**

Various reactivity effects in nuclear reactors are usually determined by compensating the given reactivity with the control rods to maintain the critical state. Calibration of the control rod (determination of reactivity worth per unit movement of the control rod) is thus essential when the control rods are used as reactivity standards to measure the reactivity changes caused by any other perturbation in the reactor. Rod worth and control rod calibration data are also important for the reactor operation; using the control rod calibration data, the operator can estimate the reactivity caused by the control rod movement and will be able to operate the reactor safety. Furthermore, determination of excess reactivity and shut-down
margin of the reactor is one of the strictest requirements to safety reactor operation. Thus, measurement of rod worth and control rod calibration of a new core is the most essential experiment to be performed immediately after the approach to criticality prior to the experiments.

Two methods of control rod calibration are utilized in this experiment: the positive period method and the rod-drop method. In the first method, the reactor is made supercritical by withdrawing the control rod to be calibrated a certain amount, and the resulting (positive) period is determined from the measured doubling time to derive the reactivity. This technique is the basis of various reactivity measurements. The rod-drop method is to measure the subcriticality; the rod to be calibrated is dropped from a certain position at the critical state, and the resulting decay of the neutron flux is observed and related to reactivity. This method is utilized for measurement of negative reactivity, where the period method is no more applicable.

Experiments on measuring efficiency and calibration of control rods can be made for any of the above critical assemblies. Both positive and negative reactivity can be measured by the inverse solution of the point kinetics equations from the time history of the neutron flux signal (so-called reactivity meter).

Measurement of thermal neutron flux distributions
When a thermal reactor is operated with constant power, its thermal neutron flux forms a unique distribution, determined by the reactor characteristics. Since the level of this flux distribution is proportional to the reactor power, one can determine the reactor power by measuring the relative flux distribution in the reactor and the absolute flux level in a certain reactor location. Compared to detectors, such as ionization chambers and fission chambers, track detectors are insensitive to Gamma ray and can be used in locations where other detectors could not be used because of their size.

Experiments on measuring thermal neutron flux distributions can be made for any of the above critical assemblies. These measurements can be made by means of track detectors that can be placed between the fuel tablets inside the fuel rod cladding or on the aluminum plate close to uranium foil. The ratio of thermal to epithermal neutron fluxes is determined by measuring the Cadmium ratio, using the track detectors with uranium foils covered with and without Cadmium covers. A special measuring device is used to count tracks on detectors.

Experiment of Feynman-$\alpha$ method
The main purpose of noise experiments of a zero-power reactor is to determine the reactor kinetic parameters by measuring the fluctuation of neutron density around its mean value. It is well known that for a truly random neutron source, the number of detected neutrons in a certain interval of time forms a position distribution, where the variation-to-mean ratio becomes one. A neutron multiplying system, such as a nuclear reactor system, which is placed between the random neutron source and the detector, will cause the observed variance-to-mean ratio deviate from one. This deviation of the variance-to-mean for the observed counts from one results from the correlated neutrons born in the chain reaction of fission and is a function of kinetics parameters of a reactor.

The Feynman-$\alpha$ method, determining the reactor parameters from variance-to-mean ratio of neutron counts in a certain time interval, is used in this experiment to illustrate the application of reactor noise theory to measurement of reactor parameters. Neutrons emitted from a Cf-252 neutron source are detected by a few He-3 proportional counters. The pulse-rate analyzer, making part of the system for collection, processing and storage of experimental data, is used to record the neutron pulse signals from the detectors. Various reactor parameters, such as $\beta / \lambda$ (ratio of the effective delayed neutron fraction to the neutron lifetime), subcriticality and reactor power are determined by analyzing the experimental data.

Experiment of the pulsed neutron method
The basis of the pulsed neutron method is that the time rate of change in the neutron density following the neutron pulse injected into a media is closely related to the characteristics of the media. The neutron burst, generated by an external accelerator, is introduced into the subcritical reactor; due to its subcritical state, the resulting thermal neutron density in the reactor is multiplied, but rapidly decays. After a certain time from the initial neutron burst, higher order harmonics of the neutron flux decay, and the time behavior of thermal neutron density is dominated by its fundamental mode, which decays in an exponential form. The pulsed neutron method determines the reactor kinetics parameters by measuring this decay constant.

This experiment demonstrates the application of pulsed neutron theory to reactivity measurement and control rod calibrations. The experimental system consists of a pulsed neutron source, a neutron detector and a time analyzer. The pulsed neutron source used in this experiment is a shield-tube type source, which generates 14 MeV neutron pulse by D-T reaction. Time behavior of the neutron density after the initial burst is detected by fission chambers, BF$_3$ proportional counters and He-3 proportional counters. Reactivity of a previously calibrated control rod is measured by proposed Simmons-king, Sjoestrand and Gozani methods, compared with reactivity obtained from preceding measurements of control rod calibration.

**Temperature effect**

When the reactor is operated at appreciable power, the energy produced by the fission reaction induces the increase in temperature of the fuel, the moderator and other material present in the core of the reactor. This, in turn, leads to a modification of the core reactivity. In order to study the temperature effects, the following experiment on uranium-water critical assembly can be carried out.

The reactor is stabilized in the critical condition. The critical position of the regulation rods and the water and fuel rods temperature is measured. The core is heated by an external heat source to a temperature not higher than 90 °C. The new critical position of the regulation rods is defined. The water and fuel rods temperature is measured. The regulation rods graduation data are used to determine the reactivity temperature effect.

For a possibility of carrying out of experiments on measurement of temperature effect of reactivity the system of external heating of critical assembly should be created.

6. **Conclusions**

The JIPNR-Sosny has huge experience in theoretical and experimental research in nuclear power, including experiments on nuclear reactors and critical assemblies. This experience can be used to train university students to work at the NPP under construction in the Republic of Belarus. The strategy of education should be aimed at supplementing theoretical and training courses on simulators by experimental (laboratory) research at nuclear research installations, such as the critical facilities «Crystal» and «Giacinto». It requires relevant modernization and upgrade of these installations (the control and protection system, the collection and processing of experimental data, etc.), development and experimental testing of laboratory operations, and organization of a classroom having all facilities for presenting experimental data at the critical assemblies. Implementation of such training courses ensures a practical and comprehensive understanding of the reactor physics, design and safety of the reactor operation.
ABSTRACT

Located in the south of PARIS, the ISIS research reactor is operated by the French Alternative Energies and Atomic Energy Commission (CEA). ISIS reactor is an essential tool for the Education and Training programs organized by the National Institute for Nuclear Science and Technology from CEA. A large set of training courses have been developed on the ISIS reactor, focusing on the operational and safety aspects, both in normal and incidental operation. The courses are addressed both to students and professionals. In 2012, about 40% of these courses were carried out in the frame of international academic or vocational programs. This paper presents the ISIS research reactor and the practical courses that have been developed on ISIS reactor. We also discuss the development of Internet Reactor laboratories (IRL) on ISIS reactor, which consists in broadcasting the training courses via internet.

1. Introduction

Part of the French Alternative Energies and Atomic Energy Commission (CEA), the National Institute for Nuclear Science and Technology (INSTN) is a higher education institution [1]. Its objective is to provide students and professionals a high level of scientific and technological qualification in all disciplines related to nuclear energy applications. In this frame, INSTN carries out education and training (E&T) programs on nuclear reactor theory and operation. Its strategy is to complete theoretical courses by training courses and laboratory works carried out on an extensive range of training tools that includes software applications, simulators, as well as the use of research reactors [2, 3]. For all of the practical exercises, specific emphasis is given to the safety issues aspects of reactor design and operation, both in normal and incidental operation [4].

From 1961 till 2007, the INSTN was operating its own reactor, an Argon type 100 kW reactor called ULYSSE. In 2007, the E&T activity was transferred to the ISIS research reactor which is operated by the Nuclear Energy Division. For this purpose, the ISIS reactor went through a major refurbishment from 2004 till 2006. This paper presents the characteristics of the ISIS reactor. It describes the curricula of the academic and vocational courses in which the practical courses are integrated. Finally, this paper presents the Internet Reactor Laboratories (IRL) that is under development and will consist in broadcasting the training courses via internet to remote facilities or institutions.
2. The ISIS research reactor

The ISIS research reactor is located on the CEA Saclay site. It belongs to the same nuclear facility as OSIRIS reactor and is operated by the Nuclear Energy Division. Both reactors are open core pool type reactors and exhibit the same core characteristics (size and configuration of the core, fuel and rod characteristics).

The schematic of the reactor pool and the water primary and secondary circuits is shown in figure 1. The pool of ISIS reactor is 7 meters deep. At the bottom of the pool, a big metallic piece called the base sustains the core of the reactor. The core, with a section of 62 cm x 70 cm, is composed of an Aluminum box with 56 cases. It contains 38 fuel assemblies, 6 control rods, 7 Beryllium assemblies, as well as 5 experimental boxes. The MTR fuel, in silicide U$_3$Si$_2$Al form, is enriched at 19.75%. The beryllium assemblies are used both as neutron reflector, to reduce neutron leakage on one side of the core, and as the starting neutron source, through $(\gamma, n)$ reactions.

The experimental boxes can be used to place devices to be irradiated or tested (instrumentation, samples to be activated, test fuel, …). Above the core a stainless steel chimney separates the water from the primary water loop from the rest of the pool. A gate, which is place on one side of the chimney, can be removed to load or unload fuel assemblies of experimental devices between the poll and the core. Figure 2 is a photograph of the top of the pool in the reactor hall.

For the E&T activity, a supervision software has been specifically developed. The logic of the safety system, the control system hardware, the ergonomics of the control board and control room have been adapted to this specific activity. For example, the logic of the safety system was modified to enable the individual drop of each rod during standard reactor operation, and a specific operation mode was created for E&T activities, with a power limit fixed to 50 kW allowing the reactor operation in natural convection.

Figure 3 shows the information displayed by the supervision system that extracts the signals measured during reactor operation. For each experiment, the parameters to be displayed are chosen by the instructor: the power, the core temperature and the position of the rod used to control the reactor for the study of the temperature effect.
3. Courses on the ISIS reactor and associated curricula

A large set of experiments, which are shown in figure 4, have been developed for the E&T programs organized by the INSTN. These experiments are integrated in nine courses, each course with duration of 3 hours.

- Control of the reactivity during fuel loading
- Approach to criticality
- Reactor start up and stabilization
- Drawing of the calibration curve of a rod
- Evaluation of the global worth of a rod by the rod drop technique
- Influence of experimental devices on the core reactivity
- Reactivity change in the core – shadow effect
- Demonstration of the role of precursors (delayed neutrons) for the control of the reactor
- Study of the temperature effects (temperature coefficient, self-stabilisation)
- Radiation protection applied to reactor operation
- Study and setting of the neutron detection systems
- Neutron cartography / Neutron activation analysis
- Reactor operation under the supervision of ISIS staff and INSTN instructors

Fig. 4 : Content of the training courses developed on ISIS reactor.

Training courses on ISIS reactors are addressed to students and engineers from different institutions at a national and international level. This includes training courses carried out in the frame of:

- an international master in Nuclear Energy organised by the INSTN in collaboration with other universities and engineer schools [5],
- a one year specialisation course in Nuclear Engineering which was developed by the INSTN in 1956 and contributed to the qualification of up to 140 engineers every
year since this date [6],

- nuclear engineering modules of various master and engineer degrees in which the INSTN is involved,

- a collaboration agreement between Sweden and France that ensure the financial support for 2,5 day training sessions for students from three Swedish universities (Chalmers University of Technology, KTH Royal Institute of Technology, Uppsala University).

Concerning continuing education for professionals, training courses on ISIS reactors are addressed to a very wide public including researchers, engineers and technicians. This includes training courses carried out in the frame of:

- a 8 weeks course which is compulsory in the qualification process of the operators of the French research reactors,

- different courses (taught in English or French) organised on a regular basis (at least once a year) and related to the principle, the operation, the safety and the neutronics of nuclear reactors,

- different courses organised by INSTN to respond to the specific need of the nuclear industry and nuclear programs, which includes courses for the personal of the French regulator body, for young engineers from the Italian company ENEL, for project managers of the Vietnamese company EVN (Electricity of Vietnam), or for teachers and professors from several Polish Universities (training of the trainees).

Depending on the pedagogic and qualification goals, the trainees follow different training programs (3 to 27 hours) on ISIS reactor that can be completed at INSTN by training courses carried out using other tools such as software applications (APOLLO, FLICA, TRIPOLI, MCNP, ...) and reactor simulators (normal and accidental PWR operation).

All the experiments carried out on the ISIS research reactor focus on the practical aspects of reactor design, principle and operation. Emphasis is given to the safety aspects both in normal and incidental conditions. The feedback from the participants shows that practical exercises, as well as hands on reactor operation, are very efficient in going deep inside the understanding of the theoretical courses on reactor physics. Indeed, training courses on a real nuclear facility is the only way participants can approach and understand how different taught subjects (reactor design, principle, operation, safety, radiation protection ...) are taken into account to ensure the safe operation of a nuclear facility. The feedback from the trainee's, even years after they went through training courses on a research reactor, also shows that the impact of such course ensures comprehensive, and long standing, understanding of the reactor principle and operation that cannot be gained only with theoretical courses associated with the use of simulators.

Thus the INSTN is continuously promoting the use of the training courses on ISIS reactor in its E&T programs as they appear to be a very powerful tool for the development of the human resources needed by the nuclear industry and the nuclear programs.

4. Internet Reactor Laboratory

At an international level, a small number of research reactors are available for nuclear education programmes and human resource development. Thus, since the ISIS reactor has been specifically dedicated for education and training, CEA is promoting the use of the reactor at an international level. This is done in the frame of bilateral agreements, specific contracts or through the international courses that are organised by the INSTN.
When the supervision system of ISIS reactor was developed in 2003, the specifications were established taking into account remote access and data transmission. Nevertheless for pedagogical reasons, in-reactor training courses where promoted up to now by the INSTN. After the experience of “virtual reactor laboratory,” which linked the PULSTAR research reactor at North Carolina State University with the Jordan University of Science and Technology (JUST) as a guest institution [7] and the demand for Internet Reactor Laboratories (IRL) at an international level, CEA decided to develop the remote access to the training courses carried out on the ISIS reactor.

Keeping in mind that IRL cannot replace real hands on a research reactor, IRL can be seen as a cost-effective way to expand the nuclear education for groups of students or trainees that would not normally have access to a research reactor during their education. With this limitations and expectations, CEA has decided to develop IRL broadcasted to guest institutions. Using a system based on Visio conference equipment, the following information can be sent from the ISIS reactor (host reactor) to the remote classroom at the guest institution(s):

(1) Power point presentations,
(2) Pages from the supervision system used by the operator to follow the state of the different systems of the reactor (control rods, neutron detection systems, cooling system, safety system...),
(3) Interactive white board were the lecturer can present and explain the experiments and results,
(4) Graphs from the supervision system showing the time evolution of selected parameters for each experiment,
(5) Tables of selected data recorded by the supervision system,
(6) Curves plotted using the recorded data after calculation,
(7) Movies to be shown to introduce or illustrate some experiments or phenomena,
(8) Video signals from four cameras looking at: the lecturer, the reactor hall, the core, the operator at control desk.

Out of this information, according to the pedagogic needs during the training courses, the lecturer on the ISIS will choose to broadcast the relevant information at each stage of the course. By interacting through video conference, the remote classroom will also be able to ask for the display of particular information. At the guest institution, the information will be displayed on two screens, one dedicated to the information selected out of (1) to (7) and the other one dedicated to the video signal selected out of the camera signals (8). Concerning the interaction with and the feedback from the remote classroom, at least one camera will be installed in the remote classroom and its signal will be sent to the ISIS control room to be visible par the lecturer and the operators. IRL broadcasted from ISIS reactor will be available in 2014.

5. Conclusion

Since 1956, the National Institute for Nuclear Science and Technology provides students, engineers and researchers a high level of scientific and technological qualification in nuclear reactor theory and operation. The adopted strategy is to complete theoretical courses by training courses on training reactors. A large set of training courses have been developed on ISIS research reactor in the frame of the education and training programmes from the INSTN. The experience gained shows that such training courses bring
tremendous benefits for all trainees since they ensure a practical and comprehensive understanding of the reactor physics, design and operation. With this feedback, the implementation of the Internet Reactor Laboratory, which will be operational in 2014, appears to be a powerful tool, complementary to in reactor training courses, for the development of the human resources needed by the nuclear industry and the nuclear programs.

References


IMPLEMENTING PUBLIC PARTICIPATION APPROACHES IN RADIOACTIVE WASTE DISPOSAL IN POLAND

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ABSTRACT
The new approach to public participation in environmental decision making methods is presented in case of radioactive waste management. Some consequences of the plans of nuclear energy introducing in Poland and necessity to build a new repository for low and intermediate radioactive waste repository are discussed. Preparing the future dialogue with the public, the various actions take place. In this work the results of first public hearing and technical training for local community administrations are shown as an example of influence of nuclear knowledge broadening to environmental opinion about nuclear energy implementation and the radioactive waste repository to be built.

I. Introduction
The implementation of nuclear power in Poland will force a new approach to the current procedures and systems related to the management of radioactive waste and spent nuclear fuel. Due to the fulfillment of disposal volume in the National Radioactive Waste Repository in Różan it will be necessary to build a new repository for low and intermediate radioactive waste with a capacity of about 170 000 m$^3$ (Ref.1) In the operation of nuclear power plants with a capacity of 6 GWe over its lifetime 60 years, the discharged spent fuel will contain up to 6 800 tHM. Considering the possibility of nuclear energy introducing in Poland the following questions should be solved:
1. spent nuclear fuel management,
2. radioactive waste management produced during:
   - nuclear power plant operation period,
   - NPP and spent fuel decommissioning,
   - application of isotope techniques in health protection, industry, science and during operation of experimental nuclear objects and connected with them isotope facilities,
   - improvement or decommissioning of nuclear and isotope facilities.
All these questions should be solved based on dialogue with society of our country and trans border communication.
Regulation and international agreements in the form of conventions have been established. The nuclear and radioactive waste management industries work to well established safety standards for the management of radioactive waste. International and regional organizations such as the International Atomic Energy Agency (IAEA), The Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development (OECD) the European Commission (EC) and the International Commission on Radiological Protection (ICRP) develop standards, guidelines and recommendations under a framework of co-operation to assist countries in establishing and maintaining national standards. National policies, legislation and regulations are all developed from these internationally agreed standards, guidelines and recommendations. These standards aim to ensure the protection of the public and the environment now and in the future. International agreements in the form of conventions have also been established such as the Joint Convention on Nuclear Safety and the Joint Convention on the Safety of Spend Fuel Management and on the Safety of Radioactive Waste Management. This convention was adopted in 1997 by a diplomatic conference convened by the IAEA and came into force in June2001 following the required
number of ratifications. Other international conventions and directives seek to provide for interim alia the safe transportation of radioactive material, protection of the environment (including the marine environment) from radioactive waste and control of imports and exports of radioactive waste and trans boundary movements. In July 2011 the European Union adopted a directive for the disposal of used nuclear fuel and radioactive wastes which require member countries to develop national waste management plans for European Commission revive by 2015. The plans must include firm timetables for the construction of disposal facilities, descriptions of needed implementation activities, cost assessments and financing schemes. Safety standards promulgated by the IAEA will become legally binding within the EU-wide policy framework.

In Poland such plan is elaborated step by step and it is expected to be presented in 2013. All plans regarded to surface or geological disposal or other reprocessing possibilities have to be based on the voluntary involvement of potential host communities and IMPLEMENTING PUBLIC PARTICIPATION APPROACHES IN RADIOACTIVE WASTE DISPOSAL (IPPA project)ref.2, which become the urgent tasks.

Using scientific methods elaborated as RISCOM model, RISCOM Reference Group in Poland was established July 1 2011 with satisfactory representation of Governmental Bodies, Scientific Institutes, Radioactive Waste Managements, the local Community of Różan. In this work the description of hearings, trainings, workshops and meetings is presented and the questionnaire methods of communication with the society is discussed showing the influence to public opinion.

II. IPPA research project as a first step towards public participation approaches in radioactive waste management.

II.1. Goals of the IPPA project.

The aim of the IPPA research project is to promote the idea of participation of the society transparency in decision-making processes at various stages of implementation of repositories for the radioactive waste in European countries. The project involves the establishment of a safe arena for all stakeholders, which will allow better understanding of problems of radioactive waste disposal through active exchange of views between the interested parties. This goal can be achieved in Poland by implementing so-called RISCOM process allowing clarification and explanation of the arguments from interested parties, based on scientific grounds. The RISCOM process involves establishing a reference group as a platform for effective public participation in the decision-making process. The Reference Group in Poland was established on July 1st, 2011. Its activity is based on an agreement accepted by all its members. The Group fulfils the project objectives through participation in the implementation of 8 work-packages (WP).

The actions carried out within the project are aimed to improve the quality of decisions in the field of radioactive waste management, by strengthening the transparency and trust between all stakeholders. Recognising the importance of the radioactive waste management issues in a wider social perspective will make it possible to avoid unnecessary conflicts resulting in blocked decisions or hindered programmes of great importance for the country in the future. Correct communication with the public is a necessary condition for the success of both building new radioactive waste landfills and the Polish Nuclear Energy Programme.

II.2. Hearing

The hearing is one of the tools used within the RISCOM process, which has been applied in the IPPA in order to discuss plans to build a new repository of radioactive waste. According to the model adopted within the RISCOM process, the hearings are a form of communication with the public, carried out at the various stages of the project implementation, beginning from the very early construction plans, through the stage of research on location and its final choice, up to completion of the controversial investment. The hearings are intended to ensure public participation in the decision-making process at the earliest stages of the
implementation of the idea through active exchange of views and explanation of all the facts known at the specific stage.

At its meeting on January 24th, 2013 the Reference Group made a decision on arranging the first hearing, the subject of which was:

**Do we need a new repository for radioactive waste?**

According to the assumptions made, the hearing was intended to inform all the stakeholders of status preparations for the construction of a new landfill and the complexity of the related issues. Participants of the meeting were to find the answers to the nurturing questions, allay the concerns about the risks as well as to present their own views and expectations to the bodies responsible for the preparation of the investment.

II.3. The RISCOM hearing

The aim of the RISCOM hearing was to initiate an open debate on the need to build a new repository for low and medium radioactive waste in Poland and the choice of its location. The hearing was supposed to be an opportunity to exchange views and experience between the various groups of stakeholders, who see the need to build a repository or see the risks connected with this fact. The hearing was supposed to give an answer to frequently asked questions: What is the current state of technology in the field of storage of the radioactive waste? What are the public concerns about locating the landfills in the direct neighbourhood of homes? What to do in order that a repository will be safe and acceptable to the local community?

130 people representing various communities: researchers, practitioners dealing with waste and nuclear power engineering, local communities interested in building a future landfill in its area and representatives of the public administration, were present at the hearing, which was held on May 8th, 2013 in Hotel Radisson Blue in Warsaw. In addition to the groups of supporters of the nuclear energy and people supporting construction of new landfills in Poland there were people sceptical about those programmes as well as the declared opponents. The hearing was accompanied by a panel of experts, who presented the current state of knowledge about the repository of waste as well as issues regarding the social participation in the decision-making process and the related legal aspects. The moderator of the discussion was journalist Krzysztof Bobiński.

The participants gained extensive information about state of implementation of the project of the repository, they also had an opportunity to get familiar with the opinion of the representatives of the ecological environments, reporting a number of concerns about costs, impact on the environment and way the dialogue with the public is carried out. These doubts were answered by experts from ICHTJ, NCBJ, PIG-PIB, PAA, ZUOP and DEJ.

The hearing was an opportunity to express own views on storing waste, safety of repositories and manner of preparations for the construction of the new facility. The discussion was vivid and very instructive. Course of the hearing demonstrated the need to organise meetings that are an opportunity not only to present a substantive knowledge and exchange views, but also give an impulse to groups of stakeholders, strengthening their influence on the decisions made in the broadly-meant social interest.

II.4. Conclusions of the hearing

The hearing was the first event of such a scale, dedicated to plans of constructing a new repository for the radioactive waste in Poland. Until today such issues were discussed at the governmental level (Department of Nuclear Power, Ministry of Economy) in purely expert environments relating to the technical aspect of project execution. All groups of stakeholders both interested in construction of the repository and skeptics about this project participated. In fact, there were no declared opponents of construction of the repository for the low and medium radioactive waste produced by industrial and medical activities. However a severe conflict arouse about building a nuclear power plant in Poland. Majority of ecological organisations in the country is opposed to develop nuclear power plants and express it loudly. There is a fear that the construction of the repository is just an element of the larger
plan to build a nuclear power plant, and even a deliberate action supporting this plan, which is alleged to enable introducing nuclear power plants on the sly. Therefore the opponents of the nuclear power plants also disapprove of possible construction of the deep repositories for spent nuclear fuel and highly radioactive waste. Very often they complain about manipulations on the public fed only with information about advantages of the nuclear power plants. In their opinion the facts about the risks are unsaid.

The ecologists stress lack of discussion in wide groups of experts, representing also themselves as well as the parties more sceptical about the nuclear energy programme and see the hazards resulting from storage of the radioactive waste. In their opinion, it is commonly assumed that the term "expert" is used only when speaking of the representatives of atomists, but nobody invites the experts in the ecological law, environmental sciences and sustainable development to any debates. The ecologists complain about low relevance of the arranged meetings and debates. Also a huge mistrust of the experts representing the atomists, who not always are neutral, even when they show results of the research and commonly accepted approaches to risk analysis, was seen.

From its part, the expert side of atomists, not always sees the necessity and sense of engaging wide groups of the society into the decision-making processes. In the atomists' opinion (confirmed by research) status of public knowledge of nuclear fission and operation of the modern power reactors is very poor, and first of all, educational campaigns should be conducted in various social groups, and only then ask for expressing an opinion. The voices of the whole society, also of the uneducated people, should be heard according to the sociologist.

The participants in the meeting had an opportunity to learn of main assumptions of the Aarhus Convention and rules of applying the Convention to the radioactive waste management. Many of them, heard about the main pillars of the Convention for the first time and realised the onerous consequences for a country which does not respect the Principle of the Aarhus Convention, which are echoing in the new Directive of the EU Council 2011/70/EURATOM, which imposes transparency and social participation in the decision-making process related radioactive waste and used nuclear fuel management.

In the same time all the participants in the hearing assessed positively the attempts of organising the meetings like this one and stressed their willingness to participate in similar meetings in the future. The topic of the hearing, as well as the presentations made, received high rates. Extensive treatment of construction of the repository with consideration of its legal and social aspect as well as its implications for the environment met a particular assent. It seems that such events meet social expectations and are of much need, when the project of development of nuclear power engineering is executed in Poland with lack of interest of the public in participation in the decision-making process. The participation involves not only right to participate in this process, but also imposes obligations on the participating societies as well as implies distribution of responsibility for the decisions made.

With presence of public media (press, radio) the information about the hearing reached wide social groups. The public could get familiar not only with opinions on construction of the repository, but also with wide range of works, which must precede its construction, including in the areas of communication with the public. The society could learn that appropriate social communication is a subject of care of the state, and transparency of the decision-making processes is an indispensable element of correct operation of the civil society.

III. Technical training
III.1. Education level added to RISCOM

Technical tracing is a new approach to communication, starting from presentation the basic scientific questions related to radioactivity in environment, nuclear waste origin and management and visiting nuclear facilities.
Due to fruitful international collaboration, participation in trainings, exchange of experience about RISCOM implementation in different countries, Reference Group in Poland gained a lot of experience and knowledge how to start public participation initiative in nuclear waste management questions. In order to check the result of introduction the educational level to RISCOM, the technical for community representation was done. As a first group of listeners (Fig. 1) selected for training was the Society “Dolina Plicy” were the local community representation, administration employees, elected mayors are organized. The selected region up to now it was not exposed to any kind of antinuclear of pronuclear action. It is typical region in central Poland without industry, with rather poor farming and no dense population, looking for new possibilities and new challenges.

III.2. Methodology

The technical training was arranged 6-7 June 2013, in National Centre for Nuclear Research [3] and Radioactive Waste Management Plant [4] at Świerk where the main nuclear facilities of Poland are located and at National Radioactive Waste Repository at Różan about 150 km aside. During the training the lectures were followed by visiting installation. Before and after training the questionnaires opinions were collected and simultaneous hearings were kept. The main points of visit were following:

- Introduction about NCBJ, ZUOP, IPPA-project.
- Information about radioactive waste management in Poland.
- Ionizing radiation and humans.
- Nuclear facilities in Poland. Reactor MARIΑ its history and future (visit).
- Radioactive waste management facility (visit).
- Dept. of Education and Training - experimental presentation about detection of ionized radiation and basic nuclear facilities (visit).
- Former NPP Żarnowiec model and exhibition (visit).
- National Radioactive Waste Repository - Różan(visit). Meeting with Różan Meir
- Questionaire opinion studies. Hearings during the visits.

III.3. Results

The general presentation of participants is show on Fig.1 where the gender and age are summarized. One should stress that participant had very matter of fact approach to the visit. They came with ready questions and they have the filing of lack of knowledge about nuclear matters, in spite of the fact that the education level of that participants was high. 30 persons of 40 taking part in training, had higher education and among them 9 had technical education. The knowledge of the respondents, according their opinion, about conditions and consequences of radioactive waste repository is not satisfactory what is shown at Fig 2.
Figure 2. Knowledge of the respondents about conditions and consequences of the construction of radioactive waste repository; measure 1.

The main sources of knowledge about radioactive waste management are presented at Fig.3. One can see that media and internet are the most powerful tool of education for adult from small communities. The approach to the radioactive waste repository was changed after training, what is shown at Fig.4

Figure 3. Sources of knowledge about radioactive waste repositories (possible to mark more than one answer); measure 1.

Figure 4. The answer the question: Do you think that in Poland there is a need to build a new radioactive waste repository?

Significant fraction of participants undecided before training stated that there is necessity of repository construction. The more detailed analyze one can make using correlation between proposed distance to the repository and living place. The typical approach is NIMBY(Not in My Backyard). The estimation of the advantages and disadvantages ratio regards the plan of repository built in selected region are summarized at Fig.5 where some added value approach is evident. Economical profit is pointed out but some risk was stressed as well, first of all the following negative aspects were stated during hearing:

- risk of investors lost,
- decrease of real estate value,
- possible conflict with touristic development of village,
-social conflicts possibility.

![Figure 5](image5.png)

**Figure 5.** Benefit-risk ratio in case to build a nuclear waste repository; blue – measure 1, red – measure 2.

Fig.6 illustrates approach to the risk and profit distribution. The useful discussion were about who should decide about radioactive repository location. The consultation forms were pointed out and following preferred consultation forms were proposed: referendum, meeting with experts, habitants reunions, excursions to other existing repositories, trainings, conferences, medial information, internet. One should point out that proposed actions contain educational and information character.

![Figure 6](image6.png)

**Figure 6.** Respondents’ opinion about the benefits and risks within the local community; blue – measure 1, red – measure 2.

III.4. Conclusions

The improvement of the knowledge does not transfer to increase of acceptance but the way of training help to polarize the opinion of people previously undecided. In the selected group it was strong feeling that the decision about radioactive waste repository location should be done by whole local community. (Fig. 7) The necessity of education, training, information, before consultations are stated. It is almost impossible to separate the radioactive waste management question and approach to nuclear energy development in Poland. The attitude to nuclear energy implementation in Poland is shown at Fig.8.
One could presume that negative attitude is not the result of lack of information because these opponents did not change their attitude after training, so the source of this prejudice is somewhere else, but in other groups the acceptance increases. The organized training gives the new suggestions for future action.

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NEW PATHWAYS TO EDUCATION AND TRAINING IN THE NUCLEAR ARENA

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Much has changed in the arena of nuclear training and education in the recent decade. Traditionally, brick and mortar schools were the only paths to attaining a college degree in nuclear engineering and technology. Students would enroll at public or private institutions of higher education, pay their tuition, attend classes and several years later attain their degree. In many ways, education was a guarded commodity and metered out only to those that could afford the high cost of admission to the elite ranks of the college educated. Increasingly, these “traditional” institutions of higher education have been relinquishing their premier position as sources of knowledge to non-traditional schooling. Non-traditional schools may also be brick and mortar, but more and more of these institutions are based on online learning. The introduction and evolution of the personal computer and the growth of the World Wide Web/Internet have played a major role in the establishment of new paths to education and degree attainment.

Two of the leading paths to education are now online schools and the most recent development of MOOCs (Massive Open Online Courses). An online institution offers the courses it has developed to students for a fee, the students then partake in online learning. This form of learning involves readings, discussions, assignments and tests all done via the Internet. The learning can be both synchronous as well as asynchronous learning depending on the format developed by the institution for that particular course. A number of colleges offer online courses, but the premier example of an online or non-traditional school is Excelsior College in Albany,
NY which offers a host of Associate, Bachelor and Master Degrees including a Bachelors degree in Nuclear Engineering Technology. Currently, the college has approximately 36,000 enrolled students from throughout the United States and the world, has graduated more than 150,000 students, and is one of the most respected distance learning institutions of higher education in the United States. The college provides multiple venues for earning college credit and a degree, with the focus on what students know, rather than on where or how they learned it. Undergraduate and graduate credits may be earned through a variety of accredited sources. Those include for-credit examinations, credit aggregation of course work, military and corporate training, online course work, courses offered through CD-Rom, as well as through portfolio assessment.

One of the most important aspects is the credit aggregation of course work. In many instances learners take courses at numerous colleges because of household moves or military deployments. In so doing they attain the knowledge but never have enough credits at one particular college to qualify for a degree. Once students submit their transcripts to Excelsior College, those transcripts are then evaluated regarding the courses and credits earned. Based on the assessment, credits are then awarded to the student toward one of the Excelsior College degrees. If there are gaps in the student’s knowledge, the institution offers online courses to fill the gaps. Students may also earn credit based on their life experiences by completing a portfolio assessment course or take for-credit exams to earn credits.

What quality education is free, available to anyone, anytime, around the world? The answer is MOOCs. MOOCs – Massive Open Online Course – are a recent phenomena and addition to the educational and training mix. MOOCs are online courses that anyone can register for, free of charge. There is no limit to enrollment size as there are no classrooms; hence, thousands of people can be taking the same course at the same time. Current estimates place
approximately 6 million students as enrolled in these online courses worldwide. MOOCs are developed from traditional courses and are considered the very best offerings from such distinguished schools as MIT, Harvard, Princeton, Stanford, and UC Berkley. They include such courses as Introduction to Engineering Mechanics, Chemistry, Material Behavior, and many others, spanning a host of educational disciplines. Learners take these courses online and the ultimate goal is to receive college credit upon completion. There have been some teething pains with MOOCs including a higher than normal dropout rate and no way to validate if actual learning has occurred, and by whom. Promoters of the MOOC concept contend that once or if certification or degrees are offered based on MOOCs, the dropout rate will be similar to traditional institutions. Regardless of these startup problems, it appears that this innovative and wildly embraced mode of learning is here to stay.

Much has changed in education in recent years. The slide ruler gave way to the handheld calculator, and the personal computer, linked with the Internet, has opened doors to education that could only be dreamed of a scant few years ago. Education is no longer secreted and locked behind ivy walls. Nor is it reserved for the socially elite. Non-traditional schools provided learners with alternative means to attain a college degree through, at one time paper based courses, and in recent years, online courses. Now, the entire educational system may be on the verge of a dramatic upheaval of how learning occurs, and how recognition is awarded to students through the MOOC system of transmitting knowledge. MOOCs are unhindered by the size of classrooms, geographical borders, and the financial condition of the learner. They also offer the many benefits of any online course including the flexibility that most adults need.

However the knowledge is attained, through online courses, MOOCs, or any of the paths that Excelsior College offers, the goal is the same--to provide quality education to those willing
to study, assimilate and embrace the information that is there for the taking. The nuclear industry is poised for the long-awaited renaissance, and the educational tools that can help to supply experienced, safety minded individuals to staff those new plants, is now in place and ready to do its part as the industry moves forward in the 21st century.
COLLABORATIVE NUCLEAR SAFETY TRAINING EFFORTS TO MEET THE NEEDS OF A SMALL COUNTRY

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ABSTRACT

In Finland, the Ministry of Employment and the Economy (MEE) launched a project in late 2010 to survey the know-how in the nuclear field in Finland. The task was started with a comprehensive questionnaire sent to all stakeholders, including regulators, industry, research organisations and the academia, and projected the personnel needs in the field up to 2025. The demand for new experts in the nuclear energy field in Finland was estimated to be 2400 persons in 12 years, when the current workforce is 3300 experts.

Experts on the non-nuclear areas need to be educated on the specific requirements of nuclear safety when employed in the nuclear energy field. To tackle this challenge, the Finnish nuclear energy organisations have arranged basic professional training courses on nuclear safety since 2003. The syllabus was planned according to the IAEA model, adjusting it for domestic conditions. We have completed ten courses and have started the eleventh one in October 2013. The length of each course has varied between 19 and 30 working days in 5-6 modules scattered from October to March. The number of expert lecturers on each course has been around 100 and the average number of participants about 60.

1. Introduction

The presently operating nuclear power plants have been designed, built, and operated by a generation of experts in various fields. The transfer of their know-how to a new generation is a prerequisite for a continued safe and economical operation of NPP's. Besides replacing retiring experts, Finland alike many other countries are planning or already building new NPP units, and this increases the need for new experts.

The replacement of the experts in the nuclear energy field is a challenge, because the current plants were mainly built in the 1970's and 1980's, after which there were few new-builds for about two decades. This period of stagnation led to fewer new job opportunities in the organisations and, thus, a smaller need for education capacity.

The so-called nuclear renaissance started about 10 years ago. The new interest that has led to new NPP projects also in Europe, together with the aging of the personnel that built and operates the existing plants, have brought all stakeholders to a new situation: new experts...
must be employed in unexpectedly increasing numbers. Universities and polytechnics need to re-focus their curricula onto engineering of power systems, and nuclear engineering in particular, as well as other fields relevant to NPP’s like radiochemistry, automation and project governance. As a parallel effort, nuclear energy organisations need to strengthen the training of their new personnel. The effect of the Fukushima Daiichi accident in March 2011 is not yet clear, but already now its influence varies a lot from country to country.

2. Survey of competence needs

In Finland, the Ministry of Employment and the Economy (MEE) launched a project in late 2010 to survey the know-how in the nuclear energy field in Finland (the so-called Competence Committee). The task was started with a comprehensive questionnaire sent to all stakeholders, including regulators, industry, research organisations and the academia. The goal was to map the current situation and to obtain a reliable estimate of the personnel needs in the field up to 2025.

The coverage of the questionnaire was ensured with several reminders and replies were finally obtained from all significant stakeholders, which make the results as reliable as any projection to the future can be. In the final report of the project [1] the replies are displayed from various perspectives. The current workforce is classified according to the area of competence, education level and the number of years in the nuclear field. These data are also displayed separately for power companies, regulators, and research organisations and universities. Then the needs of experts on various fields are projected to 2015, 2020 and 2025 collectively for all organisations. For illustration, Fig. 1 shows the estimated need for personnel in various competence areas that require a higher university or polytechnic degree.

When taking into account the multidisciplinarity of the nuclear energy field, the need for new experts in the nuclear energy field in Finland was estimated to be 2400 persons in 12 years, when the current workforce is 3300 experts. Roughly half of the new recruits replace retiring experts and the other half are needed in the new projects: one new reactor is being built in Finland, two more are being planned, and the nuclear waste repository for spent nuclear fuel is also being commissioned. Altogether this means a total of 200 new recruitments per year, all of whom should have at least a basic understanding of nuclear safety.

Answers to this need are also given in the final report of the MEE project that broadly covers education and training, research, and infrastructure as well as participation in international projects and plant construction projects. As seen in Fig. 1, the demand is not only for experts on specific nuclear issues like reactor physics or nuclear fuel, but also more generic issues like structural materials, power electronics, automation, and radiochemistry.

One aim of the project was to reveal any bottlenecks in the education and training system. No severe difficulties were noted, but a clear need for improved cooperation and coordination of activities between universities and polytechnics was observed. Fortunately, the contacts between the academia on one hand and the other stakeholders on the other hand are functional in Finland, an advantage of being a small country. Even though the end-user needs are readily taken into account in the academia, the inherent education delays must be remembered: usually it takes five years to educate a master or engineer and additional five years to get a doctoral degree.
Fig. 1. The estimated need for personnel in various competence areas that require a higher university or polytechnic degree [1].

3. Basic professional training: the YK course

Experts on the non-nuclear areas need to be educated on the specific requirements of nuclear safety. Aalto University (Aalto) and Lappeenranta University of Technology (LUT), the main educational institutes in this field in Finland, are giving basic courses on nuclear energy to an increasing number of engineering students; a minority of them will finally major in nuclear engineering. Additionally, Aalto is currently planning a minor subject in nuclear energy for Master level students with any engineering major, thus implementing one of the recommendations of the MEE report [1]. However, the industry, regulators and research organisations are also recruiting many
science and engineering professionals from other universities than Aalto and LUT, and they must receive at least basic training on nuclear safety. In-house training courses are the traditional solution in the nuclear energy field. As an additional means to tackle this challenge, the Finnish nuclear energy organisations have collectively arranged basic professional training courses on nuclear safety since 2003, known as the YK course\(^1\) that is a joint endeavour of all major stakeholders [2]:

- Ministry of Employment and the Economy (MEE)
- Radiation and Nuclear Safety Authority (STUK)
- VTT Technical Research Centre of Finland
- Aalto University
- Lappeenranta University of Technology (LUT)
- Fennovoima Oy
- Fortum Oyj
- Posiva Oy
- Teollisuuden Voima Oyj

The planning of the YK course was started in the autumn of 2002, just a few months after the Parliament had ratified the positive decision-in-principle for Finland's fifth nuclear power unit, Olkiluoto 3. The syllabus of the YK course was originally planned according to the IAEA model [3], but it was adjusted for domestic conditions already on the first course YK1 that started in October 2003. Over the years, the contents have evolved from the original model course in order to utilize the time resources most efficiently. Table 1 displays the themes and their current volumes. The adaptation of the nuclear safety course to Finnish conditions is emphasized by the choice of Finnish as a working language.

The YK course is planned, developed and implemented by a steering group where all participating organisations have their representative. Now that the course is relatively mature, the steering group meets 4-5 times per year. The organisation responsible for all practical arrangements is LUT. However, each course module is hosted by a different organisation. This adds another important dimension to the course besides new knowledge, namely networking and becoming acquainted with the whole field.

We have completed ten courses by the spring 2013 and celebrated this with the YK1-10 Anniversary in March, collecting some 250 participants and lecturers of the past courses. YK11 started in October 2013 with 72 participants. The length of each course has varied between 19 and 30 working days in 5-6 modules scattered from October to March. The average number of participants on each course has been about 60, so by now over 600 persons have taken the YK course. Most of these participants are recently recruited university or polytechnic graduates, but also some more experienced professionals have refreshed their knowledge.

It should be noted that the YK course is utilised for dual purposes. Namely, it is possible to include the course in the doctoral studies at Aalto and LUT. Participating in the course and doing the home exercises gives 8 ECTS. This opportunity has been used by several course participants each year. YK may also be accredited in the participant's learning portfolio. These aspects are discussed in more depth in Ref. [4].

The number of expert lecturers on each course has been around 100. Many lecturers have a single lecture on the course on the subject where he/she is the top expert in Finland. This has led to some challenges to keep the course as a whole consistent and to avoid excess overlapping of lecture contents. Progress has been made in these respects, not least thanks to participant feedback over the years.

A very special feature of the YK courses is that there are no course fees to the participants or their employees. Each organisation obtains a number of seats on the course on the basis of the number of lectures that the organisation is giving on the course. Some running expenses are paid collectively by the participating private companies.

\(^1\) YK comes from the Finnish word "Ydinturvallisuuskurssi", i.e., a Nuclear Safety Course.
Table 1: Themes in YK11. The total hours include lectures, group works and excursions.

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<thead>
<tr>
<th>Part</th>
<th>Theme</th>
<th>Total hours</th>
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<tr>
<td>0</td>
<td>Orientation</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td>Nuclear reactor principles</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>Principles of nuclear safety</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Starting and implementing a NPP project</td>
<td>4</td>
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<td>4</td>
<td>Radiation protection</td>
<td>4</td>
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<tr>
<td>5</td>
<td>Design of a nuclear power plant</td>
<td>12</td>
</tr>
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<td>6</td>
<td>Safety classification</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Deterministic safety analyses</td>
<td>13</td>
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<td>8</td>
<td>PRA/PSA principles</td>
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<td>9</td>
<td>Human performance</td>
<td>3</td>
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<tr>
<td>10</td>
<td>Research infrastructure</td>
<td>3</td>
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<tr>
<td>11</td>
<td>Plant operational safety</td>
<td>14</td>
</tr>
<tr>
<td>12</td>
<td>Surveillance and maintenance programs</td>
<td>6</td>
</tr>
<tr>
<td>13</td>
<td>Fuel cycle, waste management, decommissioning</td>
<td>10</td>
</tr>
<tr>
<td>14</td>
<td>Plant life management</td>
<td>5</td>
</tr>
<tr>
<td>15</td>
<td>Limiting conditions for operations</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>In plant accident management</td>
<td>14</td>
</tr>
<tr>
<td>17</td>
<td>Regulatory control</td>
<td>7</td>
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<tr>
<td>18</td>
<td>Emergency preparedness</td>
<td>4</td>
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<tr>
<td>19</td>
<td>Safety culture</td>
<td>3</td>
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<tr>
<td>20</td>
<td>Quality management</td>
<td>2</td>
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<tr>
<td>21</td>
<td>Public communications</td>
<td>2</td>
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<tr>
<td>YK11</td>
<td>Total</td>
<td>141</td>
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Despite the no-fee-principle, the YK courses are, of course, a significant investment for all participating organisations. The lost working days of the participants during the course as well as the lecturers preparing their slides can be estimated, at least on the rough level, and it is easy to see that the total sum becomes large. One can also add in costs due to traveling and accommodation. Yet, the YK course is a cost-effective way to introduce newcomers to the safety culture in this field. Each YK course has a finite number of seats and the candidates are competing of entrance.

One interesting aspect is that less than 5% of the course participants have changed their field after the course. There are naturally more people who have changed organisation, but they have remained in the field, so the YK investment has still served the nuclear energy community in the country. One can speculate whether the training course also leads to increased loyalty.

4. Conclusion

In our opinion a real safety culture presumes that nuclear safety is a common goal, so the regulator/licensee role or the competition for market shares are no obstacles for cooperation in training activities. With true collaboration, the best expertise is made available to all stakeholders and the costs can be kept very reasonable. This kind of collaboration can be achieved when there is a real need.

The basic professional training course that is currently given for the 11th time has filled a real need in the Finnish conditions. In the beginning, it was thought that a couple of courses
would be sufficient, but now it seems that the YK course has an established position in Finland and will be running annually in the foreseeable future.

5. References


UTILIZATION OF BRAZILIAN RESEARCH REACTOR TRIGA FOR EDUCATION AND TRAINING

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ABSTRACT

With the revival of the Brazilian nuclear program, it is anticipated a large demand for training in nuclear technology. The Nuclear Technology Development Center (CDTN), a research institute of the Brazilian Nuclear Energy Commission (CNEN), offers the Operator Training Course on Research Reactors (CTORP). This course has existed since 1974 and about 258 workers were certificated by CTORP. This article describes the activities of CTORP and presents a proposal for expansion of its activities in order to meet the current demand in the nuclear technology. Experimental research projects programs would be created in the postgraduate course at CDTN. In addition to the normal reactor physics topics addressed by CTORP, new subjects such as thermal hydraulic and instrumentation should be added and discussed in more detail.

1. Introduction

Nuclear reactor technology play a number of significant roles in improving the quality of our environment while at the same time has the potential to generate virtually limitless energy with no greenhouse gas emissions during operations. In recent years there has been a growing interest in nuclear energy, leading to a “nuclear power renaissance” in countries the world over. In Brazil, the nuclear renaissance can be seen in the completion of construction of its third nuclear power plant and in the government's decision to design and build the Brazilian Multipurpose research Reactor (RMB). The role of nuclear energy in Brazil is complementary to others sources. Presently two NPPs are in operation (Angra 1 and 2) with a net output of 2000 MWe. A third unity (Angra 3) is under construction. Even though with such relatively small nuclear park (approximately 3% of electric power consumed), Brazil has one of the biggest world nuclear resources being the sixth resource of natural uranium in the world, and has a fuel cycle industry capable to provide fuel elements.

Brazil has four research reactors in operation: the MB-01, a 100 W critical facility; the IEA-R1, a 5 MW pool type reactor; the Argonauta, a 500 W Argonaut type reactor; and the IPR-R1, a 100 kW TRIGA Mark I type reactor. They were constructed mainly for using in nuclear research, education and radioisotope production.

With the revival of the Brazilian nuclear program, it is anticipated a large demand for training in nuclear technology. The Nuclear Technology Development Center (CDTN), offers the Operator
Training Course on Research Reactors (CTORP). This course has existed since 1974 and so far about 258 workers were certificated by CTORP. It is a three-week practical training course using the IPR-R1 TRIGA research reactor which emphasizes basic nuclear reactor neutronic principles. Subjects such as the neutron multiplication factor, criticality, delayed neutrons, reactivity, period, control rods calibration, and poisoning are discussed in such a manner that even someone not familiar with reactor physics and kinetics can easily follow it. Few mathematical equations are used and several tables and graphs illustrate the text.

This article describes the activities of CTORP and presents a proposal for expansion of its activities in order to meet the current demand in the nuclear technology. Experimental research projects programs would be created in the postgraduate course at CDTN. In addition to the reactor physics and instrumentation topics addressed by CTORP, new subjects such as thermal hydraulic should be added and discussed in more detail. Among the new items that should be studied, may be cited: reactor thermal power calibration, fuel and water temperatures, heat transfer, fuel thermal conductivity, temperature coefficients, Design Basis Accident, etc. Validation and verification of neutronic and thermal-fluid dynamics computer codes such: Monte Carlo, WIMS, RELAP and CFD. Theoretical and experimental burn-up calculations and introduction to reactor control and safety system based on the microprocessor.

2. The IPR-R1 TRIGA Reactor

The IPR-R1 TRIGA reactor at Belo Horizonte is a typical TRIGA Mark I light-water and open pool type reactor. The fuel elements in the reactor core are cooled by water natural convection. The heat removal capability of this process is great enough for safety reasons at the current maximum 250 kW power level configuration. However, a heat removal system is provided for removing heat from the reactor pool water. The basic parameter which allows TRIGA reactors to operate safely during either steady-state or transient conditions is the prompt negative temperature coefficient associated with the TRIGA fuel and core design. The IPR-R1 was designed for training in reactor operation, neutronic and thermal-hydraulic researches and isotope production, but has been used practically only for characterization of samples by neutron activation analysis technique. Figure 1 shows one photograph of the reactor core.

Fig. 1: Nuclear reactor IPR-R1 TRIGA view of the pool and core
3. **THE OPERATOR TRAINING COURSE ON RESEARCH REACTORS (CTORP)**

One of the requirements for the commissioning of the Angra 1 Power Station, the first Nuclear Power Plant in Brazil, was the training program for future nuclear reactor operators [1]. In general, training programs in countries with experience in the nuclear area included training in research reactors operation or in reactor simulators [2], [3]. At that time, Brazil had three research reactors in operation. The IEA-R1 located in São Paulo, reached its first criticality in 1957, while the Argonauta, in Rio de Janeiro, reached it in 1965. The IPR-R1 at Nuclear Technology Development Center (CDTN) situated at Belo Horizonte, state of Minas Gerais, reached its first criticality on November 11th, 1960.

The possibility of using the IPR-R1 TRIGA reactor in the training of the Admiral Álvaro Alberto Nuclear Power Station – CNAAA operators was one of the factors which stimulated the creation of CTORP. The content of this training program was first drawn by experts from the Nuclear Utilities Services Corporation, an American company, working in behalf of FURNAS, the reactor operator, together with Brazilian staff from the Radioactive Research Institute – IPR (later its name changed to Nuclear Technology Development Centre – CDTN). During several days, the requirements for the training program were quoted with the experimental installations available at CDTN, and adaptations were provided, either to adjust the texts to the existing equipment or to make them match the practical character intended for the training.

In the middle seventies the Operator Training Course on Research Reactors CTORP [4] was structured with the aim of filling part of the reactor operators training for Angra 1, which started its commercial operation in 1985. Since then, CTORP has been given 25 times and has certified around 258 professionals for the Brazilian nuclear sector.

Additional requirements of the program for the first applications were that the operators had some experience in the operation of thermal power stations and that they should get in advance the written description of the experiments to be made at the TRIGA research reactor existing at CDTN.

The CTORP is structured as a three-week intensive course. It is inherently practical and the experiments are divided into three categories: Reactor Experiments, Laboratory Experiments and Radiological Protection Experiments.

The material for this course is divided into two volumes. The experiments in each volume are divided into two categories: Reactor Experiments and Laboratory Experiments. The Reactor Experiments cover topics related to reactor kinetics and operation, while the Laboratory Experiments cover subjects as health physics (radiological protection) and reactor instrumentation. Volume 1 deals with the basic theoretical training and a facility description section. This material should prove very helpful to the trainees and should be read before the start of the course. This way, this volume is sent in advance to the trainees. Each experiment described in Volume 2 is further divided into several sections. These sections are: purpose, discussion, procedure, questions, and references. In order to obtain maximum benefit from the program, it is important that the student read the experiment before performing it. Tables 1 and 2 present the summaries of the Volume 1 and 2, respectively.
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The application methodology of the course consists of:

I. The trainees are divided into two groups. The first one conducts the reactor experiments in the morning, and the laboratory and radioprotection experiments in the afternoon, while the other group performs the training in inverse order;

II. Each practical class is preceded by a presentation, which last approximately thirty minutes, in order to give a basic theoretical background about it with particular emphasis on the Purpose and Discussion. With a thorough understanding of these sections, the student will be in a better position to pay full attention to the dynamics of the experiment and to obtain the data necessary to write it up;

III. Finished the oral presentation, students follow the teachers in implementing the proposed experiment;

IV. After the practice, the students together write up a report which should contain the experimental data, graphs and analysis of the results;

V. Finally, questions about the experiment must be answered individually by the students.

After the first and the second weeks, the trainees do written tests to measure their progress in learning the fundamental principles. At the end of the third week of the course a written and oral exams will be administrated to each student to evaluate the student’s knowledge at the end of the program. The practical test is necessarily applied by two experts who did not teach in the course. This procedure aims to avoid any prejudgment that could occur due to the student-teacher interaction during the course.

The final evaluation of the trainees is done on the basis of individual questionnaires, partial tests and final exams. Approval is given to the trainees who obtain final grade equal or greater than 70 %.

The CTORP is applied indiscriminately to professionals with high school and also with higher levels (Fig. 2). For this reason, this course avoids the application of differential and integral calculus, using only elementary mathematics. A few equations are used and several tables and graphs illustrate the text. This approach does not diminish the level of the course. The physical concepts which could be masked by a more elaborate mathematical treatment are better understood and assimilated by the trainees.

![Trainees in CTORP](image)

Fig. 2. Number of trainees in CTORP until the 22\textsuperscript{th} class

During the practical classes, special attention is given to each trainee to participate effectively in the experiment, and everyone in the class is expected to participate in the discussions. Another
important point in the philosophy of this course is the student-instructor relationship. It is our intention to treat all students as equals, regardless of their company position or academic background. Further, although the students will perform many startups and other operations on the Reactor Control Console, it is essential to remember that the licensed Reactor Senior Operator is fully responsible for the reactor at all times and no action affecting the reactor shall be performed without his knowledge and consent.

4. PROPOSAL FOR A PROGRAM IN REACTOR TECHNOLOGY USING THE IPR-R1 TRIGA

Nuclear Technology Development Centre (CDTN) was the first nuclear research institute in Brazil. In the sixties there was the pioneer project conducted by a research group called Thorium Group. The aim of the project was to develop a thorium fueled reactor. This project realized several progresses in conceptual design (fuel technology, reactor physics, thermal hydraulics, reactor vessel and materials). In the early seventies, with the Brazilian Government’s decision to build a Westinghouse PWR (Angra1) in a turn key bases, the Thorium Group discontinued its activities. However, the human power and knowledge developed under the frame work of this initiative were very useful for the future Brazilian nuclear program [5]. Until the late eighties the CDTN provided reactor technical support to the Brazilian nuclear power plants.

During the last decade there was a recovery in several areas of research in CDTN, leading to the creation of the Postgraduate Course in Science and Technology of Radiation, Minerals and Materials. With the conclusion of Angra 3, the RMB design and construction, and the resumption of the Brazilian nuclear program, it is anticipated a large demand for training in nuclear technology.

Then, the aim of this paper is to propose the expansion of training activities in the IPR-R1 TRIGA reactor with the creation of research programs in the reactor technology area in the CDTN postgraduate course. To perform this aim, it is in progress the update of the reactor instrumentation that will be used to monitor its operational parameters. The new system will be microprocessor based, and will be used large LCD displays that are typical of state-of-the-art control rooms.

A digital system is being developed to monitor, store and simulate the behavior of operating parameters [6]. Figure 3 shows two user-friendly interface of the system in two computer video screens. In the foreground can be seen the integral curve of a control rod. The graphical interfaces will provide greater reliability and transparency in IPR-R1 TRIGA reactor operations. Besides allowing online reactor parameters visualization and transmission through the internet or in the networks, the data can be stored and made available for exercises.
In addition to the neutronic, instrumentation and radiation protection topics addressed by CTORP, new items as thermal hydraulic should be added and discussed in more detail, in the proposed postgraduate program at CDTN. Among the new items that should be studied, may be cited:

- Validation and verification of reactor physics and kinetics computer codes, such as: MCNP, WIMS-D and TRIGLAV-W.
- Validation and verification of thermal-fluid dynamics computer codes, such as RELAP and CFX.
- Development of codes, including coupling of neutronic and thermal-hydraulic codes.
- Calculation of various research reactor physics parameters and models.
- Burn-up calculations and experiments.
- Core optimization.
- Safety requirements, strategic planning and IAEA standards for research reactors.
- Design Basis Accident (DBA).
- Reactor thermal power calibrations and heat transfer.
- Fuel and water temperatures, and heat transfer.
- Reactor instrumentation, digital control and safety system based on the microprocessor.

5. CONCLUSIONS

The CTORP so far has been applied 25 times, and about 258 trainees received Research Reactor Operator certificates. The efficiency and success of the course have been confirmed over the years by the good performance of the workers in the later stages of the training program. The experience of the CTORP certifies that it is possible to provide an effective training on research reactors using only elementary mathematics.

With the revival of the Brazilian nuclear program, it is anticipated a large demand for training in nuclear technology. The IPR-R1 TRIGA research reactor at Nuclear Technology Development Center (CDTN) has been used particularly for the needs of the Brazilian nuclear power plants operators training. This paper proposed the expansion of training activities at the IPR-R1 reactor. Research projects programs would be created in the postgraduate course at CDTN. In addition to the normal neutronic and instrumentation topics addressed by CTORP course, new fields as thermal hydraulic should be added and discussed in more detail. In order to perform a research program and training using the IPR-R1 reactor, it is needed the update of its
instrumentation for control of its operational parameters.

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5. References

CENEN - NET - New generation nuclear energy partnership

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CENEN-NET project is solved of Operational Program Education for Competitiveness in priority axes no.2 - Tertiary Education, Research and Development and area of support no. 2.4. - Partnership and networking. The goal of project is to intensify collaboration between involved universities which offer education in field of nuclear energy and the members of CENEN (Czech Nuclear Education Network).

Involved organisations:
- Czech Technical University in Prague
- Istitute of Chemical Technology Prague
- University of West Bohemia Pilsen
- VŠB-Technical University of Ostrava
- Brno University of Technology
- Technical University of Liberec
- State Office for Nuclear Safety
- CEZ GROUP
- Nuclear Research Institute Řež
- ŠKODA JS a.s.
- VÍTKOVICE ÚAM a.s.

Fundamental activities of the project are interships among individual working compartment, together with workshops and conferences which are important to strengthen and foremost making new contacts in national and international academic, state and even industrial bodies. Key part is foundation of project support office aimed to help CENEN members to prepare domestic and international projects.

Activities are focussed to transfer of knowledge and moreover forwarding of contacts to industrial institutions home and abroad from Prague universities to universities outside of Prague. Another part is to arrange sharing of contacts between regional universities themselves.
The main output of the project is than tighter collaboration between universities, state and industrial bodies and creating of contacts.

Target group of project are academic workers and students from out off-Prague universities involved in nuclear education. Particulary it covers 7 workplace at level of departments from 7 different faculties at 4 universities (University of West Bohemia in Pilsen, Technical University of Liberec, VŠB - Technical University of Ostrava and Brno University of Technology). Information about project and state of its solution can be found at project web site: www.cenen.net and homepage of CENEN: www.cenen.cz

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