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The more objective reporting on nuclear energy in media in recent times is very much welcomed. Ideology and emotions are gradually making way to a greater willingness to discuss the undeniable advantages of nuclear power and its contribution to a sustainable energy mix. Such an open debate is needed because it helps to better understand the perspectives for nuclear energy in the European Union.

The facts speak for themselves: With the expansion of the EU to the east 151 nuclear power plants are now operating within the EU and providing 32 % of the electricity generated. The EU's claim to become the most rapidly growing region in the world with the Lisbon strategy cannot be realised without competitive generation of power using nuclear energy. The decisions in Finland and France in favour of the European Pressurized Reactor (EPR) as well as the upcoming debate in Poland on the commissioning of a nuclear power plant by around 2020 are impressive confirmation of this. The governments of Sweden, Britain and Belgium are again debating the role to be played by nuclear power in the future energy mix. In Germany this is not yet the case but a similar debate is likely to take place in the near future. This is due to the fact that a competitive energy price is more and more considered as a major location factor. In addition, the 700 million tons of CO_2 annually avoided through nuclear power in the EU amount to one and a half times the volume to be saved, to which the EU has committed itself under the Kyoto Protocol. The initiated trade in emissions certificates will make the economic dimension of this aspect even more obvious. The continuously rising energy demand worldwide, especially in Asia, and in parallel the EU's increasing dependence on fossil energy sources makes nuclear energy an essential supporting element to secure European energy supply. The base load capacity and the competitiveness of CO_2-free nuclear energy also provide a solid basis for the further expansion of renewable energies in the EU.

The decision-makers in Brussels should more and more take these facts into account and guarantee reliable boundary conditions for the continuing use of nuclear energy in Europe. The declaration of the first European Nuclear Assembly (ENA) is a significant joint signal on the part of the European nuclear industry. I am confident that many politicians, economists and scientists will support the mission of the ENA declaration. To be clear: Nuclear power is without doubt not the only solution but there is no sustainable solution without nuclear power.

Dr. Ralf Güldner,
Chairman, German Nuclear Society (KTG)

Declaration on Europe's Future Use of Nuclear Energy for Power Generation

We firmly believe that nuclear-generated electricity should remain at the heart of Europe's energy supply system for the foreseeable future.

Energy planning in Europe is at a crucial turning point. For example, in the coming years, oil resources will continue to dwindle, putting political decision-makers under increasing pressure.

In the future, Europe will need a diversified and flexible energy mix to meet two combined challenges – maintaining security of energy supply and reducing CO_2 emissions. Facing up to the challenge of climate change will call for the mobilisation of all low-carbon and zero-carbon technologies in the decades ahead.

The nuclear industry already makes a valuable contribution to achieving Europe's objectives in terms of security of energy supply, support for the EU economy and environmental protection. Nuclear offers Europe a clean, affordable and secure source of energy.

As the generation of nuclear electricity is CO_2-free, it avoids the emission of nearly 700 million tonnes of CO_2 a year in the newly enlarged EU. This is roughly equivalent to the CO_2 emitted each year by the 200 million cars in use on the EU's roads.

It is important for EU policy-makers to create and maintain the right conditions for Europe to meet its economic and environmental objectives – by keeping nuclear as one of the central options in their energy planning.

We therefore call upon them to:

- encourage energy policies in the EU member states that keep all options open;
- recognise the important contribution made by the nuclear industry to the provision of secure and clean energy;
- promote a flexible, viable and competitive energy mix, energy efficiency and new investments in low-carbon energy sources, such as nuclear and renewables; and
- create a 'level playing field' allowing different energy sources, including nuclear, to develop and compete under liberalised market con-ditions.

The Declaration on Europe's Future Use of Nuclear Energy for Power Generation is the result of an initiative

- launched by the European Atomic Forum (FORATOM), the trade association for the nuclear energy industry in Europe,
- with the full backing of FORATOM's member associations and companies in 16 European countries, and

• timed to coincide with the first European Nuclear Assembly, a FORATOM conference that will take place every two years.

The declaration was presentend at the European Nuclear Assembly, Thursday 25 November, Brussels, Belgium

Among the first signatories:

Ph. Van Troeye, Generation Manager, Electrabel, Belgium
Fernando Naredo, Vice President, Westinghouse, Belgium
Eduardo Gonzalez, FORATOM President, Belgium
Iordan Kostadinov, Executive Director, Kozloduy Nuclear Power Plant plc, Bulgaria
Martin Roman, CEO, CEZ, Czech Republic
Anne Lauvergeon, AREVA Group, France
Bruno Lescoeur, Director, Executive Chairman of the Executive Board Vice President of EDF, France
Pertti Simola, CEO, TVO, Finland
Tapio Kuula, Head of Power and Heat, FORTUM, Finland
Walter Hohlefelder, Member of the Board, E.ON, Germany
Gert Maichel, President & CEO, RWE Power, Germany
Giancarlo Bolognini, CEO, SOGIN, Italy
Viktor Sevaldin; Director General, Ignalina Nuclear Power Plant, ithuania
A. M. Versteegh, Nuclear Research Director, NRG, Netherlands
Ioan Rotaru, Director General, Nuclearelectrica, Romania
Adolfo Garcia Rodriguez, President, Empresarios Agrupados, Spain
Martin Regano Ureta, Director General, Nuclenor, S.A, Spain
Francisco Martinez Corcoles, Director Iberdrola Generation, Spain
Antonio Alonso Ramos, Director General, Tecnatom S.A., Spain
Stane Rozman, CEO, Nuklearna, Elektrarna Krsko, Slovenia
Alf Lindfors, Executive Vice President and Head of Nordic Generation, Vattenfall, Sweden
Dr. Manfred Thumann, CEO, Nordostschweizerische Kraftwerke AG, (NOK), Switzerland
Mike Parker, Group Executive, BNFL, United Kingdom
Helmut Engelbrecht, Urenco, Chief Executive Designate, United Kingdom

Statement by the Kerntechnische Gesellschaft (German Nuclear Society, KTG) about the Current Mix of Social, Economic and Nuclear Policies in Germany

KTG
Kerntechnische Gesellschaft e.V.

In 2003, the Board of KTG welcomed the objective of Agenda 2010 to improve the international competitiveness of the German economy by reforming the social systems. At the same time, attention was drawn to the conflict this implied with the existing nuclear power policy banning any further use of this important, competitive source of primary energy, and planning to shut down prematurely economically viable nuclear power plants operated under valid operating licenses.

Today, the ban in force on state funding of further developments for the use of nuclear power in Germany, above all, contradicts the current efforts of the federal government to achieve greater contributions to growth through research and development. The reputation of German scientific research is damaged if, for political reasons, internationally approved technologies are abandoned in the development of which Germany played a leading role. Last, but not least, this ruins the possibility to exert any competent influence on the development of nuclear safety internationally.

In a foreseeable future, also the consequences in the power economy of this opt-out policy will be felt more and more strongly. Over the past few months, world market prices of numerous commodities and energy resources have increased markedly because of growing demand in a number of threshold countries. This trend is going to stabilize as soon as industrialized countries and developing countries achieve consistently higher economic growth. As a consequence of rapidly propagating automation, considerable increases in demand must be anticipated especially for electricity in the baseload range. Only nuclear power is able to supply major growth in demand worldwide quickly, at low cost, and without polluting the environment, and this irrespective of fuel reserves existing close to centers of consumption and/or suitable transport systems. At the same time, fossil fuels, renewable energies, and efficient uses of energy are indispensable elements ensuring flexibility and efficiency of specific supply solutions.

In addition to more and more numerous indications in the economy of the future indispensability of nuclear power, growing interest in many countries is indicative also of a broad shift in attitudes. Under the new conditions now developing, political credibility will not be achieved by tenacious clinging to outdated opt-out decisions. Responsible policies will have to be geared towards advancing this source of energy in specific ways so as to make it even safer from misuse and terrorist attacks in a changed environment, but also make it still more efficient and more widely usable. In the management of radioactive waste, not only existing approaches must be completed in close international cooperation, but also basically new ways must be sought and developed.

The Board of Kerntechnische Gesellschaft considers it its duty to call upon all political parties and the social partners in Germany to meet these new challenges in a constructive response. The unavoidable conflict of opinions this will entail must be settled in an unbiased way without exploiting the subject for other purposes.

Finally, it is just as important to inform the public honestly in a way adequate to the seriousness of the situation. All these are important touchstones for responsibility and honesty in the necessary development of a new nuclear policy for Germany.

German Nuclear Society (KTG, Kerntechnische Gesellschaft e.V.)

VHTR: The Reactor of the Future?

With gas prices skyrocketing, increasing emissions causing global warming, and the forecasts of the impending demise of the oil age, new nuclear power plant construction is back in the news. There are new technologies ready for near-term construction such as AREVA's European Pressurized Water Reactor (EPR) or Boiling Water Reactor (SWR 1000). Much research and development is being devoted to the longer-term Generation IV reactors for commercial deployment around 2020. Among these concepts, the Very High Temperature Reactor (VHTR) seems to be the most promising. AREVA, working through its subsidiary, Framatome ANP, has been working for over 20 years on High Temperature Reactors (HTR) and AREVA is now accelerating its work on the VHTR because its technology is recognized for its economic high-efficiency electricity generation as well as high temperature process heat application.

AREVA's strategy is to develop a simple, inherently safe, highly reliable VHTR nuclear heat source (NHS) that can be used for a family of applications that will support an expanded role for electricity generation. The technology is also suitable for carbon-free hydrogen production as well as other process energy applications. In addition, Framatome ANP intends to play a lead role in the next generation nuclear plant (NGNP) demonstration project initiative being developed by the Idaho National Engineering and Environmental Laboratory (INEEL).

Design Approach

The VHTR, one of the Gen-IV reactor concepts, is a helium-cooled, graphite-moderated, reactor with an outlet temperature up to 1000ºC. The fuel is coated particles aggregated in cylindrical compacts.

Framatome ANP has participated on the US/Russian Gas Turbine Modular Helium Reactor (GT-MHR) program used to dispose of Russian weapons-grade plutonium. In addition, the company has experience with pebble-bed reactors. Based upon this experience, the company has chosen a design with prismatic fuel blocks and an indirect-cycle architecture. An indirect-cycle uses a secondary loop that is coupled to an application through an intermediate heat exchanger (IHX). For electricity generation, the NHS is coupled via the IHX to a combined-cycle power conversion system similar to a natural-gas fired combined cycle gas-turbine (CCGT). The hydrogen production plant will be coupled to the NHS, also via an IHX.

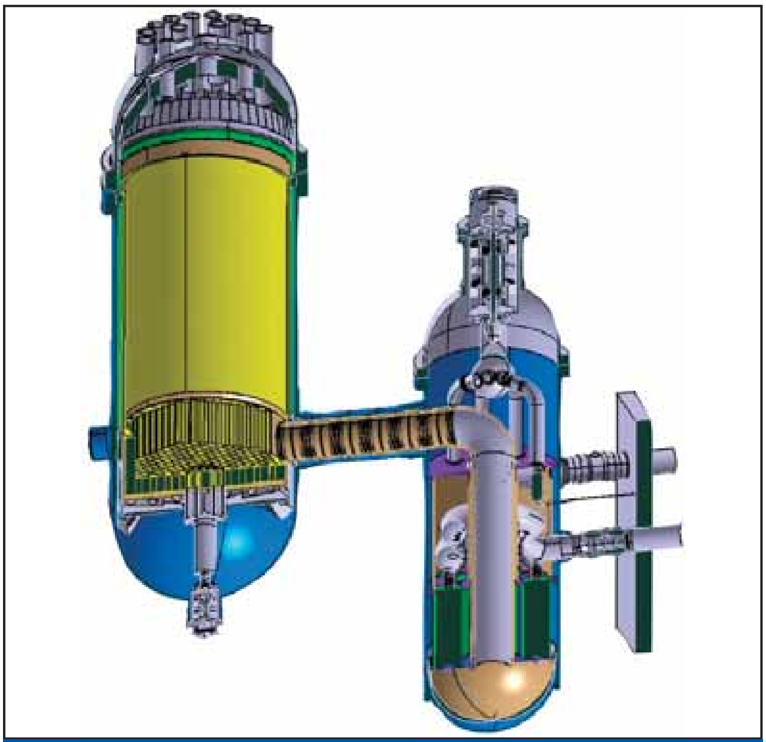

Figure 1. *The Generation IV VHTR is an inherently safe reactor producing less nuclear waste than current designs.*

INEEL's NGNP Demonstration Plant

In early 2005, INEEL and the Argonne National Laboratory West will be combined into the Idaho National Laboratory, "a new national laboratory with nuclear energy research and development at the core of its mission. This new lab will play a critical role in US development and exploration of next-generation nuclear plant technology [NGNP] – an advanced, Generation IV concept that will produce cost-effective electricity and hydrogen." (*Nuclear Energy Insight)*

The Framatome ANP HTR design and performance objectives mesh well with the NGNP demonstration plant function and requirements. These same design and performance objectives are fully supportive of AREVA's needs for the commercial deployment of the VHTR.

Conclusion

The AREVA concept minimizes the cost and development risk associated with the Nuclear Heat Source and the Power Conversion System.

Advantages

- High-efficiency electricity production (~50%)
- Adapted to hydrogen production to help fuel the "Hydrogen Economy," without generating any greenhouse gasses
- Less nuclear waste
- Can easily handle different fuel types, such as reprocessed plutonium and minor actinides
- Inherently safe: no severe fuel damage is possible
- Competitive capital and operating costs

Comprehensive Factory Testing Speeds up I&C Startup on Site

Tianwan Nuclear Power Station at Lianyungang in China is a shining example of successful Chinese-Russian-German cooperation. This is the first time that a Western vendor, Framatome ANP, an AREVA and Siemens company, has made a major contribution to the construction of a Russian-designed plant by supplying large parts of the plant's electrical equipment as well as all of its operational and safety instrumentation and control (I&C) systems. Each I&C component was thoroughly tested prior to shipment, thus enabling startup at the plant in China to proceed much faster.

Building "O" at Framatome ANP's site in Erlangen, Germany may appear relatively unimpressive at first sight, but appearances can be deceiving; this building houses the test facilities in which the digital operational and safety I&C platforms TELEPERM™ XP and TELEPERM XS are tested from top to bottom before being shipped to customers all over the world. It is here that the digital equipment is carefully tailored to individual plant needs, thus significantly reducing the time needed for I&C startup on site. Until the end of March 2004, it was also home to the I&C systems destined for Unit 2 of Tianwan Nuclear Power Station, which are now on their way to China by ship.

At the Lianyungang site some 400 kilometers north of Shanghai, the Russian company Atomstroyexport/ OKB Gidropress is building two VVER-1000 Model V-428 reactors, the latest version of the Russian-designed 1000-MW PWRs. Framatome ANP's large scope of supply includes eight emergency diesel generator sets, each with a rated output of 6 MW, heating, ventilation and air conditioning systems, electrical components for the 24-volt DC converters and, together with Siemens Power Generation, the entire operational and safety I&C equipment. "We were looking for highly advanced, state-of-the-art systems, which is why we chose the digital operational and safety I&C platforms TELEPERM XP and TELEPERM XS," explains Cheng Zhao Bo, Managing Director of Jiangsu Nuclear Power Corporation (JNPC) which operates the plant. Unit 1 is scheduled to go on line at the end of 2004, with Unit 2 following a year later. The highly productive Chinese-Russian-German cooperation is a key factor in helping the project meet this ambitious schedule.

Given the made-to-measure nature of reactor I&C systems, adapting these extremely modern digital platforms to the Russian plant design was not a problem. A three-stage standard test is used to verify proper component interaction. First, engineers at Erlangen used the SIVAT simulation tool to check that fundamental safety I&C functions were operating correctly with measured plant data. "We usually detect 99 percent of all faults at this stage alone", explains I&C Project Manager

Figure 1. *Germans and Chinese work side by side at the test facility in Erlangen, Germany (photo : AREVA)*

Figure 2. *Tianwan nuclear power station (photo: AREVA)*

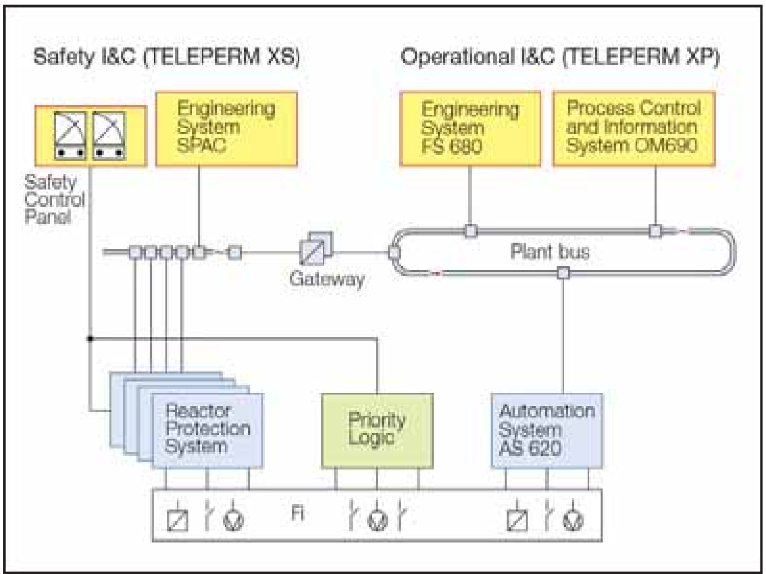

Figure 3. *Tianwan I&C system structure*

Joachim Mende. Next, experts at OKB Gidropress in Moscow used simulation techniques to check the performance of the reactor I&C equipment under all possible operating conditions, including accident scenarios. Finally, all of the operational and safety I&C equipment was set up at the test facility in Erlangen for a comprehensive functional test program. Testing of the safety I&C systems for Tianwan 1 took no less than six months. The experience gained during this process and the results of I&C startup in Unit 1 enabled the overall on-site testing time for Unit 2 to be cut down to just four months. The end result was a perfectly integrated system which can now be installed and put into service in record time.

Tianwan is not AREVA's first project in China. Together with its Chinese partners, the company has already built two units for each of the Daya Bay and Ling Ao nuclear power plants. However, Tianwan has been a special challenge due to the trilateral cooperation: "This is the first time that a Western vendor has been involved so extensively in the construction of a nuclear power plant of Russian design. Our products make a decisive contribution to the good operating performance and high safety levels of Tianwan 1 and 2", says Ulli Kraft, Framatome ANP's Senior Vice President for Electrical and I&C Systems. As Units 1 and 2 near completion, preparations are already under way to build another two reactors at the site in Lianyungang to help meet China's huge demand for electricity, which only an expanded nuclear power program can satisfy.

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A Tale of Two Theories

High Reliability Theory vs. Normal Accident Theory

by **A. T. Teller,** ENS, Brussels, Belgium

1. The origin of the problem

Attitudes towards advanced technologies fall into two groups characterised by opposite conclusions. Both groups can nevertheless claim the support of specific theoretical developments. High Reliability Theory (HRT) claims that it is possible to devise measures that will effectively guard against the occurrence of significant accidents.[1] Normal Accident Theory (NAT) holds that significant accidents are an inherent, and therefore inescapable, feature of these technologies, which it identifies as high-risk. When trying to assess the relevance of these two theories to the civil use of nuclear power, one comes to the conclusion that neither is really satisfactory. A brief review of the past attempts at evaluating accident probabilities will explain why. The publication, in 1975, of the Rasmussen report, also known as WASH 1400, constituted a first milestone. The conclusions of this report were extremely optimistic: even with twice the number of reactors currently operating in the United States, the probability of seeing a significant accident in one's lifetime would be extremely low. The critics of nuclear power, those who would later espouse later the views upheld by NAT, did not fail to question this assessment. Using their own methods and figures, they reached the conclusion that a park of 700 reactors (the number of reactors expected back in 1976 to be operating in the United States in 1990) would lead to one accident every six years[2] [1] (page 24). Four years after the Rasmussen report, the Three-Mile Island (TMI) accident dealt a most serious blow to those who thought that reactor technology was fully under control. This very event was the starting point of Charles Perrow's work. Tackling the question from the vantage point of an organizational theorist, he coined the phrase "normal accidents" and made it the title of his best-known book [2], first published in 1984. Despite the fact that its author had a number of ideological axes to grind, the book contained a number of compelling observations.

- The hindsight bias has a most damaging influence on the post-mortem analysis of the events leading to an accident. In other words, the very knowledge of the outcome of a sequence of events blinds the reviewer to the situation of those who had to cope with the said sequence *before* they knew where it was leading to.
- In designing plants so that various parts can fulfil an accessory function (e.g. emergency recovery) in addition to their main process, one induces feedback loops that add greatly to the complexity of the plant as a whole.
- Having suffered a major accident does not necessarily lead to impeccable performance afterwards, as is evidenced by the case of Union Carbide. Nine months after the Bhopal tragedy, this company experienced another release of toxic material, this time in a plant in the United States. Fortunately, in this case there were no casualties. However, the lessons drawn from the first disaster had not led to foolproof corrective actions [2] (pp 358 – 360).
- Significant accidents do not automatically result in a high number of casualties. To bring about large-scale damage, a great number of adverse conditions must prevail at the time of the accident, which constitutes in itself an unlikely event. Bhopal was an egregious exception to the more general outcome of accidental sequences.

One suspects that the success of the book did not rest only on such perceptive comments. *'Normal Accidents'* most probably owed part of its fame to the paradoxical flavour of its title and to the fact that it contained the following statement [2] (page 348):

"I would expect a worse accident than TMI in ten years – one that will kill and contaminate."

As everybody knows, this forecast was proven right two years later, in April 1986.

However convincing the objections raised by *'Normal Accidents'* might look on paper, they do not give a satisfactory account of what happened in the years following its publication. Eighteen years have elapsed since Chernobyl[3] and the accident rates predicted by the supporters of NAT have not been borne out by the facts. Too little attention has been paid to the fact that C. Perrow's claim was vindicated for the wrong reasons. Although the author did not qualify his prediction, the context of the book indicates that he was focussing on the United States and that the causes of the expected accident would be rapid ageing, uncontrollable complexity and latent (hardware) failures [2] (page 60). It is well known that none of these factors played a significant role in the case of Chernobyl.

This observation does not, however, do the supporters of nuclear power any good. They had claimed that the three-barrier design of nuclear power plants would be so effective that no significant accident would ever have to be feared. TMI came as a painful contradiction to this assertion. Chernobyl later reinforced an already unfavourable impression. Moreover, there remains a lingering doubt as to the interpretation of these two accidents: must they be regarded as the most spectacular teething troubles of a technology resolutely progressing towards maturity or are they precursors of the worst, which is still waiting to come?

This is the situation as it stands today. With this picture in mind, it is legitimate to ask whether either of these theories is capable of providing an appropriate framework for assessing future performance.

2. NAT's critique and the HRT-inspired approach

On the face of it, the objections raised by Normal Accident Theory are damn-

1 In the context of nuclear power generation, we shall define a significant accident as any accident exceeding level 4 on the International Nuclear Event Scale (INES). This cut-off has been chosen so as to concentrate on accidents entailing off-site risk.

2 Adjusting this figure for the number of reactors actually in operation in the world (440), one arrives at a rate of one accident every 9.5 years. After Chernobyl, critics of nuclear power confirmed the six year estimate on the basis of the actual number of reactors.

3 For the record, the 1999 Tokai-Mura accident was rated 4 on the INES scale. It is not therefore a significant accident as defined in Footnote 1.

ing [2], [3] (especially Chapter 7, Latent Errors and System Disasters). Human operators are expected to cope with failures in the design, maintenance and managerial framework of highly complex, rapidly evolving systems. Defects in these areas might have been planted in the system long before the occurrence of the mishap that will reveal their presence. System automation and defence-in-depth make the situation only worse by rendering the responses of the facility more opaque and unpredictable. Myriad individual failures, none of them very serious in its own right, can propagate in the most unpredictable fashion and pave the way to disaster. Such is the variety of accident scenarios that it would be pointless to implement remedies to any one actually experienced. James Reason [3] observes (page 174) that

"Since the same mixture of causes is unlikely to recur, efforts to prevent the repetition of specific active errors will have only a limited impact on the safety of the system as a whole. At worst, they merely find better ways of securing a particular stable door once its occupant has bolted."

Finally, one of the most impressive objections raised by NAT underlines the paradoxical nature of automated systems. The designers have considered a great number of potential conditions of the system, either normal or accidental, and have built into their design all the features needed to handle them appropriately. The consequence of this process is that operators are left to their own devices – literally – to handle precisely those situations that have not been foreseen by the system designers. And to add insult to injury, they are supposed to do so by relying on mental tools poorly adapted to such a task, as evidenced by recent advances in cognitive psychology [3] (chapter 4: Cognitive Underspecification and Error Forms).

When a serious obstacle to achieving a certain objective is identified, two responses are possible. One can look no further and say, "this shows that the objective contemplated is unattainable, so let's drop it". Alternatively, one can say, "is there anything we can do in order to remove the obstacle?" This difference in attitudes is probably what epitomizes best the divide between opponents and supporters of nuclear power. The former are content to accept the obstacles identified as the elements of quasi mathematical proof of impossibility, the latter see them as physical challenges one must try to overcome.

Scope	Safety-enhancing measures
components (hardware)	contractor certification experience feedback material sciences (including ageing mechanisms) non destructive testing predictive maintenance quality control
system	operator certification probabilistic safety analysis single failure criterion
man-machine interface	human factor engineering [4][4] defence-in-depth human reliability analyses simulator training
management	ISO standards quality management
multi-level	best practice IAEA standards incident reporting systems peer reviews quality assurance regulatory supervision
meta-measures	continuous improvement safety culture

Table 1. *Safety-enhancing measures*

Table 1, which does not even purport to be complete, shows what responses the second attitude can elicit in the context of nuclear safety. The 23 measures listed above were developed over time to close the gaps through which accidents might slip and defeat the high reliability objective. These measures have been grouped into categories, of which the application levels range from the most restricted (individual components) to the most general (whole plant, operating staff included). They also vary widely in nature; some are simply design principles or collections thereof, others refer to full-fledged organizations or to a large range of activities. Some of them act at only one level or can address several of them at the same time. The last level, called meta-measures for lack of better wording, does not address any aspect of an operating plant but rather the way in which the other measures must be implemented. Finally, it must be emphasized that this table does not allow justice to be done to the thousands of people who work relentlessly to increase the knowledge and expertise needed to harness the power of the atom. These people are found in universities, research institutes, companies, as well as national and international safety organizations.

Explaining in detail how these measures contribute to the intended high reliability goal would go well beyond the scope of the present paper. We shall restrict ourselves to examining to what extent they stand the test of the seemingly overwhelming objections of NAT.

3. NAT's response to the HRT-inspired approach

When lo th and computer simulation, one would be at a loss to name one single reference to these in [2] (1999 edition) or in [3] (1990 edition). This is despite the number of accident-free years having elapsed between the TMI accident and the timing of these authors' reviews of the event. Tellingly, C. Perrow decided to devote the 1999 revision of his book to spelling out why Y2K was likely to lead to a large-scale catastrophe, not to re-examining the cogency of his 1984 analysis of TMI.[5]

Secondly, defence-in-depth and computer simulation are indeed mentioned by NAT authors, but these exceptions confirm the rule previously stated: both measures are considered to generate further problems, not solutions. The argument is however

4 Article 3.102 of reference [4] indicates that the IAEA had issued relevant recommendations as early as 1984.

difficult to understand. Why would defence-in-depth add to the opacity of the system when one of its aims is to provide early warnings of departures from normal operations [5] (pp 5-6)? The supporters of NAT are not clear at all about this rather strange claim. Why would simulation not give NPP operators a better feel for the system they are supposed to keep under control? Again, the inadequacy of computer simulation is asserted without providing any supporting argument.

Thirdly, the claim that each serious failure is intrinsically original with respect to previous ones is neither borne out by facts nor consistent with other elements of the NAT picture. The root cause of Chernobyl was very different from TMI's. But this does not prove J. Reason right (see quotation above): he himself observes that there had been precursors to TMI [3] (page 191). C. Perrow, who mentions, as indicated earlier, the repetition of toxic leaks in Union Carbide plants also confirms the occurrence of precursors. In the case of potential repetitions, it is the high reliability approach consisting of setting up incident reporting systems, such as those set up by the IAEA, the NEA and WANO, that is justified: experience shows that precursor events do happen. Furthermore, it should be noted that the measures taken by the industry in the wake of the TMI incident were not restricted to securing any particular kind of stable door. The analysis of the accident led to identifying a whole range of causes of the accident and the modifications made to NPPs addressed classes of potential accidents rather than just the one experienced. Once again, one can only regret that the "post-TMI measures" have not been chosen as a topic for investigation by NAT.

The fourth and last observation is however more serious. Any measure aiming at ensuring safety is only as good as the effectiveness of its implementation. Any safety measure can look good on paper and be worth nothing in practice if it is not properly carried out. And NAT is perfectly correct in underlining the size of the challenge this represents. This is where the safety meta-measures in Table 1 – continuous improvement and safety culture – do play an essential role. Continuous improvement is necessary as a way of avoiding boredom and precluding complacency. Safety culture is meant to engender the requisite mindset to perform any task in environments where safety is an overriding concern. So far, safety culture and continuous improvement have proven to be equal to the challenge at hand. They have been instrumental in turning what could have remained a mere wish list into a list of achievements.

The discrepancy between forecast and reality should have provoked some line of inquiry from NAT supporters. It appears, however, that they handled the said discrepancy mainly by ignoring it. Such an attitude can be ascribed to their pseudo-mathematical demonstration of the impossibility of ensuring safety. If one is content to settle a matter through theoretical reasoning, one will have little incentive to examine practical evidence. Nuclear safety, however, is about the real world; this is why it is a mistake to eschew the confrontation between theory and observations. Another approach, adopted by many critics of nuclear power, comes down to claiming that the accident probability is actually high, and the long period of safe operation we have enjoyed since Chernobyl is due to sheer luck. It should be clear to everybody that this is trying to have one's cake and eat it. If an event has a high probability of occurrence, it must occur sooner rather than later. If the said event takes longer than expected to occur, then the very definition of probability forces us to conclude that its likelihood is lower than that initially assumed. Claiming that we are in fact witnessing the unlikely case of its non-occurrence would be tantamount to rejecting the foundations of statistical inference, which, needless to say, is not warranted.

In conclusion, given the experimental confirmation available and the absence of satisfactory objections to HRT, one feels entitled to ascribe the low level of significant accidents experienced so far to the measures taken by the nuclear safety professionals. The overall success of nuclear power generation over the past 20 or so years would therefore indicate that the NAT analysis relies too much on preordained opinion and not enough on a straightforward assessment of what is technically achievable. Notwithstanding this, the supporters of HRT should heed the warning given to all would-be investors: past performance provides no guarantee as to future behaviour. This is clearly HRT's main challenge in the future.

4. The future of high reliability

The situation regarding nuclear safety is paradoxical in more than one respect. One paradox is that the ideologically motivated criticism levelled by anti-nuclear pundits has been turned into a self-defeating prophecy by the professionals responsible for the safety of nuclear installations. Another paradox is that these professionals are the only people fully aware of all the work done to ensure a very high level of nuclear safety. The safety measures outlined above are ignored not only by NAT exponents, but also by the general press. The media's influence on public opinion is sometimes exaggerated. However, the fact remains that, if it cannot *tell people what to think*, it is extremely effective at *deciding about what people think* [6] (page 30). By simply ignoring the work and achievements of the nuclear safety professionals, the media contributes mightily to entertaining the idea that NAT is the final word on nuclear safety. We therefore end up with a situation in which the laymen who should know about the safety measures implemented are starved of information and the professionals who should act as though nothing existed yet are fully aware of past achievements. The prevalence of these two paradoxes is not sustainable in the long run. On the one hand, dogmatic criticism is destructive. On the other, while the public should not be left with an unduly grim picture of nuclear safety, the safety professionals should take no account of their past successes. This is essential to protect the latter from overconfidence and complacency. And the fact that it is these twin pitfalls which constitute the main threat to high reliability was recently underlined by the chairman of WANO [7].

Effectively monitoring overconfidence and complacency, however, requires overcoming two difficulties. The first one, taking C. Perrow's lead, is that these pitfalls become apparent with the benefit of hindsight, i.e. when it is too late. The second one is that they might constitute a 'none of the above' explanation, to be invoked when no

5 The fact that Y2K ended up being a non-event highlights how difficult it is for any one individual to make two successful predictions of major import.

other cause seems to apply. An indicator, or a set of them, which would be capable of giving an early warning regarding lapses in safety performance would therefore be most welcome. This has become the topic of a research project undertaken under the European Union's 5th Framework Programme [8]. Noting that the usual safety indicators measure degradation only when it has already set in, the problem tackled in this project is to define new indicators that would act as predictors of future trends.

This paper does not seek to solve this challenging problem. Nevertheless, I believe that researchers might find a promising avenue by comparing the safety-related pattern of activities of two categories of nuclear facilities during well-chosen periods of time:

the facilities that had apparently achieved a high level of safety *before* this was contradicted by the occurrence of an accident; and

the facilities recognized for having greatly improved their safety performance *after* an accident.

Of course, such an analysis will have to factor out the possible presence of hidden defects planted in the system before the beginning of the period under investigation. Once this is done, what might differentiate the two patterns of activities might also provide a suitable basis for the identification of complacency and overconfidence without falling prey to the hindsight bias. The said differences could then be translated into a new safety performance indicator or several of them. To ensure high reliability, the nuclear safety professionals would then have at their disposal, not only the tools listed in Table 1, but also the indicators needed to ensure that their own performance remains highly reliable as a matter of routine. If this can be achieved, it is submitted that High Reliability Theory will definitely provide the appropriate framework for the safety assessment of the next fifty years.

The views expressed here represent solely those of the author and do not necessarily reflect those of FORATOM.

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IEA *Energy Outlook:* Call for Urgent and Decisive Policy Responses

Claude Mandil, executive director of the Paris-based International Energy Agency (IEA), presented a reassuring assessment of the prospects for global energy supplies in the newest World Energy Outlook 2004, but drew attention to serious concerns about energy security, investment, the environment and energy poverty. He called for more vigorous action to "steer the global energy system onto a more sustainable path".

Claude Mandil stressed that "the central message of the WEO remains an optimistic one. The earth contains more than enough energy resources to meet demand for many decades to come. The world is not running out of oil just yet. Moreover, there is more than enough money globally to finance the large expansion of energy infrastructure that will be needed."

But, he continued, soaring oil and gas prices, the increasing vulnerability of energy supply routes and ever-increasing emissions of climate-destabilising carbon dioxide are "symptoms of a considerable malaise in the world of energy." He described the inexorable increase in global energy demand from now till 2030 that the WEO predicts – as well as our continuing heavy reliance on carbon-emitting fossil fuels – as "deeply troubling."

In the Outlook's "Reference Scenario", which projects energy trends in the absence of new government policies or accelerated deployment of new technology, world primary energy demand is set to rise by 59% from now till 2030 (Figure 1). Some 85% of that increase will be in the form of carbon-emitting fossil fuels: coal, oil and natural gas. Two-thirds of the new demand will come from the developing world, especially China and India. Demand for oil will continue to expand, at 1.6% a year, from 82 mb/d today to 121 mb/d in 2030, and inter-regional trade in oil will double to 65 million barrels a day. Most of that additional trade will have to pass through vital chokepoints, sharply increasing the possibilities of a supply disruption. More and more oil will come from fewer and fewer countries, primarily the Middle East members of OPEC. The dependence of all importing countries on those suppliers will grow.

Gas use is projected to double by 2030, largely because it will be the fuel of choice for electric power generation. Coal will continue to supply a fifth of world energy needs, mostly in power generation and increasingly concentrated in China and India.

Nuclear power will grow very slightly, decreasing in Europe while advancing in Asia. Use of other non-carbon-emitting renewable energy sources will triple, but still will account for only 6% of world electricity production in 2030.

"These trends are, however, not unalterable. Our analysis shows that more vigorous government action could steer the world onto a markedly different energy path", said Claude Mandil. World energy demand is 10% lower and carbon-dioxide emissions 16% lower in an "Alternative Policy Scenario". The world's reliance on Middle East oil and gas are also much reduced. More efficient use of energy in vehicles, electric appliances, lighting and industry account for more than half of the reduction in emissions. A shift in the power generation fuel mix in favour of renewables and nuclear power accounts for most of the rest. "Yet, even in this alternative scenario, energy imports and emissions would still be higher in 2030 than today and would still be growing."

"What this analysis shows very clearly", he added, "is that achieving a truly sustainable energy system will depend on technological breakthroughs that radically alter how we produce and use energy." He called on governments to take the lead in accelerating the development and deployment of new technologies "that allow us to meet our growing energy needs without compromising our energy security and the environment."

As in past editions, this year's World Energy Outlook presents an exhaustive set of historical data and projections covering demand, supply, trade, investment and CO_2 emissions for all fuels for 20 major world regions and countries. This year, WEO also includes a number of special features:

• A focused study of the effects of persistent high oil prices. It concludes that, if oil prices stay high, they would erode oil demand substantially and reduce the income of OPEC producers over the medium term.

• A detailed analysis of how oil and gas companies calculate their "proven", "probable" and "possible" reserves and a comparison of current estimates. The study finds that current practices vary considerably among companies, confusing the overall reserves picture. The IEA calls for a new, universally-recognised methodology standard for reserve estimation.

• A hard look at the issue of energy poverty, including a new "energy development index", a handy measure of how far countries have advanced along the road to energy maturity in the areas of per capita energy use,

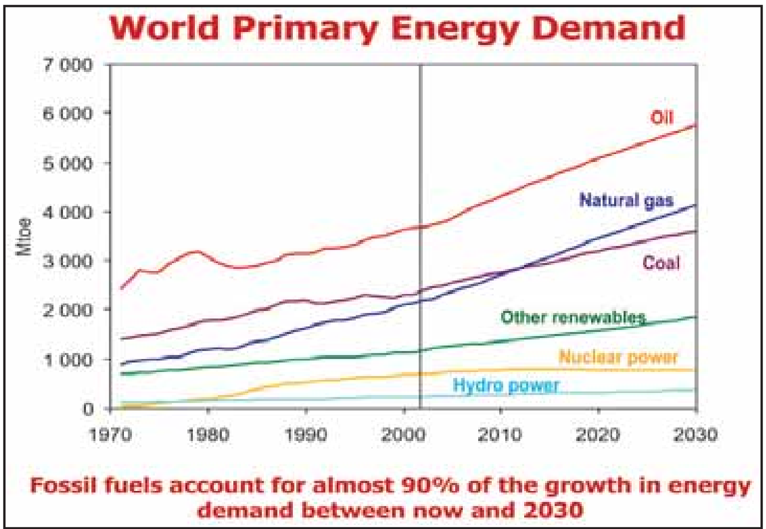


Figure 1. *Development and prospects for the World Primary Energy Demand from 1970 until 2030.*

the use of modern energy services and rates of electrification.

• An in-depth study of Russia's growing role as a major energy power. While recognising it as "the most important energy country" of the moment, there are enormous uncertainties surrounding Russia's energy future.

• A "World Alternative Policy Scenario" – which for the first time includes the developing world and emerging market economies – considers what would happen if governments decided to act much more vigorously to combat environmental problems and reduce energy-security risks.

World Energy Outlook 2004 contains almost 600 pages of detailed statistics and in-depth analysis, illustrated with hundreds of colour graphics and easy-to-read tables. In recent years, the WEO has received awards from several governments and industry bodies for its high analytical quality. In closing his presentation of the book, Mr. Mandil added: "The WEO does not pretend to solve the multiple problems that disturb our energy world, but it supplies the statistical and analytical background out of which any solution will have to be crafted. It is, in fact, an indispensable document."

Reactors for the 21st Century German Young Generation Meeting in Erlangen

from **Tim Büscher** and **Cora Fischer**, German Young Generation

For fifteen years, the German Nuclear Society has been organising information meetings for its Young Generation (YG). The idea is to foster social-technical knowledge and to support the nationwide network of students and young professionals working in the nuclear field. These two-day meetings are held twice a year at alternating nuclear sites with different subjects, combined with technical visits.

In October, Framatome ANP, an AREVA and Siemens Company, hosted the conference "Reactors for the 21st Century" at its Erlangen site. One could feel the spirit of well-known and successful reactors such as the Konvoi-PWR developed here. And new ones are being developed or already under construction, e.g. the EPR. This new reactor under construction in Finland clearly was in the focus of interest of the about 100 students and young professionals in the nuclear field attending the meeting.

The Olikuoto-3 EPR project leaders presented the nuclear and turbine islands and gave latest information on this ambitious project. This reactor can be regarded as the first of a third generation of power reactors to be erected.

Dr. Ralf Güldner, CEO of Framatome ANP GmbH and chairman of the German Nuclear Society KTG, gave an overview of the different reactor types of today and of concepts for a fourth generation of reactors under development world-wide. "But it is possible that we touch the middle of this century before they become reality", he said.

"With view to reducing CO_2-emissions, nuclear energy will have its place in the world's energy market", Erich K. Steiner, the CEO of the German utility E.ON Kernkraft GmbH, continued the look-out, introducing the panel discussion on "Challenges to the Power Generation in the 21st Century". He discussed together with Dr. Stefan Feldhaus from Siemens PG, Dr. Manfred Thumann, CEO of the Swiss utility NOK and Angelika Weikert, social-democratic member of the Bavarian parliament. "Nuclear power has no future in Germany", she presented the position of the German red-green government. A lively discussion followed.

Cora Fischer, deputy of the chairmen of the German YG, gave an overview of the numerous activities of the German Young Generation. Freshly graduated students presented their research work in order to encourage other students at the beginning of their career. "It is the second time that I attend a Young Generation meeting", one student stated, "and it is quite helpful to get in contact with the industry and other students in the nuclear field." This could be continued at the second 2004 Young Generation meeting on "Energy in the Future – Possible without Nuclear Energy?" to be held in November at the Biblis NPP. Information on this meeting can be found in the YOUNG GENERATION's Corner at www.ktg.org.

Figure 1. *Demonstration of the cloud chamber during the technical visit of Framatome ANP laboratories.*

Nuclear Power Plants: 2004 – Compact Statistics

By the end of last year, 2004, nuclear power plants were available for power generation and under construction, respectively, in 31 countries worldwide. Additionally in the Islamic Republic of Iran, where no NPP is at present in operation, one plant was under construction. A total of 441 nuclear power plants were in operation in 31 countries; this is two plants more than at the end of 2003 (439 units); their aggregate gross power was approx. 386 GWe, their aggregate net power, 367 GWe. The available power of nuclear power plants worldwide increased by approx. 5 GWe.

The units Hamaoka 5 (Japan, Boiling Water Reactor, BWR, 1,380 MWe gross), Ulchin 6 (Korea, Pressurized Water Reactor, PWR, 1,000 MWe gross), Kalinin (Russia, PWR-VVER, 1,000 MWe gross), Kmelitzki 2 (Ukraine, PWR-VVER, 1,000 MWe gross), Qinshan II-2 (China, PR, PWR, 610 MWe gross), and Rovno 4 (Ukraine, PWR-VVER, 1,000 MWe gross) went critical for the first time and have been synchronized with the power grid. In addition, unit 3 of the 825 MWe Bruce nuclear power station (CANDU, Canadian Deuterium Uranium) in Canada was restarted after a seven-year outage.

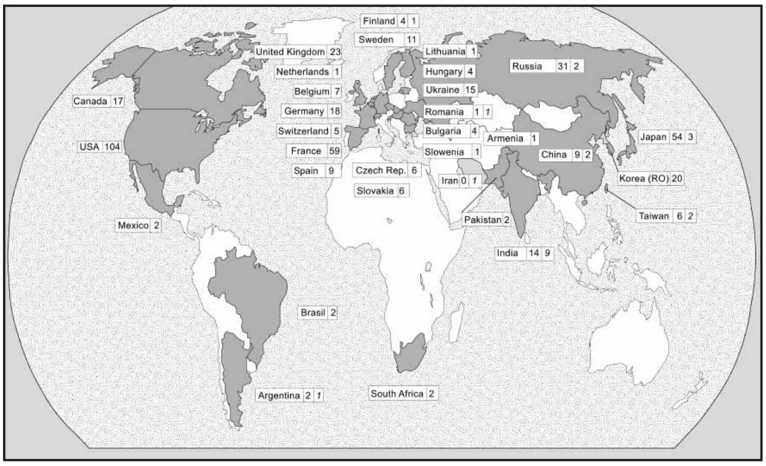
Five plants were decommissioned for good in 2004: Chapelcross 1 to 4 in the United Kingdom with 50 MWe each, and Ignalina in Lithuania with 1,300 MWe. Ignalina was closed due to an agreement between the Lithuanian government and the EU-Commission. The RBMK-reactor produced about 35 percent of the national electricity prduction.

22 nuclear generating units with an aggregate gross power of 19 GWe were under construction in nine countries in 2004. Aditionally one plant in Canada, Pickering 1, is currently returning to service. In January 2004 the operator of the Bruce units, BrucePower, launched a study into the potential restart of Bruce A Units 1 and 2. The feasibility study will involve a technical inspection of the final two laid-up Bruce A units and an assessment of how much it will cost to upgrade them to current standards.

In India, construction work was started on a new project, PFBR, Prototype Fast Breeder Reactor, with an electrical output of 500 MWe at the Indira Gandhi Centre for Atomic Research near Kalpakkam, Madras region. The Indish Prime Minister Dr. Manmohan Singh launched the construction of the PFBR on October 23, 2004.

In Finland, the Olkiluoto-3 project was heading towards an important stage: TVO was preparing to turn over the site to the consortium Framatome ANP/Siemens early in 2005. TVO expects to get the construction licence, needed in accordance with the Nuclear Energy Act, from the Council of State early in 2005.

In France the EDF decides to build a forerunner EPR nuclear reactor with about 1,600 MWe at Flamanville, Basse Normandie. The EPR project is to be carried out over a 5-year period starting in 2007



Calendar of Conferences and Events

February 2005

DAtF Winter Conference
Date: 2 -3 February 2005
Place: Berlin, Germany
Organiser: DAtF, Deutsches Atomforum, German Atomic Forum
Contact: dbcm GmbH, info@dbcm.de
More: www.kernenergie.de

Pime 2005
Date: 21 - 25 February 2005
Place: Paris, France
Organiser: European Nuclear Society (ENS)
Contact: Dionne Bosma, pime2005@euronuclear.org
More: www.euronuclear.org

International Conference on "Nuclear Power for the 21st Century"
Date: 21 – 22 March 2005
Place: Paris, France
Organiser: International Atomic Energy Agency
Contact: Ms. M. Solarik-Leahy, m.solarik-leahy@iaea.org
More: www.iaea.org

Annual Meeting on Nuclear Technology 2005
Date: 11 – 13 May 2005
Place: Nuremberg, Germany
Organiser: Germany Atomic Forum and German Nuclear Society
Contact: dbcm GmbH, info@dbcm.de
More: www.kernenergie.de

Annual Meeting 2005 - The Next 50 Years: Creating Opportunities
Date: 5 – 9 June 2005
Place: San Diego, CA, USA
Organiser: American Nuclear Society (ANS)
Contact: meetings@ans.org
More: www.ans.org

ENC 2005
Date: 11 – 14 December 2005
Place: Versailles (near Paris), France
Organiser: European Nuclear Society (ENS) and American Nuclear Society (ANS), organization by SFEN (French Nuclear Society)
Contact: enc2005@sfen.fr
More:www.sfen.fr/enc2005