November 2015

EUROSAFE TRIBUNE

Towards Convergence of Technical Nuclear Safety Practices in Europe

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Severe accident management **ETSON's safety research**

Radiological crisis management: a transboundary issue

MAKING GOOD OUT OF BAD: THE AZF CHEMICAL ACCIDENT

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Severe accident management: new directives, new questions, new research

Caring for evacuees is a major challenge for the authorities tasked with managing severe accidents. In this respect, the timeliness and accuracy of the information provided on the radioactive releases from the damaged nuclear facility play a pivotal role for taking appropriate measures.

To our readers

The nuclear safety landscape is experiencing profound changes, in particular as regards the management of severe accidents. The new EU Safety Directive – which requires NPPs to be designed in such a way that early radioactive releases, regardless of their extent, and large releases have to be practically eliminated for both current and future reactors – and the experience feedback from the Fukushima Daiichi accident has brought players in the nuclear safety arena to reconsider extreme conditions involving the loss of electrical power supply and cooling water. In the centre of these considerations is the aptitude of the defence-in-depth concept, including the level of severe accident management, to withstand extreme external hazards and to prevent core meltdown, even under such conditions, or at least to mitigate the radioactive releases in compliance with national standards and/or the EU Safety Directive.

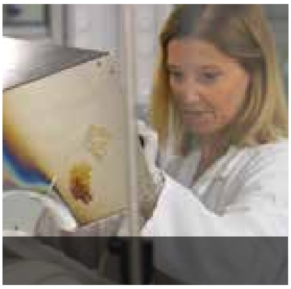
There is a variety of questions to be tackled: What about the coolability of a core degraded after a certain period of time without cooling? What is the vessel's capability to contain corium? Should the vessel fail and the corium accumulate on the basemat, how can the integrity of this barrier be maintained? How can hydrogen build-up be managed and subsequent explosive reactions prevented? In the event of radioactive releases to the environment, how can their impact on people and the environment be minimised, in close coordination with the civil protection teams?

Answering such questions is a key challenge to national R&D programmes carried out in close cooperation among nations in Europe and across the globe.

At a time when several countries contemplate building new reactors or enhancing existing ones, cooperation is more than ever a precondition to harmonising safety practices. International nuclear safety is only as good as its weakest link, discrepant technical safety practices may turn out to be a major problem. Moreover, discrepant approaches may translate into competitive gaps among competitors in the industry and into mistrust from the public. This is why TSOs must try harder to bridge knowledge gaps and foster the convergence of nuclear safety doctrines.

We wish you pleasant reading.

Frank-Peter Weiss and Jacques Repussard



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The EUROSAFE Tribune

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The EUROSAFE Tribune is a periodical from the EUROSAFE Forum
published jointly by GRS and IRSN as a contribution to the EUROSAFE approach.

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Printing
Media Cologne, Hürth
ISSN: 1634-7676
Legal deposit: November 2015

The EUROSAFE Tribune is available on the website:
www.eurosafe-forum.org

Printed on Satimat Green, FSC® certified, produced from 60% FSC® certified recycled fibre and 40% FSC® certified virgin fibre, 100% biodegradable.

Acknowledgement

Building upon our legacy

As the newly elected president of ETSON, I consider myself to be the custodian of both a valuable legacy and of a common ambition. The legacy is the work performed by fellow technical safety organisations under the pathfinding guidance and leadership of Jacques Repussard, whose resolute involvement was key in setting up the European TSO Network and opening avenues for a convergent vision of the TSO function and of the associated requirements, most notably the availability of state-of-the-art scientific and technical capability as a support for dependable nuclear safety assessment work. History was to prove him right.

Now the common ambition is to keep momentum in strengthening the scientific and technical basis of our work, thereby meeting the goals set by the 2014 European directives on nuclear safety and security and on radiation protection as well as the future IAEA safety guide on the TSO function. This involves continuing the work performed by drafting technical safety assessment guides available to anyone in charge of nuclear safety assessments, as such initiatives in themselves lead to greater convergence of technical nuclear safety practices in Europe and beyond. It also implies strengthening the link between ETSON and the IAEA TSO Forum through an ever more pivotal input to initiatives such as the International Expert Meetings, the Response and Assistance Network, and the missions conducted as part of the Integrated Regulatory Review Service. On an EU level, it means supporting the Commission in making the implementation of the aforementioned directives a success and a source of inspiration for other parts of the world.

I am fully aware of the challenges to be met to achieve our goals and of the obstacles along the way, but I am confident in our capability to overcome difficulties, as I know I can count on the support of my ETSON colleagues, just as they know that they can rely on me.

Benoît De Boeck
General Manager, Bel V
President, ETSON

Front cover: Emergency operations carried out at the Fukushima Daiichi nuclear power plant, Japan.

Kaleidoscope

LESSONS LEARNED

Guidance Document Issue T: Natural Hazards Head Document
This document, issued in April 2015, provides guidance for the WENRA Safety Reference Levels for Natural Hazards introduced as lesson learned from TEPCO Fukushima Daiichi nuclear power plant accident. Downloadable on:
www.wenra.org

MEETINGS

A selection of forthcoming meetings organised by the IAEA in Vienna, Austria is proposed below for the last quarter of 2015 and first quarter of 2016:

30 November-
04 December 2015
Technical Meeting on the Development of Nuclear Instrumentation for *In Situ* Environmental Monitoring Programmes

22-26 February 2016
International Conference on Human and Organisational Aspects of Assuring Nuclear Safety – Exploring 30 Years of Safety Culture
More on: www.iaea.org > Conferences & Meetings

ETSON NEWS

The next EUROSAFE Forum will take place on 07 and 08 November 2016 in Munich, Germany. The selected topic will be announced in a forthcoming issue of the EUROSAFE Tribune. Papers from the previous EUROSAFE Forums as well as previous issues of the EUROSAFE Tribune are downloadable on:
www.eurosafe-forum.org

On the occasion of ETSON's General Assembly held in July 2015 near Munich (Germany), the Board elected Benoît De Boeck, General Manager of Bel V, as the new President of the Network.

BOOKS

The Fukushima Daiichi Accident
The result of an extensive international collaborative effort involving about 180 experts from 42 Member States, this set of books provides a description of the accident and its causes, evolution and consequences, based on the evaluation of data and information from a large number of sources. More on: www.iaea.org > Publications > Scientific & Technical

ENSTTI COURSES

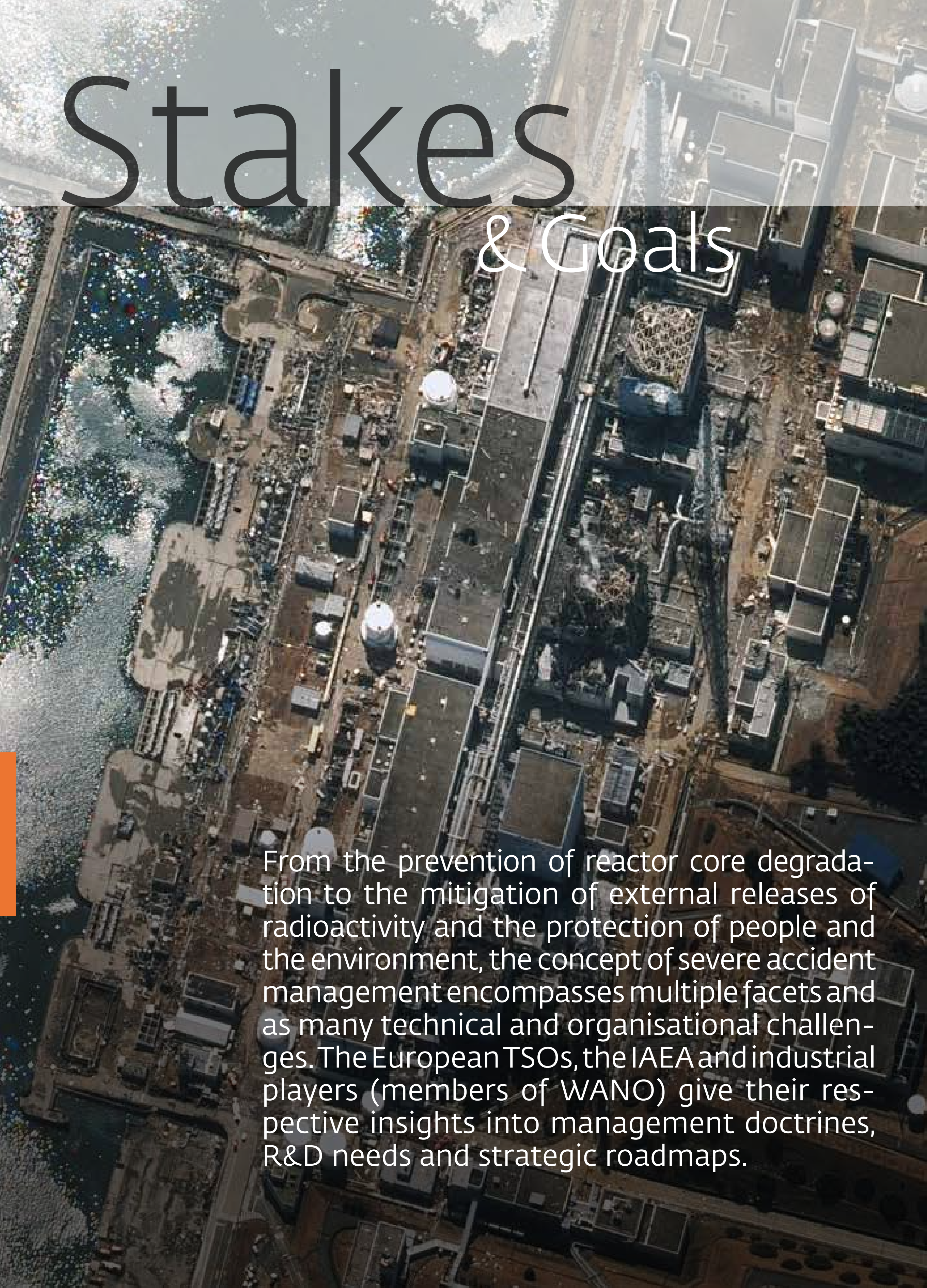
16-20 November 2015
Nuclear Reactor Safety 2015
Bologna, Italy

23-27 November 2015
Criticality Safety
Kaunas, Lithuania

24-25 November 2015
Safety aspects and regulatory requirements related to fusion reactors in France
Barcelona, Spain

30 November -
04 December 2015
Regulatory Control of Nuclear Site Evaluation and Inspection During the Siting and Construction Phase
Fontenay-aux-Roses, France
More on:
www.enstti.eu > Training

Stakes & Goals



From the prevention of reactor core degradation to the mitigation of external releases of radioactivity and the protection of people and the environment, the concept of severe accident management encompasses multiple facets and as many technical and organisational challenges. The European TSOs, the IAEA and industrial players (members of WANO) give their respective insights into management doctrines, R&D needs and strategic roadmaps.

Severe accident management improvement

Martin Sonnenkalb is Head of the Barrier Effectiveness Department, Reactor Safety Research Division of GRS and an expert in ETSON's Severe Accidents Expert Group, with 20 years of experience in research on severe accident management. He gives below an insight into the Network's doctrine and prospects in this field.

ETSON and severe accident management

One of the ways that ETSON fosters convergence of technical nuclear safety practices in the European Union is through joint nuclear safety research projects with its 13 member TSOs and cooperation in the research programmes of the OECD/NEA and EURATOM. ETSON's Safety Research Group defines open safety research issues, including severe accidents, and identifies gaps and the resources needed to fill them. To harmonise work on joint review projects, ETSON develops and publishes a series of Technical Safety Assessment Guides, including its *Deterministic Severe Accidents Analysis*, although there is no specific document on severe accident management.

Yet much has been done for severe accident management. In the 1990s, several European TSOs participated in a project called SAMIME to exchange information and compare the severe accident management actions, measures and requirements of the European countries with those in the US, Japan, and Korea. At that time, the US owner groups decided they would be better prepared for a potential severe accident by developing severe accident management guidelines (SAMG) using the existing capabilities of the plants. These guidelines have been widely adopted around the world. Still, a number of European countries believe that more could be done by upgrading the plants with specific hardware.

Examples of the different hardware measures implemented in nuclear power plants (NPPs) in Europe to prevent or mitigate severe accidents can be found in reports prepared in connection with the IAEA's Nuclear Safety Convention. A couple of these hardware measures are used worldwide today and are dedicated to leading severe accident phenomena. One is the prevention of hydrogen combustion, which would challenge containment integrity. For many BWRs, the containment atmosphere is inerted with nitrogen to prevent hydrogen combustion. For PWRs, research identified two other ways: deliberate ignition (burning the hydrogen at low concentrations to prevent build-up), and passive autocatalytic recombination (recombining hydrogen with oxygen to form steam). Another is to vent the containment to prevent over-pressure failure. Many plants have installed containment venting systems, whether filtered or unfiltered.

In parallel, different safety research activities were conducted. Most ETSON members have

also been members of the European Severe Accident Research Network of Excellence (SARNET), which has provided many new insights through experiments and analyses, and identified pre- and post-Fukushima severe accident research priorities.
In addition, ETSON published a position paper, "*Research Needs in Nuclear Safety for Gen 2 and 3 Nuclear Power Plants*" in October 2011 and contributed to the SNETP report "*Identification of Research Areas in Response to the Fukushima Accident*" in January 2013. The original input of this position paper is the encapsulation of the safety approach and culture developed by the ETSON members in the safety requirements identified for the design of new reactors.

Post-Fukushima actions

After the Fukushima accident, the European countries conducted stress tests of their NPPs both at the European level, as part of the ENSREG stress tests, and at the national level. The focus was not limited to severe accident phenomena; it included extreme natural hazards and the availability of power supply. All of the European TSOs in ETSON participated in the stress tests process. As a consequence, the countries' severe accident management concepts were significantly improved.
There were many unexpected events at Fukushima, but most of the physical phenomena – core oxidation, hydrogen generation, melt behaviour, and so on – were well-known and generally understood. The more severe the accident, the more difficult it is to simulate it. Several ETSON members are partners with the ongoing OECD/NEA Project for the Benchmark Study of the Accident at the Fukushima Daiichi Nuclear Power Plant (BSAF). The objective is to provide analytical results of the accidents with regard to core melting and fission product releases by applying well-known codes such as ASTEC, MAAP or MELCOR. The results will support Japanese organisations in their preparations for the decommissioning of the damaged plants, while the code benchmark and comparison with scarce measured plant data are used to improve the codes and identify further research needs.

Open research issues

ETSON members have already gained considerable new insight by comparing results from these and other studies and ongoing experiments. We are improving our code models and the modelling used for the calculations. Agreement on core degradation, for example, is getting better, so the picture of the accident given by the analysis is sharper than it was two years ago. We can use this knowledge for our own plants, and we can reassess previously implemented severe accident management measures. All of this leads to a significant improvement of plant safety.
The experiments done so far are not sufficient; we have not learned everything. One of the few BWR-specific phenomena that regained attention after Fukushima was pool scrubbing. Experiments done in the 1990s were used to develop models applied in commonly used codes, but the results so far show significant under-prediction of fission product retention in the big BWR suppression pools. Late core melt relocation phenomena, especially for BWRs, is another example where information is still missing. Much more information exists for PWRs. To my mind, the PHEBUS experiments conducted by IRSN in the 90s at Cadarache were the best severe accident experiments ever because they involved real materials and allowed the study of many severe accident phenomena simultaneously.
In the future, ETSON will contribute to the convergence of technical nuclear safety practices within the EU and beyond, notably by providing a forum for exchange on safety assessment and research, and initiating, implementing and conducting common nuclear safety research projects. ✖

IAEA's guidance for future research

With a view to strengthening the effectiveness of research and development in the light of the accident at the Fukushima Daiichi NPP, the IAEA set up dedicated International Experts' Meetings. IAEA experts **Abdallah Amri, Katsumi Yamada** and **Lyndon Bevington** report on the outcomes of these working sessions.

Background

The Fukushima Daiichi accident triggered a number of initiatives at the national and international level aimed at analysing the technical and human aspects and identifying the lessons learned. Most of the countries with operating nuclear power plants (NPPs) have reported on the reassessment of safety margins in the light of extreme external hazards. These countries have also reported on the safety improvements that have been implemented at their NPPs in response to these assessments. At the international level, the IAEA Action Plan on Nuclear Safety (the Action Plan) was unanimously endorsed by the Member States in September 2011 and set down 12 main actions with the aim of defining a programme of work to strengthen the global nuclear safety framework. The Action Plan addresses a number of different issues including assessing the safety vulnerabilities of NPPs, strengthening emergency preparedness and response, strengthening the effectiveness of regulatory bodies and operating organisations, improving the international legal framework, infrastructure development and capacity-building, and research and development (R&D). The Action that addresses R&D encourages all relevant stakeholders and the IAEA to effectively utilise the results of R&D and to share them, as appropriate, for the benefit of all Member States. In addition, another Action requests

Experts from IAEA Member States participate in *in-situ* safety reviews (here at Fukushima Daiichi NPP) and factor the feedback from their missions into guidelines aimed notably at enhancing the efficiency of safety policies and R&D.

the IAEA to organise International Experts' Meetings (IEMs) to analyse all relevant technical aspects and learn the lessons from the Fukushima Daiichi accident.

In response to these two actions, the IAEA, in cooperation with the OECD/NEA, organised the eighth in a series of IEMs on "*Strengthening Research and Development Effectiveness in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant*". The IEM was held in Vienna, Austria, on 16-20 February 2015 and was attended by 150 participants from 35 countries and 5 international organisations.

The IEM addressed the topics of:

- R&D strategies after the Fukushima Daiichi accident;
- measures to protect nuclear power plants against extreme external and internal events;
- technologies to prevent severe accidents and mitigate their consequences;
- severe accident analysis;
- emergency preparedness and response; and
- post-accident recovery.

The IEM provided a good opportunity to exchange information on 'who is doing what and why' in relation to R&D activities in the light of the Fukushima Daiichi accident.

Discussion and lessons learned

The IEM participants recognised that the Fukushima Daiichi accident reemphasised the importance of properly considering low probability/high consequence events beyond the design basis in the design and operation of NPPs. Although the assessments of the accident did not require completely new R&D actions, there are implications for medium and long-term R&D programmes. In particular, the accident reactivated the need for using R&D to strengthen the lessons learned and the introduction of safety improvements in existing and new NPPs.

It is important when considering necessary safety-related research that the basis for the research is clearly identified. Specifically, the proposed safety research needs to identify how the results will be of use in decision-making for the safety of both operating and future NPPs.

In particular, the IEM participants recognised that probabilistic safety assessments (PSAs) can play an important role in focusing on specific aspects, such as accident phenomena, system performance, and human reliability, that are important for the overall risk posed by a nuclear power plant and may be worthy of further research. For example, a PSA can identify what effect phenomena such as core-concrete interaction could have on the overall risk and the potential benefit that could be provided by the availability of improved knowledge.

> "The IEM confirmed that the Fukushima Daiichi accident does not require completely new and immediate R&D actions, but some challenges were highlighted that were not fully appreciated beforehand."

The IEM participants discussed whether a formal strategy for R&D at the national or international level would be required; whether R&D priorities in countries and international organisations are aligned, and whether any formal prioritisation may be possible and beneficial. Questions were raised on whether any formal guidance on R&D strategy, prioritisation and use of results could be beneficial; and whether there could be benefit from further international coordination of R&D as a number of international or regional organisations are providing similar inputs into the R&D activities. Finally, the discussions addressed how available R&D results could be widely disseminated, and what role the IAEA could play in all this process. The participants noted that national R&D strategies and priorities depend on the particular situation in the country, such as the type of reactor technologies used and the national approach to regulation. There was agreement that in some topical areas there are common interests and that state-of-the-art reports on relevant topics are very useful in preserving knowledge and in identifying gaps and hence in determining priorities for future work.

Research by regulatory bodies and/or their associated technical safety organisations (TSOs) is essential for providing a sound technical basis for regulatory decision-making. Cooperation and collaboration among regulatory bodies, TSOs, utilities and owners groups is also important for effective utilisation of resources and for maximising the results in research led by the regulatory bodies. However, it was recognised at the IEM that this cooperation should not be done at the expense of regulatory independence.

Many Member States and international organisations have R&D projects relevant to address safety issues highlighted by the Fukushima Daiichi accident which are completed, on-going or planned. These projects may be grouped according to the following general objectives, focused on improving:

- **The assessment and management of risks from extreme external hazards, and for strengthening the design basis of nuclear power plants** (e.g. improve the means of evaluating the occurrence probability of external events and accounting for uncertainties, develop a better understanding of safety issues associated with multi-unit sites);
- **The understanding and modelling of accident progression**; (e.g. further experimentation and analysis of in-vessel melt retention, and of ex-vessel corium behaviour and cooling, further development and validation of severe accident analysis codes);
- **Design features for preventing severe accidents and for mitigating the consequences of severe accidents** (e.g. ensure robust measures for reactor core cooling, depressurisation and heat removal, validate the performance of passive safety systems for core and containment heat removal);
- **Tools for determining the source term resulting from severe accidents and for establishing emergency preparedness and response** (e.g. improve computer codes for source term evaluation, improve the means of combining measured data and prognosis data to understand a radiological situation in the early phase of an emergency);
- **The understanding of issues related to post-accident recovery and developing technologies for decommissioning** (e.g. decommissioning of accident-damaged reactors and removal of spent fuel and fuel debris, consider the long-term impact of radioactive contamination in different environmental compartments such as forests and the ocean).

Conclusions and recommendations

The IEM confirmed that the Fukushima Daiichi accident does not require completely new and immediate R&D actions, but some challenges were highlighted that were not fully appreciated beforehand. These challenges may need medium- and long-term R&D or reconsideration of R&D priorities, in particular to better understand existing safety margins, to develop improved tools to assess extreme external hazards and to better understand severe accident progression for design features for preventing severe accidents and mitigating their consequences.

The meeting participants agreed that a platform is necessary for the international nuclear community to continuously exchange R&D information on the safety issues highlighted by the Fukushima Daiichi accident. This will provide opportunities to the international community to strengthen long-term research programmes and to better learn about severe accidents and related decommissioning activities.

The IAEA has a central role in facilitating the collection and dissemination of Fukushima Daiichi related R&D information to Member States. The IAEA will share the results of R&D projects with its Member States and other relevant organisations as well as provide a forum for discussions on R&D to strengthen nuclear safety.

3 questions on...

NUGENIA and severe accidents

An interview with Eija Karita Puska of NUGENIA

Eija Karita Puska, Senior Principal Scientist and Programme Manager at the VTT Technical Research Centre of Finland Ltd., is currently coordinator of the Euratom FP7 project NUGENIA-PLUS and a member of the NUGENIA Executive Committee.

What is NUGENIA's position on severe accident management?

NUGENIA's position on severe accident management in the post-Fukushima era was defined in its Roadmap published in 2013 and further refined in the massive Global Vision document collected by G. Bruna (IRSN) and published in the spring of 2015. Key elements will also be present in the SNETP deployment strategy to be published in 2015. NUGENIA's position was formulated based on active contributions from NUGENIA members in industry, TSOs, R&D organisations and academia active in the field of severe accidents – one of NUGENIA's eight technical areas, based on the SARNET network – under the leadership of JP. Van Dorsselaere of IRSN. One should of course remember the outcomes of the SNETP Task Force on Post-Fukushima R&D on severe accident management (SAM), which NUGENIA as the Gen II and III pillar of SNETP has clearly endorsed. In particular, this Task Force recommended not only to deal with understanding and modelling phenomena but also to address practical applications, especially prevention and mitigation devices that can improve safety.

What are the major objectives for severe accident management?

Six major severe accident management objectives have been identified, the first three of which are directly linked to mitigation processes. The first objective is to cool the reactor core by adding water as a means of limiting or terminating severe accident progression. Substantial knowledge exists concerning the cooling of a large, intact, rod-like geometry. The main R&D objective is to address remaining uncertainties or possibly close issues concerning the efficiency of degraded core cooling.

The second objective is to preserve containment integrity against both rapid failure (steam explosions, direct containment heating) and slower basemat melt-through and/or containment over-pressurisation. The containment is the ultimate barrier to prevent or limit the release of fission products to the environment. If combustible gases concentrate locally, gas combustion could occur, leading to a pressure increase that could eventually cause containment failure. The third objective is reduction of the source term to the environment, meaning the amount and the chemical and isotopic speciation of all radioelements that can be released. At present, increased safety requirements in both existing and new nuclear power plants aim to reduce the source term through measures to limit uncontrolled leaks from the containment and to improve the filtering efficiency of containment venting systems.

And the research priorities?

In NUGENIA's view, some predominant phenomena require a better understanding, in particular to improve Severe Accident Management Guidelines (SAMGs) and to design new prevention devices or systems to mitigate severe accident consequences, or even to terminate a severe accident. New R&D projects in the coming years should clearly focus on the efficiency of mitigation systems (such as filtering systems, venting systems or recombiners in the containment) and on engineering features in terms of improvement, optimisation and innovation. The knowledge gained and the modelling improvements will allow an optimisation of severe accident management.

Major utilities operate their own research facilities to develop and test materials as well as equipment such as this cable used in EDF's plants. (right page) WANO Chairman Jacques Regaldo addressing the floor at a conference.

David Crabtree joined WANO London in July 2013 as Programme Director for Peer Review. He spent eight years with the Institute of Nuclear Power Operators (INPO) in a variety of roles, including team leader on WANO peer review evaluations, both in the USA and internationally, and senior evaluator for equipment reliability.

Severe accident management: the industry's perspective

The World Association of Nuclear Operators (WANO) unites every company and country in the world that has an operating commercial nuclear power plant to achieve the highest possible standards of nuclear safety. This is achieved through a series of highly regarded programmes, such as peer reviews and access to technical support, professional and technical development, and a global library of operating experience.

WANO's activities in the area of severe accident management

WANO considers severe accident management (SAM) to be the management of both on-site actions and contact with off-site organisations to prevent and/or mitigate the consequences of a severe accident. It is intended to ensure that appropriate resources, facilities, equipment and documentation at the plant(s) are in place in the event of a severe accident, and to ensure activities are conducted by trained and knowledgeable personnel to manage severe accidents in an efficient and reliable manner. These activities are complementary to WANO's activities in emergency preparedness.

Following the Fukushima Daiichi accident, a project was initiated to expand the scope of WANO programmes to include SAM. The project has developed a set of draft performance objectives and criteria (PO&Cs) to help severe accident managers develop and establish high standards of performance and provide guidance for personnel responsible for executing the measures for accident management. This includes ensuring emergency facilities and equipment are upgraded according to the updated strategies and new operating experience. It must also ensure effective crisis communication plans are in place to guarantee staff are prepared to effectively communicate to external agencies, key stakeholders and the public. Currently, each Regional Centre is

500

peer reviews have been conducted by WANO since 1992 at operating nuclear power plants in 31 countries/areas. (source: www.wano.info)

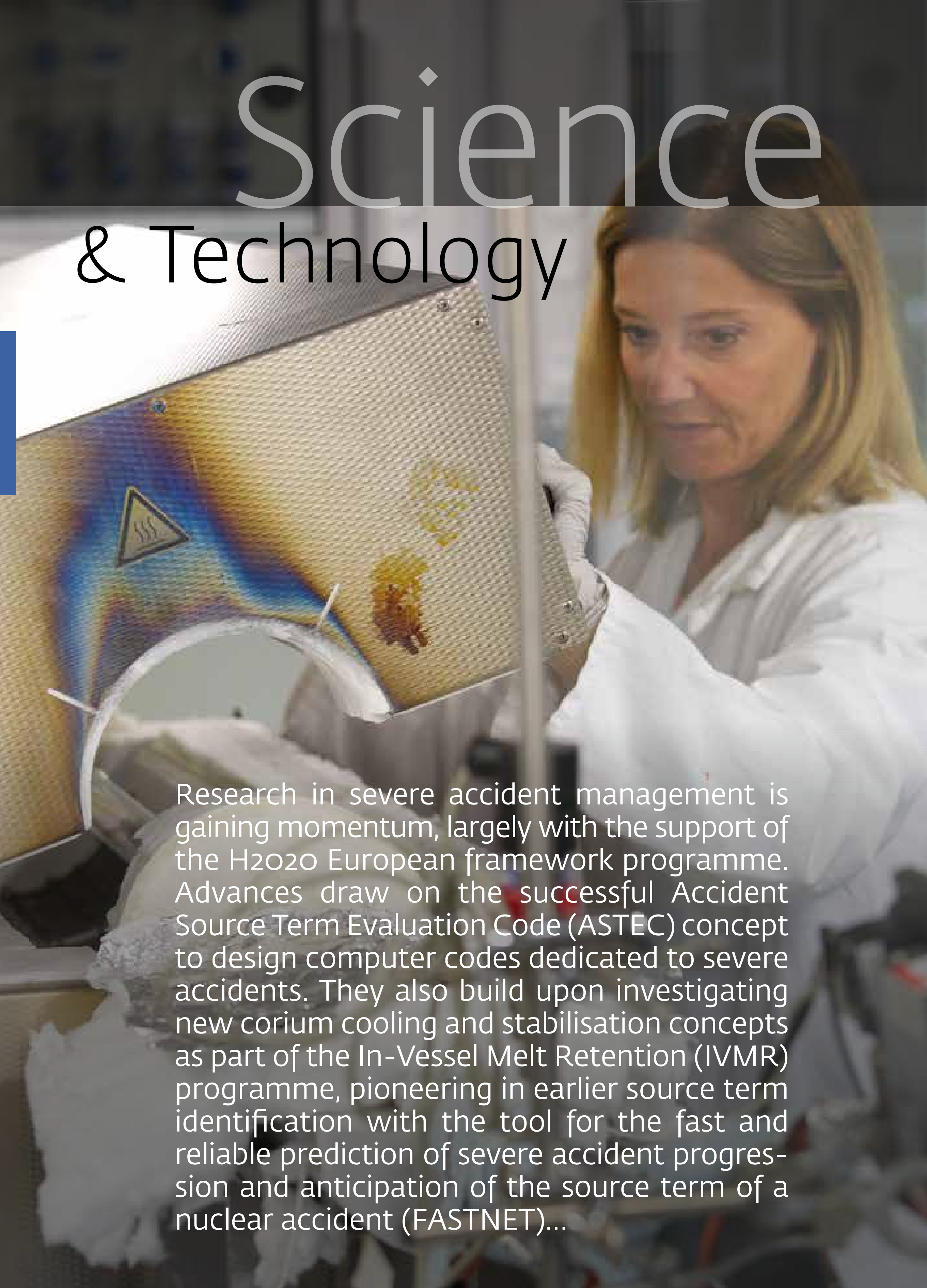
coordinating self-assessments of SAM readiness among our members.

WANO will review the completed self-assessments and draw overall conclusions regarding the industry's performance relative to the draft SAM PO&Cs, and it will develop recommendations regarding future WANO direction in this area. The results of the self-assessment analysis will be shared with members at WANO's 2015 Biennial General Meeting in Toronto and will be available on the WANO members-only website.

Balancing commercial viability with the demands of safety

It is our observation that the safest nuclear power plants are the most commercially successful ones. The station practices and behaviours that support high levels of safety are easily extended to activities that result in cost-effective operation. Examples exist of units that have entered long-term shutdown as a result of flaws in the operating organisation's safety culture. The continuous effort to improve one's safety culture does not have to compromise commercial viability.

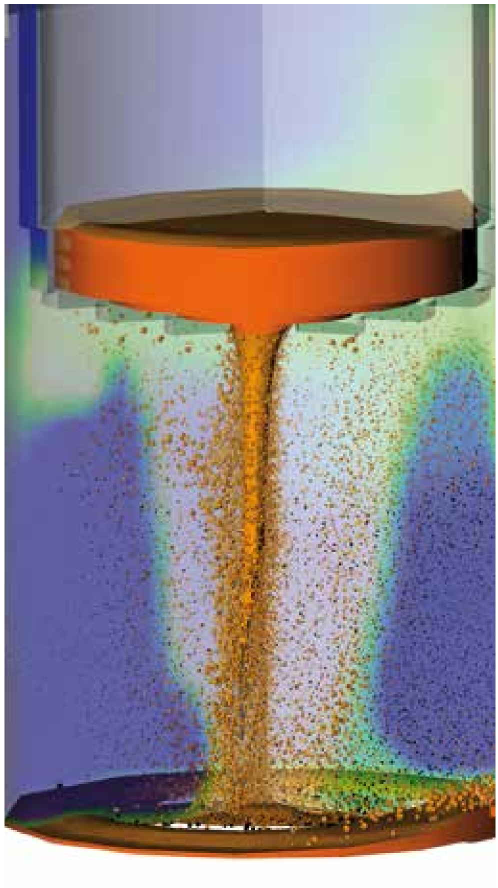
Science
& Technology



Research in severe accident management is gaining momentum, largely with the support of the H2020 European framework programme. Advances draw on the successful Accident Source Term Evaluation Code (ASTEC) concept to design computer codes dedicated to severe accidents. They also build upon investigating new corium cooling and stabilisation concepts as part of the In-Vessel Melt Retention (IVMR) programme, pioneering in earlier source term identification with the tool for the fast and reliable prediction of severe accident progression and anticipation of the source term of a nuclear accident (FASTNET)...

Cooling & stabilising corium

The Fukushima accident in Japan highlighted that both the in-depth understanding of severe accident phenomenology and the further development of severe accident management (SAM) measures are key to safety enhancements at nuclear power plants operated in Europe. **Florian Fichot**, an IRSN expert, explains how the in-vessel retention of molten corium is a major prospect for improvement in severe accident management strategies.



3D simulation of corium spreading in a reactor pit in the event of vessel failure. The results from simulations are compared to those obtained through experimental programmes carried out in research facilities such as PEARL, a facility dedicated to the phenomena associated with the coolability of debris beds formed in the reactor core during a severe accident.

One of the SAM strategies that is attracting more and more interest from the EU's main players – utilities, TSOs, NPP vendors, research institutes… – is the in-vessel melt retention (IVMR) strategy (see box page 16) for PWR, BWR and VVER-type light water reactors (LWRs). Ensuring that the **>Corium<** could stay inside the reactor pressure vessel (as was the case with the TMI-2 accident) during a severe accident would significantly reduce the loads on the last barrier (the containment) and therefore decrease the risk of fission product release to the environment for most scenarios. This type of SAM strategy has already been incorporated into the severe accident management guidelines (SAMGs) of a few small-sized light water reactors in operation in Finland, Hungary and Slovakia, and it is part of the SAMG strategies for some Generation III+ pressurised water reactors, such as the AP1000. These guidelines were drafted by each operator – i.e. FORTUM for the Loviisa NPP (Finland), Paks Utility for the Paks NPP (Hungary) and Slovenske Elektrarne for the Slovakian NPPs respectively – in collaboration with research institutions.

For the benefit of all LWRs

Florian Fichot summarises the main objective of the IVMR project, which was selected by the EC at the first Horizon 2020 call for projects: "*It is to assess whether the in-vessel melt retention strategy could be applicable to LWRs with a total power of around 1,000 MWe, knowing that this represents a significant part of the EU's reactor fleet. The IVMR project will involve 23 participants from all over Europe, under IRSN's coordination, from June 2015 to May 2019.*" The project will review the in-vessel melt retention concept in the light of recent knowledge

>Corium<
Mixture of materials (fuel, cladding and structural materials) resulting from a reactor core meltdown.

gained about corium behaviour and about new technologies or devices that could improve the efficiency of such a strategy, for instance a simultaneous in-vessel injection of water or a passive system to delay the arrival of molten corium in the lower plenum. This work should benefit different reactor types, taking advantage of the only limited differences between the designs in terms of inventory of the molten corium, shape of the vessel, presence of vessel penetrations, etc.

The need for new simulation tools

"*One of the project's aims is to improve the quality of numerical simulation tools used by participating countries to study severe accidents and to explore the capabilities of more detailed numerical approaches that could provide a better insight into the complex convection patterns of the corium,*" Florian Fichot points out. For such an SAM strategy, the safety demonstration requires very careful assessments. Hence, the numerical simulation tools used must be reliable, up-to-date and accurate, based on the most advanced modelling techniques. Those tools should also include codes to estimate the mechanical resistance of the vessel wall.

"*Among the proposed experiments, IRSN will provide new data obtained on* **>PEARL<** *through its PROGRES programme, with a view to identifying the conditions for which it is possible to stop the progression of melting within a debris bed. If not, it will help determine the transient evolutions leading to a fully molten pool,*" Florian Fichot concludes.

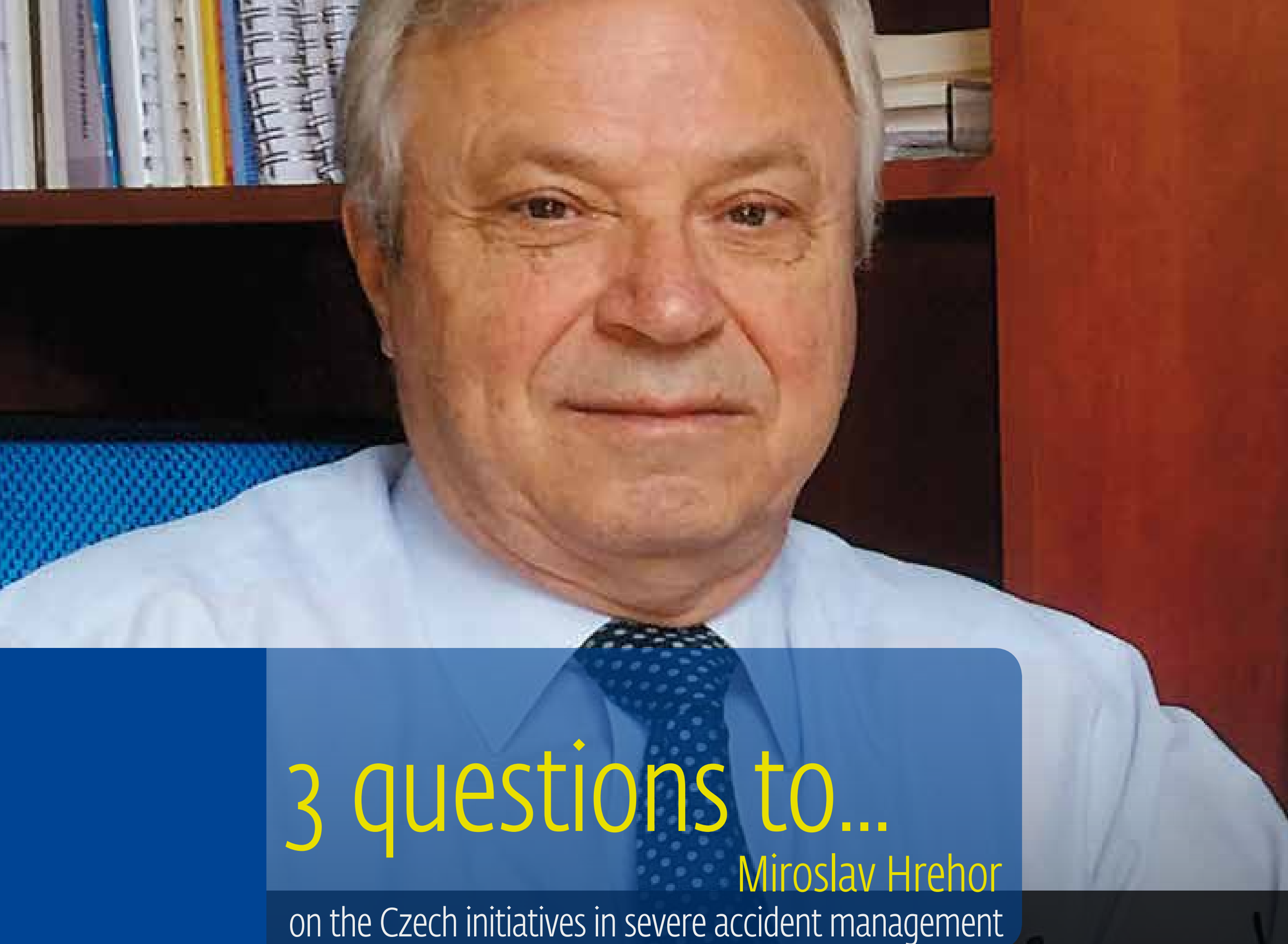
>PEARL<
Located at Cadarache in south-eastern France, the PEARL facility will be used for experiments to study, as part of IRSN's PROGRES programme, phenomena associated with the coolability of debris beds formed in the reactor core during a severe accident.

The operating experience of current reactors and technological developments is aimed to enhance the safety features of equipment such as this suction pump installed in the EPR, a Generation-III reactor design.

The approach of the IVMR programme

Maintaining and further developing the technical competence to:

- Perform a comparative assessment of the existing results, assumptions and models that are applicable to assess the safety margins for various types of existing reactors. This encompasses high-power reactors (1,000 MWe or above) for which the safety demonstration is more difficult owing to low margins. The assessment will include a review of the possibility, for several reactor designs in Europe, to retain the corium inside the vessel by means of external cooling.
- Provide new experimental results that will allow less conservative assumptions in the models used to evaluate heat transfers from the molten corium to the vessel wall. Experiments with real materials will help understand the transient evolutions of material layers in the molten pool and the effects of the presence of crusts. In addition, experiments with simulant materials (including IRSN's PEARL facility) will help understand the heat transfers associated with transient evolutions of material layers.
- Deliver new experimental results for external cooling of the vessel, including innovative technologies such as porous coating, spray cooling or optimisation of baffle shape for semi-elliptical vessels.
- Establish a new methodology drawing upon new, less conservative assumptions and new models based on the new data obtained. The methodology will consider several Generation-II and III reactor designs as well as supplementary SAM options, such as the combined in-vessel reflooding, to optimise IVMR. The assessment of uncertainty will also be included.



3 questions to...

Miroslav Hrehor

on the Czech initiatives in severe accident management

The Czech Republic currently operates a fleet of 6 units at Dukovany and Temelín plus research reactors in Řež and Prague. Miroslav Hrehor, TSO Director at ÚJV Řež, summarises the plan aimed at preventing and mitigating any severe accident in these facilities.

What lessons have been learned from stress tests on the Czech nuclear power plant fleet?

The safety of Czech NPPs is achieved by design safety and the power plant's operational culture, including qualified personnel, quality documentation, operating experience, technical control, radiation protection and fire safety. Their operation is under strong surveillance by the State Office for Nuclear Safety (SUJB). All units have a good operational record. Like other European NPPs after the Fukushima accident, the Czech NPPs underwent stress tests ordered by the EC. The evaluation of their safety margins under extreme weather conditions and with loss of off-site power, and of their ability to cope when the situation develops into a severe accident, confirmed the existence of safety margins and sufficiently robust defence-in-depth barriers. Nonetheless, the stress tests identified opportunities to further enhance safety for highly improbable beyond-design-basis events.

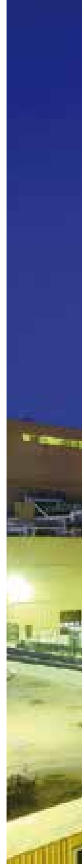
What is the Czech action plan to enhance prevention and mitigation?

The lessons learned from the stress tests were summarised in the Post-Fukushima National Action Plan (NAcP) on Strengthening the Nuclear Safety of Nuclear Facilities in the Czech Republic. The plan aims to minimise the probability of damage to nuclear fuel and barriers in extreme external conditions and to improve preparedness. In the emergency preparedness section, the NAcP includes measures for off-site exercises, enhancing radiation monitoring and communication systems, enhancing support infrastructure, and analysing the medical and human aspects of response teams.

What research is being conducted on severe accident prevention?

In parallel with the NAcP, the Řež Research Centre, as the TSO of the Czech regulatory authority SUJB, and other institutions are working on an R&D project called "Prevention, preparedness and mitigation of consequences of severe accidents at Czech NPPs in relation to lessons learned from stress tests after Fukushima" sponsored by the SUJB and the Czech Ministry of Interior. The project seeks to improve knowledge on severe accident prevention and preparedness at the state level. Specifically, it will develop analytical tools to evaluate severe accident processes and consequences and make them available to State authorities responsible for crisis management, and it will establish an independent knowledge base for assessment and decision-making on severe accident prevention and mitigation. Project activities include the selection of accident scenarios leading to beyond-design-basis accidents (BDBA) with fuel degradation in an active core; the development of models simulating BDBA with use of alternative technical means for their management and mitigation of consequences; analyses of source terms and their time development; assessment of realistic time margins to "cliff-edge effects" and use of alternative technical means to avoid them; robustness, redundancy and functioning of internal radiation monitoring systems; dose scenarios for emergency personnel and methods of dose reduction; and finally contamination scenarios of monitoring and mitigation systems.

Of course, implementation of all the lessons learned from the Fukushima accident in our country will be a long-distance run...



Pioneering CESAM

Today, the Accident Source Term Evaluation Code (ASTEC) developed jointly by GRS and IRSN stands as a reference in Europe – and increasingly in other regions – among the computer codes devoted to the simulation of accidents in water-cooled reactors. Drawing upon this success, the two TSOs decided to partner further in a project named CESAM aimed at enhancing ASTEC's modelling capabilities for the management of severe accidents. **Jean-Pierre Van Dorsselaere** (IRSN) and **Holger Nowack** (GRS) present the progress of the project.

The Code for European Severe Accident Management (CESAM) is an R&D project coordinated by GRS with strong IRSN involvement. Started in April 2013 for four years as part of the 7th EC FP, CESAM gathers 19 partners from 12 countries (see box on page 19) plus the Joint Research Centre of the EC. The project aims at enhancing and extending the ASTEC code (see Learn more opposite) for use in severe accident management (SAM) analyses of Generation II-III NPPs (including spent fuel pools) in operation or to be commissioned in the near future in Europe.

The current status

Three main types of research activities are performed as part of the project:

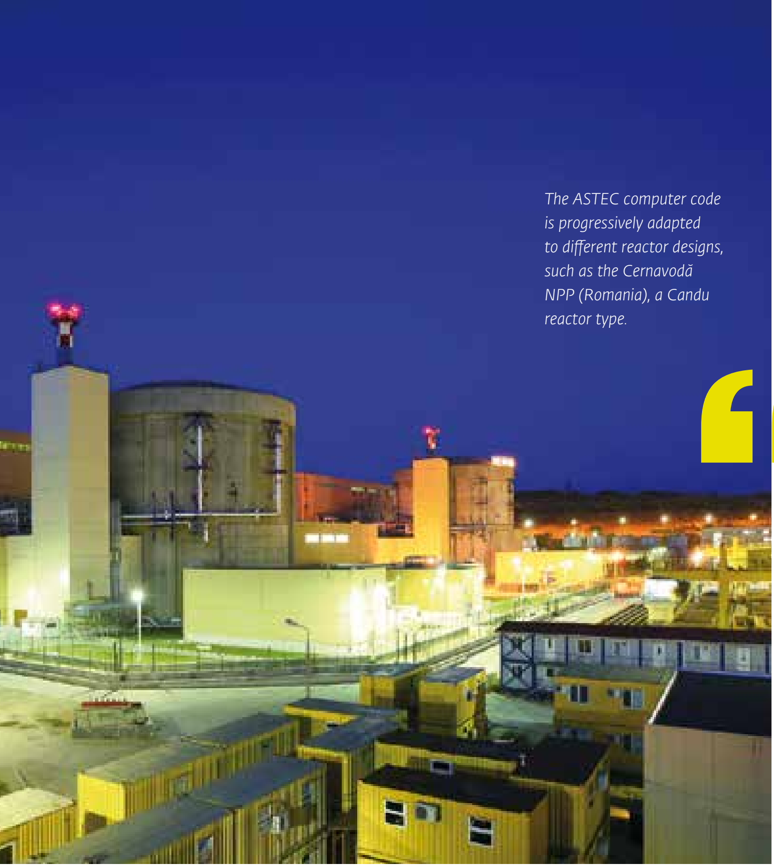
- Validation by all partners of ASTEC models important for SAM, in particular for the phenomena relevant to the Fukushima Daiichi accidents (e.g. re-flooding of degraded cores, pool scrubbing, hydrogen combustion, spent-fuel pool behaviour...);
- Modelling improvements by IRSN and GRS, especially for BWRs. The code is also being extended to cover the support to diagnosis capabilities in emergency centres;
- ASTEC applications to severe accident scenarios in European NPPs (PWR, BWR, VVER and CANDU or PHWR), with a view to assessing prevention and mitigation measures, and benchmarks with other integral codes such as MELCOR or MAAP.

Adapting to all reactor types

The release in 2015 of ASTEC's new major version V2.1 is an important milestone, as it includes new models for re-flooding of degraded cores and for core degradation in BWRs and pressurised heavy-water reactors (PHWRs) as well as improvements of models pertaining to fission product gas chemistry kinetics and corium coolability during molten-core/concrete interactions. The partners are currently switching to this new version by starting validation tasks and adapting the available NPP input decks (such as the French 900 MWe PWR, the Konvoi 1300 PWR, the VVER-1000, and the VVER-440).

Different types of scenarios will be analysed in the second half of the project, including SAM actions such as reactor cooling depressurisation, core re-flooding, containment spray activation, etc. Combining the best

> **Learn more:**
>
> *The purpose of the ASTEC integral code is to simulate the sequence ranging from the initiating event up to the possible release of radioactive products (the "source term") outside the containment of water-cooled reactors. It is considered as the European reference, as it capitalises most of the knowledge acquired through co-funded past and current EC projects such as Phébus-FP or the International Source-Term Programme. About 40 organisations (inside and outside Europe) are using the code, including many TSOs (in particular a large majority of the ETSON members). Today, most ASTEC models are close to the state of the art, in particular those pertaining to core degradation and the behaviour of fission products.*



The ASTEC computer code is progressively adapted to different reactor designs, such as the Cernavodă NPP (Romania), a Candu reactor type.

knowledge of the different teams using ASTEC in Europe and India with the advice of the ASTEC code developers will provide a valuable basis on which users might develop specific plant models.

Dissemination of knowledge includes annual technical workshops open to all ASTEC partners, beyond those in CESAM, the mobility of young researchers between partners as well as papers in journals and conferences.

CESAM partners

INRNE (Bulgaria), JRC IET (EC), VTT (Finland), AREVA NP SAS, EDF and IRSN (France), GRS, KIT, RUB and USTUTT (Germany), NUBIKI (Hungary), BARC (India), ENEA (Italy), LEI (Lithuania), IVS and VUJE (Slovakia), JSI (Slovenia), CIEMAT (Spain), PSI (Switzerland).

FAST Nuclear Emergency Tools (FASTNET)

When dealing with the matter of emergency, two issues with completely different time requirements and operational objectives – and thus different methods and tools – have to be considered: preparedness and response. Both issues need to be addressed by combining the efforts of organisations active in these two areas so that already identified deterministic reference tools and methods can take a decisive step forward. In particular, their capabilities need to be extended to tackle the main categories of accident scenarios in major types of operating or planned water-cooled NPPs in Europe, including spent fuel pools.

On 1st September 2015, a new H2020 EURATOM project starts: FASTNET. Bringing together 22 organisations under IRSN's coordination, it aims to develop rapid source-term assessment tools to support decision-making and implementation of appropriate measures to protect the population in the event that radioactive products should be released into the environment during an accident.

The involvement of leading organisations (*) shows the extent of a project that is likely to impact the way radioactive releases from NPPs during a severe accident are assessed and dealt with in the respective national emergency plans.

(*) CNSC (Canada), the IAEA, SEC NRS (Russian Federation), the US NRC (USA).

Egidijus Urbonavičius
Senior researcher
Lithuanian Energy Institute

Learn more:

Information on CESAM is downloadable at: www.cesam-fp7.eu/

The latest from SARNET

The success story goes on: **Jean-Pierre Van Dorsselaere** (IRSN) explains how, after its valuable achievements as a EC-funded body, the Severe Accident NETwork of excellence (SARNET) continues pointing the way, under IRSN's coordination, within the scope of the Nuclear Generation II & III Association (NUGENIA).

A second life within NUGENIA

Launched in 2004 as part of the 6th and 7th FPs to better coordinate at the EU level national efforts in the severe accident area, SARNET has proved a success within 8 years, both on gaining knowledge and on "networking" with partners (see box) through sharing of information, seminars, ERMSAR conferences, learning to work together, etc.

Along with the progress of knowledge, the focus was placed increasingly on severe accident management (SAM) aspects, including safety systems and procedures. The 2011 Fukushima Daiichi accident shed a crude light on the pivotal role of SAM, particularly as regards the corium behaviour and water injection strategies to cool the corium.

The self-sustainability of the network was achieved through its integration mid-2013 in NUGENIA (see interview with Eija-Karita Puska p. 11) with the strong involvement of the TSOs. SARNET thus has become a "brand" that attracts in particular new non-European partners and newcomers in nuclear power programmes. The American Electric Power Research Institute (EPRI) has called SARNET in to review their report on a preliminary Fukushima interpretation in 2011 just after the accident, and in September 2015 a seminar was held to discuss possible NUGENIA/SARNET-EPRI collaboration, mainly on SAM-related aspects. On their side, the US NRC on the one hand and Asian (Japanese, Chinese...) organisations on the other hand plan to initiate similar networking activities.

● An attractive programme ●

As part of FP7, more than 40 organisations of different kinds (research organisations, universities, industrial companies, energy utilities, safety authorities and technical safety organisations) from 22 countries participated in the SARNET projects, including most key European R&D players and a few important non-European organisations, i.e. AECL (Canada), BARC (India), KAERI and KINS (Korea) as well as the US NRC (USA). Most of them are continuing work now in the NUGENIA frame. It is important to note that almost all ETSON members have participated in the network, contributing in particular to important tasks such as the network coordination (by IRSN), the ASTEC code improvement (by IRSN and GRS) and the ranking of R&D priorities (expert group led by GRS).

Focusing on mitigation

Paving the way for the severe accident part of NUGENIA's R&D roadmap, the research priority update by SARNET in 2013 clearly emphasised the necessary improvements in the prevention of severe accidents and the mitigation of their consequences for current or future R&D projects.

SAM guides for Ignalina: concrete benefits derived from SARNET

"Through its participation in SARNET since 2004, LEI (the Lithuanian TSO) developed specific ASTEC models for the analysis of severe accidents in RBMK reactors and spent fuel pools; it also gained valuable knowledge in containment issues, including notably the behaviour of hydrogen. The experience gained benefitted the preparation of Severe Accident Management Guidelines (SAMGs) for the Ignalina NPP, which was the pilot project for the RBMK-type reactors.

After the two units at Ignalina were shut down in 2004 and 2009 respectively, Lithuanian specialists took further advantage of SARNET to deepen their knowledge of severe accident simulation regarding spent fuel pools, as well as the mixing processes of hydrogen, air, water vapour and other gases inside the containment buildings.

With numerous 'Spreading of Excellence' activities, including training courses and internships for young experts such as PhD students, publications and international conferences, I think LEI's participation in SARNET was most productive, compared with all other international projects."

Eugenijus Ušpuras,
Chairman of the Scientific Council and Head of the Laboratory of the Nuclear Installation Safety, Lithuanian Energy Institute

This concerns in particular the mitigation of:

- **In-vessel accident progression:** corium configurations in the lower vessel head (in particular the impact of a metallic layer on lower head integrity), and cooling of corium and debris in the lower head by water injection in the vessel and flooding of the cavity;
- **Early containment failure risks:** premixing phase of steam explosion to provide reliable initial conditions for the steam explosion phase and gas combustion in the containment (deflagration/detonation, efficiency of countermeasures such as recombiners…);
- **Ex-vessel phenomena that could lead to delayed containment failure:** MCCI (for instance the impact of metal from corium and/or basemat) and cooling of corium in the cavity by water injection;
- **Source term:** decrease of iodine and ruthenium release into the environment by trapping or filtration (filtered containment venting systems, pool scrubbing), including long-term accident situations.

Results from research conducted in experimental facilities such as PEARL are used to enhance the capability of simulation codes to model phenomena in a realistic manner.

Some new projects already address these issues:

- **Ongoing ones as part of *FP7* or *H2020*:** PASSAM (led by IRSN) on source term mitigation, CESAM (led by GRS) on ASTEC improvements towards a better simulation of SAM in all main types of European NPPs, and IVMR (led by IRSN) on in-vessel melt retention,
- **Planned ones in OECD/CSNI** on source term such as STEM2 and BIP3.

Prospects exist in the SARNET community to forge closer links with the SAM community, notably for drafting concrete and implementable documents on knowledge to support SAM improvements.

Learn more:

- *www.nugenia.org*
- *www.sar-net.eu*
- *www.cesam-fp7.eu*
- *https://gforge.irsn.fr/gf/project/passam*
- *www.irsn.fr/en > Newsroom > News and press releases*

Methods
& Organisation

A transboundary issue by essence, severe nuclear accidents trigger increasing international cooperation, notably with a view to field-proving the efficiency of emergency preparedness and coordination plans through drills. Some lessons learned are presented on the next pages.

Radiological crisis management: a transboundary issue

HERCA, the association of the Heads of European Radiological Protection Competent Authorities, was created in 2007. Its goal is to contribute to a high level of radiological protection throughout Europe. Its Working Group on Emergencies focuses on the harmonisation of radiological emergency management, as explains **Georges Piller**, Director of Radiation Protection at the Swiss Federal Nuclear Safety Inspectorate (ENSI) and Chairman of this Working Group.

The role of HERCA and its Working Group on Emergencies

HERCA is a voluntary association with the aim of identifying common issues and proposing practical solutions for them. Between two annual meetings, solutions are worked out in Working Groups, Task Forces, Networks and Workshops.

Since its creation, HERCA has identified the need for a harmonised approach to Emergency Preparedness and Response (EP&R) in Europe as a top priority. In 2011, HERCA set up the Working Group on Emergencies (WGE) with the mandate to come up with practical and operational solutions leading to a uniform way of dealing with any serious radiological emergency situation, regardless of national borders. Its aim is to develop a comprehensive approach to harmonisation and to obtain a uniform cross-border application of countermeasures. This should enhance public credibility and acceptance of recommendations issued by the authorities.

Even with the important actions undertaken by the EC, IAEA, NEA and WHO, further harmonisation efforts are needed with regard to recommendations to citizens, evaluation of the radiological impact, sharing of information and, last but not least, streamlining of the communication efforts.

Currently, almost 50 senior experts in nuclear safety, emergency preparedness and radiological protection from 24 European countries participate in the activities of the WGE. Furthermore, observers from the EC, IAEA and WHO contribute to the efforts of the WGE.

Major Achievements

In 2011, HERCA produced practical guidance (see Learn more/Reference 1) that covers the definition, purpose and rationale of three of the most important early countermeasures, namely sheltering, evacuation and thyroid blockade.

The guidance covers the planning phase, the intervention and the lifting of protective actions. The limitation and possible complication of the actions are addressed, together with risk and benefit consideration. In addition, the tasks of the authorities are clearly indicated.

The HERCA-WENRA approach has the potential to improve the coherence of the response in case of a nuclear accident with an impact on the territories of other countries.

After the Fukushima accident, HERCA first analysed the actions taken by European countries and published its findings in June 2013 (see Learn more/Reference 2). The report provides an overview of the important radiological issues that competent authorities have to consider in the event of a nuclear or radiological emergency in a distant country. The aim is to improve preparedness in some areas.

In 2014, HERCA and WENRA (Western European Nuclear Regulators Association) agreed on a Common Integrated Approach for better cross-border coordination of protective actions during the early phase of a nuclear accident (see Learn more/Reference 3). The document presents the general mechanism for a common European EP&R approach, independent of the type of accident. It also includes a simplified scheme for coordination in the highly unlikely event of a severe accident in one or more nuclear power plants, requiring rapid decisions for protective actions while little or no confirmed information is available.

The HERCA-WENRA approach has the potential to improve the coherence of the response in case of a nuclear accident with an impact on the territories of other countries. National EP&R arrangements are respected and taken into account. The approach can be used as guidance to implement Article 99 of the 2013/59/Euratom Directive (Euratom-BSS) on international cooperation. Besides WENRA, HERCA also collaborates with government administrations and national safety authorities.

Current Activities

The HERCA Board approved a new mandate for the WGE that addresses issues with importance for a cross-border and trustful EP&R. Current activities undertaken by the WGE refer to the development of tools for successful implementation of the common HERCA-WENRA approach and the transposition and implementation of the Euratom BSS. The WGE currently treats the following Work Packages:

- elaboration of a guidance document for bilateral agreements as well as elaboration of 'Country fact-sheets' on national EP&R;
- assessment and prognosis in response to an emergency at a nuclear power plant;
- development of a common understanding of the provisions related to emergency workers as well as of the concept of reference levels concerning EP&R ;
- contamination of non-food products;
- follow-up of the implementation by HERCA countries of the measures for distant accidents (see Learn more/Reference 2) and for better cross-border coordination (see Learn more/Reference 3).

Learn more:

References
[1] Practical Guidance – Practicability of Early Protective Actions.
[2] Practical proposals for further harmonisation of the reactions in European countries to any distant nuclear or radiological emergency.
[3] HERCA-WENRA Approach for better cross-border coordination of protective actions during the early phase of a nuclear accident.

Documents downloadable at: www.herca.org > Documents and statements

Transboundary exercises aim at field-proving the capability of emergency teams from involved countries to coordinate their human and material resources under harsh constraints.

Transboundary cooperation is not an option, it is a prerequisite

"Because of the location of the Chooz NPP – a French enclave on Belgian territory – France and Belgium have a long tradition of cooperation between safety authorities and TSOs. For more than 20 years, a dedicated Franco-Belgian working group has met twice a year, and emergency preparedness and response are systematically discussed. We also participate in exercises for the Chooz NPP, although in the first stage these are 'Franco-French' exercises for which the scope and objectives are defined by France. The ultimate goal would be to develop a common emergency response plan for a site like Chooz. But sovereignty is a major issue. That same issue applies to the organisation of a full bilateral exercise: Who will define the scope and objectives? Who will be the leader? Transboundary cooperation is necessary to avoid unilateral, uncoordinated decisions on protective actions. To achieve this goal, bilateral or multilateral cooperation must rely on a clear and accepted allocation of responsibilities and on sufficient commitment by all parties to align protective actions along borders. That leads to common understanding and mutual trust, which are success factors for an efficient response."

Didier Degueldre
Area Manager, Inspections of Nuclear Installations, Bel V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SCENARISTE

Emergency preparedness in France

In a country such as France, where a fleet of nearly 60 reactors is in operation on 19 sites throughout the territory, getting prepared to emergency situations requires the coordination of important means from local to governmental levels, as explains **Sylvie Supervil**, Head of the division dedicated to nuclear and radiological crisis and emergency at IRSN.

Which are the major issues linked to emergency preparedness in France?

For many years now, the French public authorities have anticipated the possibility of a severe accident occurring in one of the country's nuclear reactors. They approve On-Site Emergency Plans to be implemented by nuclear facility operators as well as Off-Site Response Plans coordinated by the competent authorities at the prefecture level. These plans are supervised at the government level by the Ministry of Interior, supported by the civil or defence authorities as well as by IRSN in its capacity of national public expert in nuclear and radiological risk. The Chernobyl and, more recently, the Fukushima accidents made clear that nuclear crises reach far beyond local borders, pushing public authorities, in a January 2012 bulletin on the organisation of the Inter-ministerial Commission for Crisis, to tighten the link between the local and governmental levels with a view to identifying the specific features of a nuclear and radiological event in the management of a severe crisis with nationwide and even transboundary impacts. As regards more specifically emergency preparedness, the government's plan is outlined locally with a focus on the specific context of each region. It encompasses land and sea transport of nuclear materials as well as situations such as the impact on the French territory of a nuclear accident occurring in a neighbouring country, or the care for French nationals impacted by a nuclear accident occurring in a distant country. Ten to fifteen national exercises are carried out annually under the supervision of the French Minister of Interior, fostering dialogue between experts, operators and public authorities, starting with the regulatory bodies in charge of safety (ASN) and security (DSND) respectively. Such exercises are a cornerstone of the preparedness approach developed in France. Moreover, some 2,000 training hours per year dedicated to preparedness are dispensed by IRSN to its own crisis experts.

How does the feedback from past exercises impact IRSN's priorities?

IRSN participates in many types of exercises: local ones involving only the operator and the IRSN technical emergency centre to deeply test expertise methodologies and tools; national ones in order to test mainly communication and to understand developing situations between all stakeholders; international ones through the OECD NEA INEX framework or the IAEA CONVEX framework. But other transboundary drills such as the exercise carried out at Cattenom NPP near the border to Luxemburg in 2013 allowed the interfaces between several countries as regards the radiological care of populations and the initial steps of post-accident phase management to be proven in the field. Such drills are invaluable to the assessment of the robustness of the public safety and emergency preparedness provisions at the local, central and international levels. Generally speaking, national exercises are a way for IRSN to test its expertise methodologies and the response tools developed, which also allows the improvement of its internal organisation. International exercises are generally designed to share best practices and to develop an awareness of different approaches. These exercises allow IRSN enhance its global capability and compatibility with others.

What are the main challenges in interfacing with other EU Member States?

The French emergency system encompasses all aspects relating to safety, security and the protection of the environment as well as the health of the impacted population, which is not the case for all countries. Hence, challenges arise in the identification of counterparts in countries with totally different organisational patterns and with other expertise methodologies. This is an important consideration in multi-partner projects such as FASTNET (see article page 19), where two assessment methods will be enhanced and applied to all European reactors in order to give to the European framework of expertise a common ground to build the next generation of expert emergency responders. In this respect, the IAEA, with its new role in emergency response, or associations such as HERCA, with its new coordination scheme between European countries during an accident, are irreplaceable bodies for disseminating best practices and exchanging working methods.

Prepared to Respond

IAEA's Incident and Emergency Centre (IEC)

What do you imagine when you hear of the IAEA's Incident and Emergency Centre?" asks *Elena Buglova*, Head of the Centre, *"A big room, many computers and telephones, large screens showing CNN Breaking News? Well that's mostly right. But the IEC is more than a well-equipped facility, more than a centre that operates in an emergency…"*

"… Its staff, for instance, train more than 1200 professionals worldwide – every single year –, develops safety standards in emergency preparedness and response (EP&R), assists countries in enhancing their EP&R arrangements. The IEC is the focal point for preparedness and response for nuclear or radiological emergencies, regardless of whether they arise from an accident, natural disaster, negligence, nuclear security event or any other cause," Mrs. Buglova goes on.

A (nearly) thirty-year-long history

The roots of the IEC go back to 1987 when the Emergency Response Unit was created. Along the years, the unit grew and in 2000 the Emergency Response Centre was established as the IAEA's 24-hour warning and operational focal point. To stress the fact that the IEC also responds to emergencies triggered by nuclear security events, the IAEA established the Incident and Emergency Centre (IEC) in 2005. Since its creation, the IEC has been operating on a vision: that all States and relevant international organisations should be prepared to respond in an efficient and timely manner to any nuclear or radiological emergency.

Enhancing Member States' emergency preparedness and response

The IEC assists IAEA Member States to enhance their own preparedness for response. It also develops EP&R-related safety standards, guidelines and tools. *"This year, the IAEA established the Emergency Preparedness and Response Standards Committee with the aim to further strengthen national and international* EP&R *through continuous improvement of the IAEA Safety Standards and a stronger engagement of national* EP&R *experts,"* Elena Buglova stresses.

Available upon request, the IEC provides appraisal services to assist Member States in strengthening their EP&R arrangements. By developing, implementing and sustaining a comprehensive EP&R-capacity-building programme, the IEC assists Member States in their capacity-building efforts and ensures that the IAEA's staff members are capable of responding effectively when called to the IEC.

● Close-up on… RANET ●

As part of the IAEA's strategy for supporting the practical implementation of the Assistance Convention, the IEC manages the IAEA Response and Assistance Network (RANET), a network tasked with providing international assistance, upon request from a State, following a nuclear or radiological incident or emergency. Its aim is to make available qualified experts, equipment and materials provided by State Parties to the Assistance Convention in areas such as nuclear installation assessment, decontamination, dose assessment, medical support, etc.

Lessons learned from CURIEX-2013

"CURIEX-2013, which is the acronym for Cáceres Urgent Response International Exercise, was a three-day general drill performed in November 2013 as part of the off-site emergency plan of the Almaraz I and II NPP in Spain. The drill brought to light the need for updates and improvements of some aspects of the plan. Among them are the updating of the Nuclear Emergency Plan, the refurbishment and enlargement of the Emergency Management Centre at Cáceres from which the drill was steered, and bespoke training for the emergency staff called on to take over operations at the power plant. Moreover, personal radiological data transmission systems have been completely updated and field-proven during exercises carried out in the wake of CURIEX. Last but not least, the need for better coordination between participants in exercises involving foreigners was a major lesson learned from this drill."

José Manuel Martín Calvarro
Head of Emergency Planning Section
Subdivision of Emergency and Physical Protection
Consejo de Seguridad Nuclear

Prepared to respond

The IAEA's operational role includes prompt notification of the emergency to Member States and relevant international organisations; exchange and/or provision of official information; assessment of potential consequences and prognosis of possible emergency progression; coordination of international assistance upon request of the Member State concerned; provision and/or coordination of timely, accurate and appropriate public information and coordination of the inter-agency response. The IAEA discharges its role through its Incident and Emergency System, consisting of a warning point (24-hour contact point) and the IEC as the operational focal point.

> "It is of the utmost importance that international organisations speak with 'one voice' in an emergency."

Elena Buglova
Head, Incident and Emergency Centre
Department of Nuclear Safety and Security, IAEA

Inter-agency cooperation in EP&R

Mrs. Buglova recalls that *"it is of the utmost importance that international organisations speak with 'one voice' in an emergency."* In this respect, the prime inter-agency coordination mechanism is the Inter-Agency Committee on Radiological and Nuclear Emergencies (IACRNE), for which the IEC provides the secretariat and takes care of the Joint Radiation Emergency Management Plan of the international organisations, which provides a practical mechanism for coordination and clarifies the response roles of the participating organisations. The IACRNE includes 18 international organisations (*).

(*) List of the 18 participating organisations available at: www-ns.iaea.org > Technical Areas > Emergency Preparedness & Response > International Framework > International Organizations (see box entitled "Resources" on the right)

MAKING GOOD OUT OF BAD

Special Focus

Lessons from hard times

How do severe accidents at industrial facilities contribute to changes in the laws and regulations that govern, on a daily basis, industrial operations on the one hand and urban planning on the other hand? **Jérôme Goellner,** Head of the Technological Risks Division of the General Directorate for Risk Prevention (DGPR) at the French Ministry of Ecology, Sustainable Development and Energy, provides a number of keys to understanding the approach developed in France to prevent industrial accidents and mitigate their consequences for the public.

What are the basic principles of the incident and accident control system implemented in France?

Jérôme Goellner. Today, the experience feedback from industrial incidents and accidents is organised at different levels.

The first loop is at industry level where each operator is required by law to set up and implement experience feedback procedures with a view to anticipating the repeated occurrence of drifts and malfunctions. This starts with the requirement for companies to demonstrate the compliance of their safety and security system with legal and regulatory constraints, and it includes of course the necessity to document and record non-compliance situations as well as the corrective actions taken to prevent such situations from happening again. For instance, if a sensor is out of order, the operator is required, beyond replacing the defective equipment, to investigate the root cause of its malfunction and to implement corrective actions.

Such experience feedback procedures are deeply rooted in the safety culture of nuclear operators in particular, and also increasingly in the culture of other industrial sectors. The principle is that this process is supposed to work in a self-reliant manner, independently of the public administration's monitoring and control, with a view towards ensuring the on-going improvement of operating and safety procedures.

A second loop is at the local public authorities' level, with technical and regulatory staff regularly checking the compliance of the operations carried out by industrial companies with the current regulatory requirements. At this level, the analysis of safety and security events declared by the operators can be conducive to updates in the applicable regulation to enhance requirements in areas where it was deemed insufficiently effective. Within the General Directorate for Risk Prevention (DGPR) of the

Reconsider not only industrial operations, but also the relationship with the neighbourhood.

Ministry of Ecology, Sustainable Development and Energy, a dedicated structure called Bureau for Analysis of Industrial Risks and Pollutions (BARPI), headquartered in Lyon, is tasked with managing this second loop of experience feedback from incidents and accidents, notably by comparing the situations between different operators. France, for instance, periodically experiences heat waves accompanied by dry weather. In this context, BARPI investigated the incidents declared during the successive heat waves, questioning the possible causal linkages between these events and the exceptional climate conditions. The resulting documents, made available online, provide public authorities with precious guidance to face such situations.

A third, even wider loop is triggered at the governmental and parliamentary levels by major accidents such as the AZF (*) disaster. The stakes here are to reconsider the laws that govern not only industrial operations as such, but also the relationship between industrial facilities (e.g. production plants, storage tanks, etc.) and their neighbourhood, notably in terms of housing protection, siting, etc.

(*) AZF is the French initialism for AZote Fertilisant, i.e. nitrogen fertiliser.

Would you briefly summarize the key facts about this catastrophe?

J.G. The accident at the AZF plant occurred on 21 September 2001 near Toulouse, a city with an urban area of nearly 1.3 million inhabitants located in south-western France.

At the time of the catastrophe, 300 tonnes of ammonium nitrate were stored in one of the plant's warehouses, pending use as an ingredient of fertilisers. The extent of the accident – the blast dug a 5-to-6 m deep crater with a diameter exceeding 40 m, destroying the entire factory – made it extremely difficult for investigators to identify with certainty the root causes of the disaster. However, the origin of the blast is believed to be the storage in the ammonium nitrate warehouse of a mislabelled 500-kg bin of sodium dichloroisocyanurate, mistakenly thought to be ammonium nitrate. The ambient heat and humidity may have triggered chemical reactions building up nitrogen trichloride, a particularly unstable compound and, ultimately, detonating the ammonium nitrate. The accident killed 31, injured 2,500 and caused heavy material damage to buildings and infra-

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Steel girders from the plant were found 3 km away from the explosion, heard in an 80-km radius. 2/3 of the city's windows were shattered, causing several thousand wounds.

Some densely populated suburban areas south from Toulouse suffered extensive damage. This was particularly the case of Le Mirail, located just one kilometre away from the plant.

structures in a radius of several kilometres. The total damages paid by insurance groups exceed 1.5 billion euros.

What kind of developments did the AZF accident trigger in the incident and accident control system in France?

J.G. As said earlier, drawing all the lessons from such an accident takes years, but the protection of people and their environment cannot wait.
A parliamentary committee of inquiry was set up in the wake of the accident with a view to reconsidering the prevention and control system in the domain of major accidents. Based on its findings in February 2002, a new bill was passed in July 2003 to enhance the prevention of technological and natural risks as well as the repair of damage. Its provisions greatly enhanced the previous law, notably the 1996 European Directive on the control of major-accident hazards involving dangerous substances. The most significant updates relate to two principal areas, the first one being the reduction of risks at the source, which triggered a wide-ranging enhancement of hazard studies, notably with the introduction of probabilistic assessment methods to supplement deterministic approaches. These new studies and the subsequent investments in safety and security enhancement were estimated at costing the French industry around one billion euros a year over several years.

Drawing the lessons from such an accident takes years, but the protection of people cannot wait.

The second area pertains to the vulnerability of the neighbourhood of industrial plants, where assessment studies were launched on a wide scale in the form of so-called Technological Risk Prevention Plans. The provisions of these plans largely exceed the previous texts – in particular article R111-2 of the town plan-

In Le Mirail, several schools, one university campus, hospitals and residential areas had to be evacuated, leaving thousands shocked, dazed and rudderless.

ning code – in terms of management and control of urban development around industrial facilities with a potential risk, providing the Prefect of each French department as well as local authorities with robust, consistent guidance for the limitation of urban development and control of housing in the vicinity of industrial facilities.

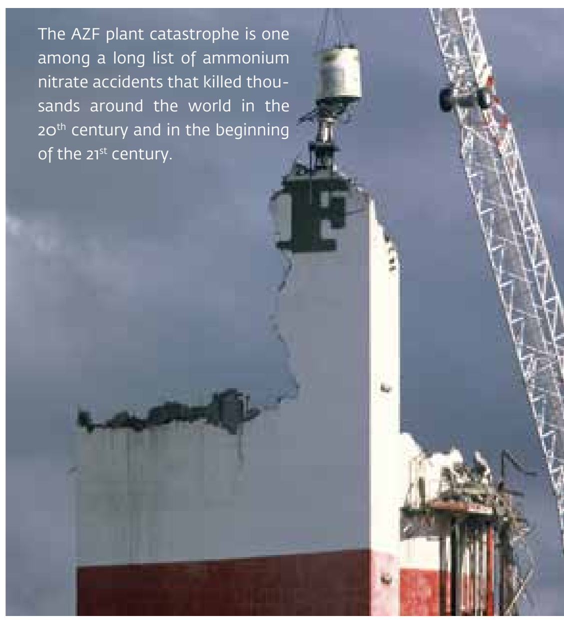
What are the main lessons learned from the AZF accident in this domain?

J.G. The AZF case shed light on the necessity for public authorities not only to restrict future urban development around industrial plants, but just as importantly to improve the existing housing stock's resistance to pressure waves or to air masses contaminated with chemical pollutants, etc. In this regard, studies carried out throughout the country revealed several spots where the promiscuity between hazardous industrial operations and the surrounding housing was just unacceptable.
The aim of the Technological Risk Prevention Plans is to go beyond the 'traditional' reduction of risks at source inside the production plants or warehouses, to enforce under the authority of the government and its local representatives – Prefects, local administrations, etc. – measures to push housing back around these facilities, leaving a sufficient buffer area. This may involve programmes to reinforce existing buildings and, in the most dangerous zones, go so far as to expropriate owners. The July 2003 bill provides also for the possibility to impose obligations on industrial companies in terms of safety and security enhancement work – sometimes beyond the state of the art – or even to envisage the closedown or transfer of the industrial facility, in case this proves a less expensive option. Let me add this is more adapted to storage facilities, such as gas tanks or hazardous product warehouses, than to production plants!

Reinforcing buildings or expropriating owners are costly decisions. Who bears the expense?

J.G. The costs associated with additional safety and security devices – such as strengthened

Complex investigations were conducted with a view to identifying the root causes of the accident that had occurred just 10 days after the September 11th terrorist attacks in the USA.



The AZF plant catastrophe is one among a long list of ammonium nitrate accidents that killed thousands around the world in the 20th century and in the beginning of the 21st century.

containment – at industrial plants are usually borne by the operating companies. These are part of the €1bn/yr investment mentioned earlier (see p. 34). Should the facility be transferred to another area, the costs are basically split three ways between the operator, the government and the local authorities, unless otherwise agreed between the parties. Costs linked to the reinforcement or expropriation of housing are shared on the same basis.

But let me point out that, beyond the money issue, getting the stakeholders – inhabitants, local elected representatives, etc. – to make decisions when it comes to housing reinforcement or transfer requires active support from public authorities at both the government and local levels, involving training sessions for community artisans in charge of reinforcement work as well as 'turnkey' accompaniment packages to the local authorities concerned. For instance, housing experts offer inhabitants to perform diagnoses, assess the reinforcement work to be carried out and appoint crafts people accordingly.

Can we go further, both in the prevention and the mitigation of industrial accidents?

J.G. Well, as previously said, the July 2003 bill is an important milestone in enhancing the prevention and mitigation of industrial accidents in France, but it is by no means the conclusion of on-going dynamics! Within this Ministry for instance, significant work is performed every day to better understand the situations potentially conducive to accidents with a view to regularly updating laws and regulations accordingly.

Learn more:

Further information about the activities carried out by the Bureau for Analysis of Industrial Risks and Pollutions is downloadable at: www.aria.developpement-durable.gouv.fr/?lang=en

21.09.12

In September 2012, eleven years after the deadly blast, a memorial to the victims of the AZF plant accident was inaugurated on ground zero.

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COMING NEXT...

Implementing the 2014 European Nuclear Safety Directive

The EU's Nuclear Safety Directive – amended in 2014 on the basis of the lessons learned from the Fukushima nuclear accident, the nuclear stress tests carried out in 2011 and 2012 as well as the safety requirements of WENRA and the IAEA – requires EU countries to give highest priority to nuclear safety at all stages of the lifecycle of a nuclear power plant and provides the TSO function with a legal basis. Issue 29 of the EUROSAFE Tribune deals with the challenges involved in the implementation of this new Directive. More on: www.eurosafe-forum.org

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