IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

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Post-Fukushima Complementary Safety Assessments

Information notice presenting IRSN analysis and conclusions following an expert review of the Complementary Safety Assessments (CSA) submitted to ASN by operators at the request of the Prime Minister after the Fukushima accident

After examining the CSA reports issued by nuclear operators, IRSN submitted its report to the French Nuclear Safety Authority (ASN) and the members of the standing advisory groups. The report was then presented to the media on 17 November 2011, during a conference jointly organised by ASN and IRSN. The full version of the report (approximately 500 pages) and a technical summary are available on the IRSN website.

IRSN would like to highlight the following key messages further to the extensive analysis work which enlisted one hundred experts to focus on the subject over several months and was completed within a very tight deadline by both the operators and IRSN.

1. IRSN analysis results - three main conclusions

Current safety levels in French nuclear facilities are the result of more than thirty years experience, including 1,500 reactor years, studies and research, innovation, investment and daily safety monitoring activities conducted by both the designers and operators and by the relevant government organisations. As a result, most French nuclear facilities, particularly the 58 nuclear power plants (NPPs), have made considerable improvements in terms of safety since they were commissioned, particularly after the ten-yearly reviews, which are based on essentially deterministic approaches, completed with probabilistic safety assessments. In this context, IRSN emphasises that the facilities for which operations are authorized in France can legitimately be considered as safe. However, there is inconsistency between declaring an acceptable level of safety at a given moment and seeking new improvements, particularly in the light of operating experience feedback, in this case, the accident that occurred in Japan in March 2011. The analyses conducted by the operators, corroborated by IRSN expert assessment within the framework of complementary safety assessments requested by the Prime Minister (which also fall within the European scope of NPP "'stress tests"), give rise to three main conclusions:

a. With regard to their approved safety baseline, a number of compliance gaps were detected at the facilities examined. Although the compliance gaps detected within the scope of the Complementary Safety Assessments were generally temporary and did not directly compromise the safety of the facilities, they are likely to constitute weakening factors for the facilities concerned within the hypothesis of an accident sequence. **IRSN is satisfied with the operators' commitment to expand the compliance review of their facilities for any equipment used in the event of accident situations involving the loss of power or cooling sources, by the end of 2012. It recommends continuing development of processes that aim to ensure that the facilities are compliant at all times.**

b. The accident in Fukushima, as well as the complementary safety assessments, highlights the necessity to take immediate steps to amend some site specific safety requirements, changes that would normally be conducted following ten-yearly reviews. Several areas are involved, such as characterizing hazards (in this regard, advantage must be taken of knowledge acquired on environmental hazards) and protecting facilities from fire or from the possibility of prolonged loss of power/cooling sources over the long term and impacting several facilities on a single site.

c. Events in Japan have shown that some assumptions made at the time of the facilities' initial design must be reconsidered, in particular the assumption that, given the provisions in place, a severe accident could not be caused by a natural phenomenon outside the facility. Although the occurrence of a natural phenomenon on a scale greater than the phenomena considered during the design phase, or during the facility safety review, is expressed as a residual probability, it cannot be ruled out completely. Similarly, the requirements do not consider situations whereby the loss of electronic power or recooling sources over long periods of time may affect several facilities on a single site and may be caused by large-scale external hazards.

It is for these reasons that **IRSN suggests making changes to the current safety approach, changes that entail protecting structures and equipment that provide vital functions used to control the main safety functions in terms of hazards considerably greater than those adopted for the general facility design. In this way, this equipment would make up a "hardened safety core" used to provide the facilities with an ultimate hazard protection system. IRSN considers that the first proposals set out by the operators to counter such situations are consistent with this approach and are suited to substantially reinforcing the safety levels at the facilities.**

2. The introduction of "hardened safety core" requirements in nuclear facilities

Continued progress in terms of safety must follow a methodical approach that results in a clear and homogeneous public decision-making process, as well as in rational investment decisions from the operators concerned. During its review of the CSA reports produced by the operators, in addition to the application of ASN-defined specifications, IRSN based its method on an analysis matrix of the relative safety levels in the facilities with regard to the hazards they may face. This matrix is derived directly from the "defence in-depth" approach, one of the essential safety principles used in the nuclear sector (and in others, for example, the aeronautics sector).

This principle consists in ensuring that the facilities' design prevents the occurrence of incident or accident situations, whilst assuming they may still occur, thus envisaging the implementation of appropriate provisions to manage them. i.e.:

- All safety functions that enable the facility to operate within its "design" range are provided in normal operation conditions by the "structures, systems and components (SSC)" dedicated to ensuring these functions. This is the first level of defence;
- If the facility goes beyond the boundaries of this operating range, dedicated resources are used to detect the anomaly and to return to the normal operating range. This represents the second level of defence;
- If degradation to the facility continues regardless, a third level of provisions, including automatic actions and manual operator actions, must be applied to recover control of the three main safety functions (control of nuclear reaction, of the cooling system and of the containment of radioactive materials) using the dedicated equipment and resources. They are designed to prevent the accident situation from deteriorating, particularly core meltdown in the case of reactors and the loss of radioactive material containment for all facilities. With regard to reactors, minimum functions must be restored to maintain the water inventory used to protect the core and the fuel assemblies stored in the spent fuel pool and the residual heat removal pool;
- Should this level of defence fail, leading inevitably to fuel assembly meltdown in the case of reactors, a fourth level of defence comes into play, mobilizing a category of safeguard devices that aim to control (particularly over time) the containment of radioactive products and to limit the release of radioactive materials into the environment;
- Finally, in the event of a release into the environment, nuclear crisis management actions are implemented both by the operator and the public authorities to effectively protect the populations located close to the damaged facility. This is the fifth and final level of defence.

For its report on Complementary Safety Assessments, IRSN used the analysis results and the proposed changes envisaged by the operators, as well as the results of its own studies and research, to examine the sensitivity of these different levels of defence to hazards outside the facilities (beyond the levels for which they were designed) or to the possible combinations of these hazards and their consequences in terms of the loss of safety functions. Efforts must be made to strengthen specific levels of defence, as illustrated by the following diagram:

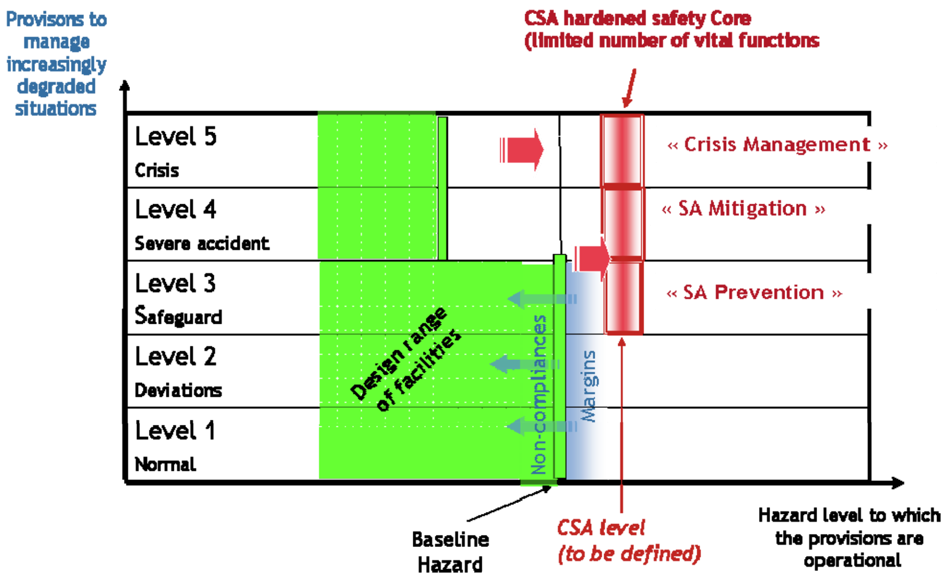

Diagram 1

This assessment led IRSN to set out the following main conclusions. The following elements are written with nuclear power plants in mind. However, these conclusions are broadly valid, ***mutatis mutandis*****, for all facilities analysed to date within the framework of the Complementary Safety Assessments, i.e. a total of approximately 80 facilities, including research reactors and industrial installations at the front and back end of the fuel cycles.**

- In their reports, the operators include the "safety margins" adopted during the design and construction phases, thus procuring a certain level of resilience in terms of withstanding hazards that may go beyond the basis of their design. **Given the uncertainties regarding the hazard levels on one hand, and the simplified nature of the approaches implemented to meet the deadlines set for the facility behaviour assessments on the other, IRSN does not consider it possible to assess the robustness of facilities in terms of these hazard levels with a sufficient degree of confidence. Additional studies are therefore required on a site-by-site basis to accurately identify any reinforcements that may be necessary in terms of flood or earthquake risks.**

- The operator reports also identify a number of extreme scenarios where the SSC providing all or part of the basic safety functions may fail because of the occurrence of large-scale external hazards (floods or other extreme climatic events, earthquakes, domino effects from accidents affecting other facilities, nuclear or otherwise). This is particularly the case for situations where these hazards may cause the loss of electrical power sources required for operations over a prolonged period of time, or the loss of cooling sources required to remove the heat produced in the reactor core or in the spent fuel pool. IRSN particularly notes that the protection of this safeguard equipment, with regard to environmental hazards is, in some cases, insufficient, even in terms of hazards adopted for the general design of the facility (on the grounds that these hazards alone are not considered to be capable of causing an accident sequence requiring the availability of the safeguard equipment). As such, for example, the depressurisation and filtering systems used by EDF for reactor containment ("sand filters"), designed to retain caesium and other radionuclides in the event of unavoidable release into the environment following core meltdown, are not actually designed to withstand a design-basis earthquake. **As a consequence, IRSN recommends that the operators identify all the "SSC" (limited by definition) that are essential in terms of the implementation of the last lines of defence in-depth (core meltdown prevention, limitation of radiological consequences of a severe accident on one or several reactors from the same site, capacity to conduct on-site crisis management) <u>and propose measures aiming to "harden" them in terms of hazards that go beyond the basis of plant design.</u> On one hand, a limited number of "hardened safety core" structures and equipment designed to withstand natural risks must be over-protected, while on the other hand, the robustness and independence of this equipment must be monitored in relation to that initially** designed to cope with accidental situations in the facility, which may become unavailable in some circumstances.**

- **The above analysis also applies for the EPR currently under construction at Flamanville. However, IRSN notes that the major progress made for this type of reactor in terms of safety, combined with the fact that its construction is not yet complete, means that the improvements expected by the CSA are both smaller in scale and easier to implement than for the existing reactors, for which, for example, the initial design did not take account of the core melt scenario.** In particular, the EPR design takes better account of the hazard combinations than the reactors in operation. Furthermore, all systems required for the management of accident situations, including severe accidents, are expected to remain operational for a safety baseline earthquake or flood.

3. Conclusions

Eight months after the Fukushima disaster, the complementary safety assessments which must be commended for both the quality of their analysis and their concrete proposals for improvement have made it possible for IRSN to:

- Assess the facilities' compliance with requirements that are applicable to them in terms of earthquake and flood hazards, as well as the loss of electrical power/cooling source risks, and to identify a number of priority corrective actions.
- Identify aspects to be reviewed in the short term in the safety baselines[1] for specific facilities without waiting for the ten-yearly reviews (determination rules for earthquake and flood hazards to be adopted for the design phase, flood protection, hazard combinations to the considered, etc.).
- Define an innovative approach designed to supplement the existing safety provisions, affording the facilities improved robustness and enabling them to cope with accident situations that were not until now considered in safety baselines, through the implementation of a "hardened safety core" ensuring the availability of equipment essential for controlling safety and crisis management functions (diagram 2).

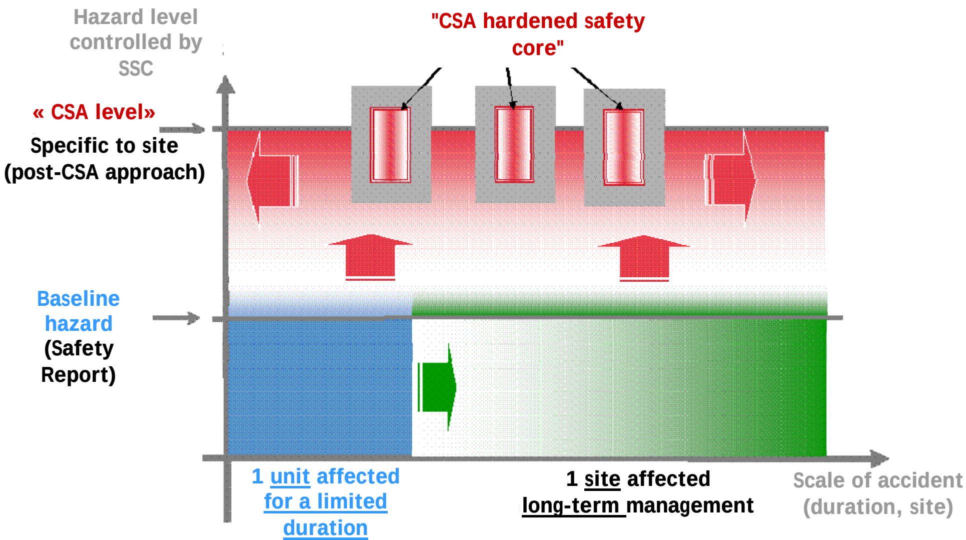

Diagram 2

Further in-depth studies and the operational implementation schedule for these steps to enhance safety will be the subject of decisions that the French Nuclear Safety Authority will be required to make over the coming weeks.

Beyond these complementary safety assessments, IRSN also reiterates that nuclear safety research programmes are under way at both a national and international level. The French government plans to assign additional resources, funded by the "future investments" system, to new research programmes into safety issues brought to light by the Fukushima accident. IRSN will contribute to these programmes and continue to drive forward nuclear safety in France and across the world.

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[1] All requirements applicable to a nuclear facility