FRANCE

Convention on nuclear safety

National report for the second extraordinary meeting

27 - 31 August 2012

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Introduction

At the 5th review meeting of the Convention on Nuclear Safety (CNS), which took place in Vienna from 4th to 14th April 2011, the Contracting Parties present decided to organise an extraordinary review meeting from 27th to 31st August 2012, in accordance with article 23 of the CNS. The purpose of this meeting is to review and share the lessons learned and the steps taken by the Contracting Parties in response to the events of the accident that struck the Fukushima Daiichi nuclear power plant (NPP).

For the purposes of this extraordinary meeting, a national report is to be produced by each of the Contracting Parties and describe the steps taken or envisaged, along with the scheduled completion dates.

This report, coordinated and produced under the authority of the French nuclear safety regulator, the *Autorité de Sûreté Nucléaire* (ASN), summarises the steps taken by France in the wake of the Fukushima-Daiichi accident. It was drafted in conformity with the recommendations of the IAEA secretariat and comprises 6 chapters, corresponding to each of the 6 predetermined topics: external events, design studies, severe accident management and recovery (on-site), national organisation, emergency and post-accident situation organisation (off-site) and international cooperation. It is based primarily on the stress tests performed by the licensees and on the analyses carried out by various ASN divisions, the French Institute for Radiation Protection and Nuclear Safety (IRSN) and the advisory committees of experts, as well as the contributions from other French entities.

In the days following the accident, ASN considered that a Complementary Safety Assessment (CSA) of the French nuclear facilities with regard to the types of events which led to the Fukushima Daiichi disaster needed to be initiated without delay, even if it no immediate emergency measures were considered necessary. This approach was to supplement the permanent safety approach, for the French civil nuclear facilities, on the basis of applicable safety baselines.

The complementary safety assessment approach was conducted at two levels: on the one-hand a European level, with the organisation of stress tests by seventeen European countries in accordance with the conclusions of the European Council of 24th and 25th March 2011 and, on the other, a national level with the performance of a nuclear safety audit on the French civil nuclear facilities in the light of the events at Fukushima Daiichi, ordered by the Prime Minister in a letter dated 23rd March 2011. These two parallel approaches are consistent.

- European stress tests framework

At its meeting of 24th and 25th March 2011, the European Council asked both the Commission and European nuclear safety regulators to perform stress tests to check the robustness of the nuclear power plants to a certain number of extreme conditions to which they could be subjected, such as earthquake, flooding, loss of electrical power supplies, loss of heat sink, combinations of events, and failures in the emergency response organisation. These stress tests performed at national level had to be examined during the "peer review" supervised by the European Nuclear Safety REgulators Group (ENSREG).

In accordance with the European Council's request, the Western European Nuclear Regulators' Association (WENRA) undertook to draft stress test specifications for European nuclear power reactors. ASN played an active part in the drafting these specifications for evaluating the safety margins of the nuclear power generating reactors in Europe, in the light of the events at Fukushima Daiichi.

These draft specifications were presented in early May 2011 to ENSREG for discussion and adoption.

After validation of the European stress tests specifications on 25th May 2011, fifteen countries of the European Union operating power reactors, plus Switzerland and Ukraine, undertook to examine the safety of their reactors using an identical analysis baseline.

In France, on September 15, 2011, EDF (Electricité de France), the operator of nuclear power plants, presented to ASN for each nuclear plant a report according to the stress tests specifications. The analysis process implemented by ASN is described in the following section dealing with the French approach.

The French national report on the stress tests conducted on the nuclear power plants was submitted to the European Commission in early January 2012.

On 11th October 2011, ENSREG also validated the principle of holding peer reviews of the stress tests conducted in the European Union. These peer reviews were organised between February and March 2012. The members of ENSREG created a "Council" consisting of qualified personalities to supervise this exercise and appointed the ASN Commissioner, Philippe Jamet, as Chairman.

The peer review was conducted in two phases: analysis by transverse theme, conducted from January to February 2012, then a phase of national reviews. In this context, a team of eight auditors of different nationalities intervened in France from 19 to 23 March 2012. It held several meetings at ASN with representatives of ASN, EDF and IRSN (Institute of Radiation Protection and Nuclear Safety) and made a visit to the Tricastin nuclear power plant.

Following the peer reviews of the stress tests performed in the European countries, a report was presented to ENSREG at the meeting of 25th April 2012.After approval, it was forwarded to the European Commission.

On the basis of this document and the work done by the group dedicated to studying the safety of European nuclear power plants, a final European Commission report will be submitted to the European Council in late June 2012.

- National CSA framework

In a letter dated 23rd March 2011, pursuant to article 8 of the Act on Transparency and Security in the Nuclear field (TSN Act) of 13th June 2006, the Prime Minister ordered ASN to conduct a study of the safety of civil nuclear facilities in the light of the Fukushima Daiichi accident.

This audit concerns five points:the risks of flooding, earthquake, loss of electrical power supplies, loss of heat sink, and operational management of accident situations.

In order to ensure that the French and European approaches were consistent ASN adopted for the complementary safety assessments the specifications issued by ENSREG for the stress tests and decided to extend the CSA to all nuclear facilities.

The French High Committee for Transparency and Information on Nuclear Security (HCTISN) was consulted on the guidelines of this approach. In its opinion of 3rd May 2011, it declared itself to be in favour of the approach and the specifications, recommending that this assessment also take account of socio-organisational and human factors, in particular for subcontracted activities in the nuclear facilities. ASN extended the CSA specifications to these subjects.

Through decisions dated 5th May 2011, the ASN commission required that the French nuclear licensees carry out a complementary safety assessment for each of their facilities.The facilities were placed in three categories:

- the first comprising nuclear facilities felt to be high-priority:nuclear power plants in operation, the main research reactors and the main nuclear facilities of the fuel cycle, for which the licensees were required to submit their reports by 15th September 2011;

- a second, in particular comprising facilities undergoing decommissioning and research facilities, for which the licensees are required to submit their reports by 15th September 2012;
- and a third list, in particular comprising waste disposal and other lower-risk facilities, for which the experience feedback derived form analysis of the Fukushima Daiichi accident will be integrated into the next periodic safety reviews, which may possibly be brought forward.

The complementary safety assessment approach concerns a large number of facilities (about 150) which are operated by a small number of licenseesConsequently, ASN introduced an intermediate stage into the assessment process, asking the licensees to present their methodology. For priority facilities, this step was 1 June 2011.

At their meeting of 6th July 2011, the advisory committee for reactors (GPR) and the advisory committee for laboratories and plants (GPU) examined the IRSN analysis of the approaches adopted by the licensees to comply with the ASN specificationsFollowing this analysis, ASN adopted a stance on 19th July 2011, considering that the approaches adopted were on the whole satisfactory, but that the licensees needed to take account of a number of specific requests from ASN.

For the facilities felt to be high-priority, the CSA reports were submitted on 15th September 2011 by the four licensees EDF, AREVA, CEA and ILL.They were published on ASN's website (www.asn.fr).

At the request of ASN, these reports were analysed by IRSN. The IRSN report, available on its website (www.irsn.fr), was presented to the advisory committees of experts (GPR and GPU) from 8th to 10th November 2011.

Following these presentations, the advisory committees formulated about ten recommendations, that ASN incorporated into its CSA reportOn 8th December 2011, this report was presented to the HCTISN and it emphasised the good information of the public throughout the complementary safety assessment process and the quality of the analyses performed by the licensees, the IRSN, the advisory committees and ASN.

The ASN report on CSA conducted on French priority facilities, issued on 3 January 2012, comprises three chapters:

- Chapter 1: Summary of targeted inspections (see below) carried out in 2011 on topics related to the Fukushima accident.
- Chapter 2:Complementary safety assessments of nuclear power generating reactors / European stress tests.This chapter constitutes the report which was sent to the European Commission.
- Chapter 3: Complementary safety assessments of nuclear facilities other than power generating reactors.

The ASN report was submitted to the Prime Minister.

In its opinion n° 2012-AV-0139 of 3rd January 2012 on the complementary safety assessments of priority nuclear facilities in the light of the accident which struck the Fukushima Daiichi nuclear power plant, ASN recalls that:

- the natural disaster which struck the Fukushima Daiichi nuclear power plant confirms that, whatever the precautions taken in the design, construction and operation of nuclear facilities, an accident can never be completely ruled out;
- the licensee has overall responsibility for the safety of its facilities while, on behalf of the State, ASN is responsible for regulating and monitoring nuclear safety, with the technical support of IRSN and its Advisory Committees. Pursuant to the law, ASN ensures that the safety of French civil nuclear facilities is continuously, in particular through the periodic review process and the integration of experience feedback.

Following the complementary safety assessments on the high-priority nuclear facilities, ASN considers that those examined show a level of safety that is sufficient to warrant no immediate closure of any of them. At the same time, ASN considers that their continued operation demands that their robustness to extreme situations be increased beyond their existing safety margins, as rapidly as possible.

ASN is thus requiring that the licensees adopt a range of measures designed to provide the facilities with the means to enable them to deal with:

- a combination of natural phenomena of an exceptional scale and exceeding those adopted in the design or the periodic safety review of the facilities,
- severe accident situations following the prolonged loss of electrical power or cooling and liable to affect all the facilities on a given site.

Among these new provisions, ASN would in particular stress the importance of the following measures:

- **for all the facilities, the creation of a "hard core" of material and organisational arrangements making it possible to manage the fundamental safety functions in extreme situations, with the aim of preventing a severe accident, limiting large-scale radioactive releases if the accident cannot be controlled and enabling the licensee, even in extreme situations, to perform its emergency management duties. This will for example involve setting up a "bunkerised" emergency management centre with diesel electricity generator, and an ultimate backup water supply. The equipment to be included in this hard core must be designed to withstand major events (earthquake, flood, etc.), of a scale far in excess of those used to determine the strength of the facilities, even if not considered to be plausible.** By 30th June 2012, the licensees shall notify ASN of the content and the specifications of the "hard core" for each facility;

- for nuclear power plants, gradual deployment, as of 2012, of the "Nuclear Rapid Intervention Force (FARN)" proposed by EDF. This is a national intervention force comprising specialised teams and equipment, able to take over from the personnel of the site affected by the accident and deploy additional emergency response means within 24 hours. The system will be fully operational by the end of 2014;

- for the fuel storage pools in the various facilities, the implementation of reinforced measures designed to reduce the risk of uncovering of the fuel;

- for the nuclear power plants and the silos at La Hague, feasibility studies concerning the use of technical measures such as a geotechnical containment or system with equivalent effect, designed to protect the ground and surface waters in the event of a severe accident.

These new requirements entail considerable work and large-scale investments, which are beginning in 2012 and will be spread over several years.

Over and above these measures, ASN considers that particular attention must be focused on social, organisational and human factors. As a result of the appraisals conducted on these assessments, ASN has identified a number of priorities in this field:

- renewal of licensee manpower and skills, which is a crucial point at a time when one generation is replacing another and when considerable work is required as a result of the CSAs;

- the organisation of the use of subcontracting, which is an important and complicated subject;

- research on these topics, for which programmes must be set up, at national or European levels.

ASN will be setting up a pluralistic working group on these subjects.

ASN has placed all the information concerning the complementary safety assessments on-line on its website www.asn.fr, under the heading "Complementary safety assessments" which is regularly updated, in particular on the occasion of the key steps scheduled for monitoring the work resulting from this approach.

Moreover, from the summer of 2012, ASN will submit semi-annually the progress of all these actions.

- Targeted inspections of the French nuclear facilities

In addition to the complementary safety assessments, ASN conducted a campaign of inspections targeted on topics related to the Fukushima Daiichi accident. These inspections, carried out during the summer of 2011 on all the nuclear facilities felt to be high-priority for the complementary safety assessments, comprised field checks on the conformity of the licensee's equipment and organisation with the existing safety baseline.

The topics covered by these inspections were as follows:

- protection against external hazards, in particular seismic resistance and protection against flooding,
- loss of electrical power supplies,
- loss of heat sinks,
- operational management of radiological emergencies.

They were each carried out by a team of several inspectors accompanied by IRSN experts and, for a given site, took the form of in-depth inspections lasting several days (continuously or otherwise) covering all the topics mentioned above.hey were based on a reference baseline common to the nuclear power plants, on the one hand, as well as to the other nuclear facilities, and emphasised field visits over documentary checks.
Thirty-eight complementary inspections were thus performed, including nineteen on nuclear power plants. They represented a total of 110 days of inspections.he overall summary of these inspections was incorporated into the ASN final report of 3rd January 2012.

The results of these inspections were also incorporated into chapters 1, 2 and 3 of this present report as actions performed by ASN further to the Fukushima Daiichi accident.

- Transparent approach

ASN attached the greatest importance to the approach being both open and transparent.

Representatives of the HCTISN, the local information committees (CLI) and several foreign safety regulators were invited to attend the meetings of the advisory committees as observers and take part in the targeted inspections carried out by ASN; these various stakeholders also received a copy of the reports transmitted by the licensees.

At each step in the process, whether European or French, ASN posted the various documents produced on its website (www.asn.fr):

- the ASN commission resolutions,
- the CSA specifications for the European and French frameworks,
- the list of nuclear facilities concerned, including the high-priority facilities,
- the reports of the stress tests performed by the licensees,
- the opinions of the advisory committees of experts,
- the follow-up letters to the inspections performed by ASN,
- the report submitted to the European Commission and the Prime Minister.

Finally, ASN published several information notices and organised four press conferences on 9th May, 14th September 17th November 2011 and 3rd January 2012.

Programme of future actions

Over and above the initial steps taken in 2011, experience feedback from the Fukushima accident needs to be further analysed. As with the Three Mile Island and Chernobyl accidents, detailed analysis of experience feedback from the Fukushima accident could take about a decade.

However, ASN has already identified a certain number of measures:

- in its opinion following the complementary safety assessments, ASN considers that continued operation of the facilities requires that their robustness to extreme situations needs to be increased as rapidly as possible. In the first half of 2012, ASN has been taking a range of decisions, officially requiring that the licensees implement the specified measures. In the light of experience feedback from the Fukushima accident, it will reinforce the safety requirements concerning the prevention of natural hazards (earthquake and flooding), the prevention of risks linked to other industrial activities, subcontractor surveillance and the processing of deviations. The corresponding ASN decisions will be published on the www.asn.fr website;

- ASN will take part in the in the European peer reviews, the conclusions of which should be examined by ENSREG in April 2012 and presented to the European Council at the end of June 2012, and it will aim to draw the relevant consequences from their results;

- ASN also considers that additional studies are required to complete certain aspects, in particular the initial analyses made by the licensees. It will ask the licensees to do so in letters which will also be posted on its website;

- ASN will be particularly vigilant in monitoring the implementation of all of its stipulations, as well as in reinforcing the baseline safety standards, especially with regard to earthquakes, flooding and risks linked to other industrial activities. As of the summer of 2012, it will periodically present the progress of all of these actions;

- ASN will continue to run the complementary safety assessment process on lower priority facilities, for which the reports must be submitted by the licensees before 15th September 2012;

- ASN considers that the first complementary safety assessments confirmed the benefits of this innovative approach, which complements the existing safety approach. It envisages making this complementary assessment of safety margins a permanent feature, by adding it as a requirement of the future ten-year periodic safety reviews;

- finally, ASN will continue to play an active part in all the analyses to be carried out worldwide, to gain a clearer understanding of the Fukushima accident and learn the relevant lessons.

Summary table - Priority facilities, including nuclear power plants

Activities	Activities of the Licensee			ASN activities		
	Status(Completed, In progress, Envisaged)	Performance dates or calendar for activities not yet performed	Result(Obtained,Not obtained)	Status (Completed,In progress, Envisaged)	Dates of performance or calendar for activities not yet performed	Conclusions available (Yes, Non)
Summary						
Drafting of specifications for the performance of the complementary safety assessments				Completed	05 May 2011	Yes
Performance of stress tests	Completed	15 September 2011	Report submission to ASN			
Submission of analysis report by ASN				Completed	31 December 2011	Yes
Targeted inspections post-Fukushima				Completed	June – October 2011)	Inspection follow-up letters on the site www.asn.fr
ASN requirements - Drafting of requirements; - Planning of the requirements implementation - Submission technical file "hard core"; - Decision "hard core"		June 2012 June 2012		In progress	2012 April 2012 End 2012 – Early 2013	No

1 External events

1.1 Earthquake

The seismic hazard is an event liable to generate failures which could affect all the facilities on a site, in particular the systems important for safety. An earthquake can have simultaneous effects on several parts of a nuclear facility and on its environment. It can cause an event initiating an accident, while disabling the safeguard systems designed to deal with this initiating event. It could have more general effects on the facility and on the environment, such as an outbreak of fire or the loss of electrical power supply to the facility.

The possibility of an earthquake is designed into the facilities and periodically re-examined on the occasion of the periodic safety reviews. The design principle adopted is that it must be possible to restore the plant to and maintain it in safe shutdown conditions, after an earthquake corresponding to a hazard level at least equivalent to that of the safe shutdown earthquake (SSE). These objectives are the responsibility of equipment, systems and structures to which behaviour requirements are attributed (integrity, functional capability, operability). Account must also be taken of the possible failure of elements which do not have a safety role but which could, in the event of an earthquake, constitute a hazard for systems which do have a seismic safety function.

1.1.1 Design of the facilities

In addition to the initial seismic design of the facility, as part of the second and third ten-yearly in-service reactor inspections, ASN issued specific requests to take account of changes to the reference baselines and scientific knowledge in the field of the hazard and para-seismic justification.

It is important to note that updating of the safe shutdown earthquakes is only one aspect of the periodic safety review concerning the seismic field. The development of methods and computing resources used for paraseismic engineering has fine-tuned the evaluation of the seismic strength of buildings and equipment. Reinforcements may therefore be decided, not simply on the basis of a reassessment of the hazard, which constitutes input data for the calculation of structures and equipment, but also on the basis of developments in paraseismic engineering.

In addition, seismic operating experience feedback (both nuclear and non-nuclear) and the construction robustness studies are also sources for evaluating seismic conformity. In particular, operating experience feedback from the earthquake of 16th July 2007, which led to prolonged shutdown of the Kashiwasaki-Kariwa nuclear power plant, was studied in detail and led to facility improvement measures, in particular with regard to the robustness of the crisis management buildings.

1.1.1.1 Seismic level for which the facilities are designed

The approach used to define the seismic loads to be considered in the design of the facilities is a deterministic one:

- it is postulated that any earthquake known in the region of the site (taking account of historical observations over a period of about 1,000 years) is liable to reoccur with the same characteristics in the position most unfavourable to the facility, while remaining compatible with the geological and seismic data;
- from this, the intensity of the "Maximum Historically Probable Earthquake" (MHPE) is deduced;

- as part of the safety approach and to take account of uncertainty surrounding the data and the available knowledge, a degree of intensity is arbitrarily added to the MHPE to define the safe shutdown earthquake (SSE);
- the installation is then designed to withstand a hazard level at least equivalent to that of the SSE; reactor safe shutdown, fuel cooling and containment of radioactive products must be guaranteed for this type of earthquake:
- this approach also takes account of soil effects and paleo-earthquakes[1].

Moreover, a fundamental safety rule (see § 1.1.1.2) defines acceptable methods for determining all the movements to which the "seismic-classified" civil engineering structures are subjected, based on the seismic motion considered and the corresponding load levels, in order to allow design and verification:
- of the civil engineering strength of these structures subjected to the loads resulting from earthquakes and other actions combined with earthquakes;
- of the correct behaviour and performance of the equipment in the facility.

Characteristics of the design-basis earthquake

ASN requires that basic nuclear installations be designed to withstand an earthquake higher than the maximum earthquake that has occurred during the last thousand years in the area in which they are sited.

The licensees are therefore required to define an earthquake for design purposes. The rule for determining this earthquake is defined in a fundamental safety rule (RFS). The RFS defined by ASN are in particular designed to explain the regulatory objectives and, as applicable, describe the practices considered by ASN to be satisfactory. They are periodically reviewed to take account of changing knowledge and new information. The first RFS on the subject dates from 1981, this is RFS I.2.c[2]. It was revised in 2001; this is RFS 2001-01[3]. These RFS are also used to check the design of the installations in operation on the occasion of the periodic safety reviews, with reinforcements defined as and when necessary.

These rules define two seismic levels, the Maximum Historically Probable Earthquake (MHPE) and the Safe Shutdown Earthquake (SSE), which is that used to check that the earthquake finally adopted by the licensee in the design of its facility (Design Basis Earthquake - DBE) is in conformity with the requirement.

Given the standardisation of the nuclear reactor fleet operated in France, EDF introduced the notion of design-basis earthquake: This is a spectrum that encompasses the various SSE spectra associated with the various sites of a given plant series.

EDF used an approach involving plant series for the nuclear reactors and, for the nuclear island, standardized groups of reactors making up the series, which enabled it to pool the design studies. The other structures, known as the "site structures" were specifically designed for each site.

The nuclear island comprises:
- the reactor building (BR), containing the reactor and all the pressurised reactor coolant systems, and the containment;
- a fuel building (BK), housing the new and spent fuel storage and handling facilities;
- a safeguard auxiliaries and electrical building (BAS/BL);
- a building for the other nuclear auxiliaries (BAN);
- an operations building (BW).

The site structures include the other buildings and facilities necessary for the operation of the plant, including the heat sink and the intake channel.

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[1] Paleo-earthquake: earthquake which left traces of deformation in the surface geological layers
[2] RFS 1.2.c of 1st October 1981 concerning the determination of the seismic motion to be taken into account for the safety of the facilities
[3] RFS 2001-01 of 31st May 2001 concerning the determination of the seismic risk for the safety of surface basic nuclear installations.

In general, the design spectra adopted were determined as follows:

- CP0 and CPY: for the design of the CP0 and CPY plant series, the spectral shape used was that known as the "EDF spectrum", defined as the smoothed mean of eight accelerograms recorded during five earthquakes of Californian origin. The accelerations are normalized according to the local seismicity.
- P4 and P'4: the DBE for Paluel, the first P4 site, was changed during the course of its construction. At the beginning of construction, the spectral shape used hitherto for the units was that of the "EDF spectrum". During construction, a new spectral shape was taken from that established by the *Nuclear Regulatory Commission* (NRC - nuclear safety regulator in the U.S.A.) in its *Regulatory Guide* 1.60, which was also adopted in France as the reference for the design of the 1,300 MWe plant series. For the buildings, this led EDF to use the following in turn:
  - the EDF spectrum normalized to 0.2 g.
  - for a transitional period, the NRC spectrum normalized to 0.2 g.
  - the NRC spectrum normalized to 0.15 g.

For the following reactors, P4 and P'4, EDF adopted the NRC spectrum normalized to 0.15 g with zero period for the standard DBE applicable to nuclear island design, compatible with the sites chosen for the reactors in this plant series.

- the standard DBE spectrum, applicable for the design of structures and facilities for the N4 plant series, is the NRC spectrum normalized to 0.15 g with zero period. It is normalized to a zero period acceleration of 0.15 g in the horizontal directions and 0.133 g in the vertical direction (which differs from the usual rule which has 2/3 of the horizontal spectrum correspond to the vertical spectrum, and corresponds to 2/3 of an acceleration normalized to 0.2 g. This is a design convention for this plant series).
- the DBE is the European EUR spectrum normalized to 0.25 g at zero period.

The following table summarises the different design spectra for the nuclear island and site structures:

Site	Plant series	Nuclear island DBE	Site structure DBE
Bugey	CP0	EDF normalized to 0.1 g zero period	EDF normalized to 0.1 g zero period
Fessenheim	CP0	EDF normalized to 0.2 g zero period	EDF normalized to 0.2 g zero period, except BL
Blayais	CPY	EDF normalized to 0.2 g zero period	EDF normalized to 0.2 g zero period
Chinon	CPY	EDF normalized to 0.2 g zero period	EDF normalized to 0.2 g zero period
Cruas	CPY	EDF normalized to 0.2 g zero period, supplemented by a "high-frequency" spectrum normalized to 0.3 g zero period	EDF normalized to 0,2 g zero period, supplemented by a "high-frequency" spectrum normalized to 0.3 g zero period
Dampierre	CPY	EDF normalized to 0.2 g zero period	EDF normalized to 0.1 g zero period
Gravelines	CPY	EDF normalized to 0.2 g zero period	EDF normalized to 0.2 g zero period
Saint Laurent	CPY	EDF normalized to 0.2 g zero period	EDF normalized to 0.2 g zero period
Tricastin	CPY	EDF normalized to 0.2 g zero period	EDF normalized to 0.2 g zero period, verified at a higher frequency site spectrum, normalized to 0.3 g
Flamanville 1-2	P4	NRC normalized to 0.15 g zero period	NRC normalized to 0.15 g zero period
Paluel	P4	EDF normalized to 0.2 g, then NRC normalized	EDF normalized to 0.2 g, then

		to 0.2 g, then NRC normalized to 0.15 g.	NRC normalized to 0.2 g, then NRC normalized to 0.15 g.
Saint Alban	P4	NRC normalized to 0.15 g zero period	NRC normalized to 0.1 g, then NRC normalized to 0.132 g.
Belleville	P'4	For the design of the nuclear island: NRC spectrum normalized to 0.15 g zero period and, for the nuclear island foundations and reinforcements, owing to the low seismicity of the site: NRC normalized to 0.1 g zero period:	NRC normalized to 0.1 g zero period
Cattenom	P'4	NRC normalized to 0.15 g zero period	NRC normalized to 0.15 g zero period
Golfech	P'4	NRC normalized to 0.15 g zero period	NRC normalized to 0.15 g zero period
Nogent	P'4	For the design of the nuclear island: NRC spectrum normalized to 0.15 g zero period and, for the nuclear island foundations and reinforcements, owing to the low seismicity of the site: NRC normalized to 0.1 g zero period	NRC normalized to 0.15 g zero period
Penly	P'4	NRC normalized to 0.15 g zero period	NRC normalized to 0.15 g zero period
Chooz	N4	NRC normalized to 0.15 g zero period, (normalized to 0.15 g in the horizontal direction and 0.133 g in the vertical direction) and spectrum offset by reducing the frequencies by a ratio of 2/3 and normalized to 0.12 g zero period.	NRC, offset and normalized to 0.12 g zero period
Civaux	N4	NRC normalized to 0.15 g zero period, (normalized to 0.15 g in the horizontal direction and 0.133 g in the vertical direction) and spectrum offset by reducing the frequencies by a ratio of 2/3 and normalized to 0.12 g zero period.	NRC normalized to 0.15 g zero period
Flamanville 3	EPR	NRC normalized to 0.25 g zero period	NRC normalized to 0.2 g zero period

Methodology used to evaluate the Design Basis Earthquake

The conformity of the basic nuclear installations with the regulations is periodically checked every ten years, on the occasion of the periodic safety reviews. These reviews are the opportunity to perform an in-depth, detailed conformity examination, to reassess the SSE levels in the light of the most recent data and new knowledge, to re-examine the scope of the equipment for which seismic resistance is required, to take account of changes in the field of paraseismic engineering and to make the corresponding necessary improvements to the facilities.

The hazard levels (the hazard takes the form of an acceleration, expressed in m/s^2) corresponding to the SSE, are established on the basis of a fundamental safety rule which has itself changed to take account of changing knowledge and data.

<u>Regulatory requirements: RFS I.2.c and 2001-01</u>

A deterministic approach is used to define the seismic hazard to be considered in the design of the facilities.

The general approach to characterising the seismic hazard follows 3 steps:

- geological and seismic characterisation of the region, to identify zones with homogeneous characteristics;
- definition of one or more reference earthquakes;
- calculation of the seismic motion at each site.

The approach is, for each site, to look for an earthquake encompassing the known historical earthquakes in the most penalising epicentre positions (in terms of MSK intensity, representative of surface effects) while remaining compatible with geological and seismic data.

The whole of France is covered by seismotectonic zoning.

Information on past earthquakes was obtained from the interpretation of historical archives describing the damage caused, characterising 1,000 years of seismicity (the SisFrance database contains about 10,000 documents describing more than 6,000 events, and 100,000 observation points), plus a catalogue of instrumental measurements taken since the 1960s (CEA/LDG database).

Definition of the MHPE

The Maximum Historically Probable Earthquakes are the earthquake or earthquakes which, for the site concerned, produce the highest intensities, bearing in mind that:

- the historical earthquakes of the tectonic domain to which the site belongs are considered as being capable of reoccurring under the site;
- the historical earthquakes belonging to a neighbouring tectonic domain are considered as being capable of occurring at the point in this domain closest to the site.

The intensity of an earthquake cannot be directly used in the design of a facility.

Earthquakes are described by their response spectrum (given by the zero period acceleration value, expressed in "g"). For this, it is necessary to determine the magnitude and the focal depth of the historical events.

For each MHPE, a "Safe Shutdown Earthquake" (SSE) is deduced by means of a simple relationship in terms of MSK[4] intensity on the site:

Definition of the SSE

The intensity of the SSE on the MSK scale is conventionally defined by:
$I_{SSE} = I_{MHPE} + 1$

The MSK scale was determined such that a one-degree increase corresponds overall to a doubling in the motion parameter.

The SSE response spectrum is obtained by conventionally adopting a magnitude which is that of the MHPE plus 0.5 on the Richter scale.

[4] The Medvedev-Sponheuer-Karnik scale (also called MSK scale) is a scale measuring the intensity of an earthquake.

Transition from RFS I.2.c (1981) to RFS 2001-01 (2001)

The first RFS for determining seismic motion to be considered for the safety of facilities dates from 1981, this is RFS I.2.c[5]. It was revised in 2001, becoming known as RFS 2001-01[6]. The RFS revision retained the general approach and added to the previous text by taking account of changes to scientific knowledge and the seismic operating experience feedback from the previous 20 years.

The main changes to the RFS concern:

- *the rule for the definition of seismo-tectonic zones in complex fault configurations (fault families);*
- *the use of the available correlations (linking magnitude to intensity and to focal distance) best suited to the French context and established on the basis of a range of homogeneous macroseismic data;*
- *the notion of fixed spectrum: the fixed spectrum characterising nearby earthquakes has been abandoned in favour of a site spectrum set at 0.1 g with infinite frequency. The RFS revision requires a check that the SSE is higher than a minimum level. This minimum level encompasses a moderate earthquake close to the facility (M=4 at 10 km) and a major event (M=6.6 at 40 km). This minimum level is defined for the two site conditions, both rock and sediment. This approach is in conformity with IAEA's recommendation (Seismic Hazard Evaluation for Nuclear Power Plants, Safety Standards series n° NS-G3-3). Considering this minimum level offers a safety margin and compensates for the lack of data available in low-seismicity regions;*
- *incorporation of seismic operating experience feedback and changing calculation methods: the operating experience feedback from earthquakes in the 1980s showed the significant influence of the surface geological layers, in particular in alluvial zones. These effects, referred to as "site effects" act on the amplitude of the seismic motion, its duration and its frequency. The response spectrum definition was supplemented in the RFS by additional indicators such as strong phase duration, the Arias intensity, the maximum soil speed, etc., which are of use for the designers of structures. Site effects are included by using spectral acceleration attenuation laws, including the complex geometry of sedimentary zones and the geological characteristics of the top thirty metres on the sites (determined by using local instrumental data), which were updated in relation to the previous RFS;*
- *taking account of new and changing knowledge in the field of geology: in the early 1990s, signs of paleo-earthquakes of a magnitude higher than certain events in the SisFrance base were discovered. These earthquakes left geological traces by disrupting geological layers or modifying the landscape.*

Site design response spectrum (design-basis earthquake - DBE)

For the design of each plant series, EDF used a design spectrum encompassing the overall SSE spectrum for each site, using the data and knowledge available at the time.

Special steps were taken for sites with seismic characteristics outside the envelope of the standardised plant series (owing to specific local, in particular geological characteristics).

Conclusions concerning the adequacy of the Design-Basis Earthquake

Following a periodic safety review, the changes decided for a plant series are implemented on each reactor, generally on the occasion of the reactor ten-yearly outage inspection. The modifications are thus deployed to the entire plant series over a time-frame that is consistent with the initial time of construction of the corresponding reactors.

As at 30th June 2011, the seismic conformity baseline applicable to the various reactors was as follows:

[5] RFS 1.2.c of 1st October 1981 concerning the determination of the seismic motion to be taken into account for the safety of the facilities

[6] RFS 2001-01 of 31st May 2001 concerning the determination of the seismic risk for the safety of surface basic nuclear installations.

Reactor	Plant series	Version of modifications implemented on the reactor	Applicable seismic baseline	Conformity of the DBE with the earthquake chosen by EDF in accordance with the RFS for the version of the modifications applicable as at 30th June 2011
Bugey 2-4	CP0	VD3	RFS 2001-01	The new SSE was reassessed at 0.145 g, which requires the installation of reinforcements to restore the seismic margins. The work has been completed on these two units.
Bugey 3-5	CP0	VD2	RFS I-2-c	The earthquake adopted is covered by the DBE. However, the VD3 baseline showed the need for seismic reinforcements. The work is complete on Bugey 5 and will be completed on Bugey 3 in 2013.
Fessenheim 1	CP0	VD3	RFS 2001-01	The earthquake to be taken into account remains covered by the design-basis earthquake.*
Fessenheim 2	CP0	VD2	RFS I-2-c	Far-field earthquakes remained covered by the "EDF 0.2 g" DBE. The near-field earthquakes involved a high-frequency overshoot of the design level, considered to have no impact on the safety of the facility. No modifications were implemented during VD2 (the high frequencies do not intercept the natural frequencies of the buildings). For the VD3 preparations, the earthquake to be considered remains covered by the design-basis earthquake (for RFS 2001-01).*
Blayais	CPY	VD2	RFS I-2-c	RFS 2001-01 was used in the preparations for VD3 and shows that the minimum fixed earthquake and the site SSE are both covered by the DBE.
Chinon	CPY	VD2	RFS I-2-c	The earthquake defined in RFS I-2-c was encompassed by the DBE. In the preparations for the VD3, the earthquakes resulting from RFS 2001-01 entailed an overshoot above 7 Hz. A study was carried out to demonstrate that there was no impact on the site structures, the buildings and the equipment of the nuclear island. A study is in progress concerning the reactor building internal structures.
Cruas **	CPY	VD2	RFS I-2-c	The earthquake resulting from application of the RFS I-2-c is covered by the DBE. The earthquake resulting from application of the RFS 2001-01 shows an overshoot above 8 Hz. The analyses performed during the preparations for VD3 show that there is no impact on all the buildings and equipment.
Dampierre	CPY	VD2	RFS I-2-c	The DBE encompasses the earthquake selected by RFS I-2-c. In the preparations for VD3, the

				DBE was compared with the earthquakes resulting from RFS 2001-01. For the nuclear island, the overshoots above 10 Hz are considered to have no impact. For the site structures, the overshoots above 2 Hz were the subject of verifications. They have no impact on the site buildings and structures. These overshoots are linked to the adoption in the new rule of the minimum fixed earthquake, given the low level of local seismicity.
Gravelines	CPY	VD2	RFS I-2-c	The earthquake resulting from RFS I.2.c was justified at the time of VD2. During the preparations for VD3, the earthquake resulting from RFS 2001-01 was verified. The new reference earthquake entailed an overshoot for the nuclear island beyond 5 Hz, considered to have no impact. The implementation of reinforcements and minor changes to the site structures and equipment has been completed at Gravelines 1 and will be carried out during the ten-yearly outages on the other reactors (end of works in 2017).
Saint-Laurent	CPY	VD2	RFS I-2-c	The nuclear island DBE encompasses the earthquake resulting from RFS I.2.c and 2001-01. The earthquake for the site structures is covered by the earthquake resulting from RFS I-2-c and entails slight overshoots beyond 7 Hz, for the earthquake resulting from RFS 2001-01. The absence of impact on the site structures and equipment was confirmed.
Tricastin 1-2	CPY	VD3	RFS 2001-01	For the design of Tricastin, two reference earthquakes were used: an EDF spectrum normalized to 0.2 g and a spectrum with more high frequencies normalized to 0.3 g to take account of the specific characteristics of the site. These earthquakes encompass those resulting from application of RFS I-2-c and 2001-01.
Tricastin 3-4	CPY	VD2	RFS I-2-c	For the design of Tricastin, two reference earthquakes were used: an EDF spectrum normalized to 0.2 g and a spectrum with more high frequencies normalized to 0.3 g to take account of the specific characteristics of the site. These earthquakes encompass those resulting from application of RFS I-2-c and 2001-01.
Chooz	N4	VD1	RFS 2001-01	The earthquake resulting from RFS 2001-01 is covered by the DBE.
Flamanville 1-2	P4	VD2	RFS 2001-01	The DBE encompasses the earthquakes resulting from RFS I-2-C and 2001-01.

Paluel	P4	VD2	RFS 2001-01	The DBE encompasses the earthquake resulting from the application of RFS 2001-01 up to 25 Hz. The slight overshoot above 25 Hz has no impact.
Saint-Alban	P4	VD2	RFS 2001-01	The DBE encompasses the earthquakes resulting from RFS I-2-c and 2001-01.
Belleville	P'4	VD2	RFS 2001-01	For the standard design, the DBE encompasses the earthquake resulting from RFS 2001-01. For the civil engineering reinforcement bars on the nuclear island and the site structures, the NRC 0.1 g spectrum entails slight overshoots beyond 4.5 Hz. Studies have confirmed that these overshoots are covered by the structural design margins.
Cattenom 1-2-3	P'4	VD2	RFS 2001-01	The DBE encompasses the earthquakes resulting from RFS I-2-c and 2001-01.
Cattenom 4	P'4	VD1	RFS I-2-c	The DBE encompasses the earthquakes resulting from RFS I-2-c and 2001-01.
Golfech	P'4	VD1	RFS I-2-c	The DBE encompasses the earthquakes resulting from RFS I-2-c and 2001-01.
Nogent	P'4	VD2	RFS 2001-01	The DBE encompasses the earthquakes resulting from RFS I-2-c and 2001-01.
Penly	P'4	VD1	RFS I-2-c	The DBE encompasses the earthquakes resulting from RFS I-2-c and 2001-01.
Civaux	N4	Before VD1	RFS I-2-c	Civaux was initially designed on the basis of RFS I-2-c. During the preparations for VD1, the facility underwent a seismic check resulting from RFS 2001-01. DBE overshoots beyond 5.5 Hz were brought to light. The licensee conducted studies to show that there was no significant impact on the buildings and equipment of the nuclear island and site structures, other than the BAS/BL equipment. Additional studies are in progress, as part of the preparations for the ten-yearly outage, to check the seismic qualification of the BAS/BL equipment.

* For Fessenheim, the need for seismic reinforcement is not linked to a reassessment of the hazard, but to the implementation of new paraseismic calculation methods performed during the periodic safety reviews (see § 1.1.1.2).
** The Cruas NPP site has the particularity of being built on a basemat resting on paraseismic supports, which considerably reduces the seismic loadings applied to the structures and equipment of the nuclear island, lowering the frequency of the island between 1 and 1.5 Hz.

It can be seen that the main DBE overshoots are, pursuant to RFS 2001-01, due to:

- the use of a fixed minimum earthquake defined conventionally for zones with very low seismicity (Dampierre, Belleville, Saint-Laurent) ;
- a reassessment in the high frequencies of the regulation earthquakes, frequencies which generally have little impact on the design of buildings and structures, as they are beyond their frequency of interest.

ASN considers that these are overshoots for which the implementation of changes and reinforcements enables the margins to be restored (the goal of a reassessment being in particular to define the changes to be implemented for conformity with reassessed requirements). In addition, when the applicable baseline safety requirement is not yet the RFS 2001-01, EDF has already carried out studies in preparation for the forthcoming ten-yearly outage inspections using this baseline, in order to define and implement the necessary reinforcements or changes.

The DBE margins for the nuclear island and the site structures are not identical, in that the site structures were designed on the basis of earthquakes normalized on local seismic characteristics.

The robustness of the civil engineering structures participating in prevention of the loss of the heat sink or electrical power supplies (in particular the electrical and diesel buildings) shall be analysed by EDF in the study that ASN asked it to conduct on the incorporation of long-term LUHS[7] or SBO site situations (see § 2).

It is important to note that updating of the safe shutdown earthquakes is only one aspect of the periodic safety review concerning the seismic field. The development of methods and computing resources used for paraseismic engineering has fine-tuned the evaluation of the seismic strength of buildings and equipment. Reinforcements may therefore be decided, not simply on the basis of a reassessment of the hazard, which constitutes input data for the calculation of structures and equipment, but also on the basis of developments in paraseismic engineering.

Seismic operating experience feedback (both nuclear and non-nuclear) and the construction robustness studies are also sources for evaluating seismic conformity.

In addition to the initial seismic design of the facility, as part of the second and third ten-yearly in-service reactor inspections, ASN issued specific requests to take account of changes to the reference baselines and scientific knowledge in the field of the hazard and para-seismic justification.

ASN considers that the seismic reassessments conducted since the design of the units, based on reassessed hazards and changes to paraseismic justification methods, were performed satisfactorily and led to improved facility safety with respect to the seismic risk.

ASN notes the conformity of the reactors with this baseline, subject to the implementation of identified reinforcements and changes, scheduled for the ten-yearly outage inspections.

1.1.1.2 Steps designed to protect the facilities from the earthquake for which they are designed

Identification of systems, structures and components (SSCs) for which availability is required subsequent to an earthquake

The plant shall be designed so that it can be restored to and kept in safe shutdown conditions after an earthquake corresponding to the SSE.

The licensee shall demonstrate that it meets the three safety objectives:

- controlled reactivity (including the safe shutdown function);
- residual heat removal;
- containment of radioactive materials.

These objectives are the responsibility of equipment, systems and structures to which behaviour requirements are attributed (integrity, functional capability, operability):

[7] See § 2, "LUHS" situation corresponds to total loss of ultimate heat sink; the "SBO" - station black-out - situation corresponds to total loss of electrical power supplies.

- integrity: applies to pressure vessel capacities playing a safety role; it aims to maintain the containment capacity;
- functional capability: aims to maintain the function of a system for a mission duration defined in the safety analysis report;
- operability: aims to ensure correct working of the mobile parts and mechanisms, for performance of the safety functions of this equipment and the nominal working of actuators and control systems.

During the design process, the equipment, systems or structures necessary for the safety demonstration are classified on a list of elements important for safety. Depending on its safety role, this equipment is placed in a safety class which comprises seismic classification requirements defined by the regulations or by the RFS (RFS IV.1.a of 21st December 1984 concerning the classification of certain mechanical equipment, RFS IV.1.b concerning the design and classification of safety-classified electrical equipment, etc).

These elements are designed to perform their functions in all plant operating situations (normal, transient, incident and accident). The behaviour requirements are determined by the role to be played by the equipment, systems or structures in the various operating situations.

The seismic classification requires justification either by calculation, or by testing on a vibrating table, or through analysis on a case by case basis.

The resulting design requirements are proportional to their safety class. For the main primary system, they are defined by the order of 26th February 1974[8] and for the main secondary system by RFS II.3.8[9], for all the reactors in service. For level 2 and 3 mechanical equipment, the design requirements and criteria are defined by RFS IV.2.a of 21st December 1984 concerning the requirements to be taken into account in the design of safety-classified mechanical equipment, carrying or containing a pressurized fluid and classified level 2 or 3. For electrical equipment, the requirements are defined in RFS IV.1.b of 31st July 1985 concerning the design and classification of safety-classified electrical equipment.

RFS V.2.g[10] defines acceptable methods for determining all the movements to which the "seismic-classified" civil engineering structures are subjected, based on the seismic motion considered and the corresponding load levels, in order to allow design and verification:

- of the civil engineering strength of these structures subjected to the loads resulting from earthquakes and other actions combined with earthquakes;
- of the correct behaviour and performance of the equipment in the facility.

Following the adoption of the new RFS 2001-01 concerning the determination of the seismic motion for surface basic nuclear installations, in place of RFS I.2.c dating from 1981, RFS V.2.g was revised to take account of changes to paraseismic engineering know-how (for example: the development of dynamic analyses on detailed 3-dimensional models, the improved knowledge of soil behaviour and soil/structure interactions, the development of time-based calculations on advanced models, the incorporation of non-linear phenomena, whether of geometrical or rheological origin) and to ensure consistency with RFS 2001-01. These requirements are included in ASN guide 2-01[11].

For example, the seismic changes implemented on the occasion of the Fessenheim VD 3, are not due to a reassessment of the seismic hazard, but to the use of new computation methods.

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[8] Order of 26th February 1974 concerning the reactor coolant system (RCS) for pressurised water reactors (PWR)

[9] RFS II.3.8 of 8th June 1990 concerning the construction and operation of the main secondary system, for all 900 and 1,300 MWe plant series

[10] RFS V.2.g of 31st December 1985 concerning seismic calculations for civil engineering structures

[11] ASN Guide 2-01 of 26th May 2006 on taking account of the seismic risk in the design of civil engineering structures for basic nuclear installations

In its CSA reports, EDF recalls that it sets seismic classification requirements for:

- IPS (important for safety) equipment (defined in the design) and certain non-IPS equipment, on a case by case basis;
- the PAM (post-accident monitoring) measures;
- certain equipment required for safety sectorisation;
- equipment adjacent to a seismic-classified system and needed to ensure the isolation between a seismic-classified part and a non-seismic-classified part;
- equipment containing radioactive materials which, in the event of a leak, could lead to significant releases.

Equipment which, if it fell, could lead to the loss of seismic-classified IPS equipment, is the subject of seismic verification (see indirect effects of an earthquake in this chapter).

In the CP0 plant series, about 5,600 equipment items are seismic-classified. In the CPY plant series, about 5,200 equipment items are seismic-classified. In the 1300 MW plant series, about 8,500 equipment items are seismic-classified. In the N4 plant series, about 9,200 equipment items are seismic-classified.

ASN considers that the implementation of this baseline safety requirement by EDF is satisfactory.

Main operating provisions

Operating principle in the event of an earthquake:

In order to be able to rapidly take adequate steps to bring the plant units to the shutdown state felt to be safest for each one, and maintain it in this state, or to continue with operations, RFS I.3.b recommends the installation of seismic instrumentation for pressurised water reactors.

The procedure to be followed then depends on the level of the earthquake in relation to the Half Design Response Spectrum (½ DRS: spectrum corresponding to an earthquake which should not modify the behaviour of the facility with regard to an SSE occurring subsequently and the spectrum of which is half the DBE).

- if the ½ DRS threshold is not exceeded, each unit can continue to operate provided that a visual inspection is carried out on structures and equipment.
- if the ½ DRS threshold is exceeded, the units must go to the shutdown state considered for each unit to be the safest. The resumption of operation may only be initiated with the approval of ASN.

The operation of this seismic instrumentation was the subject of a series of targeted inspections by ASN in 2011.

During these targeted inspections, ASN on certain sites identified seismic instrumentation deviations from RFS I.3.b, problems with operator interpretation of the measurements taken by this instrumentation, and a lack of clarity in the reactor shutdown procedures. These deviations can delay reactor shutdown as specified in RFS I.3.b, or could even lead to this decision not being taken. Moreover, the required inspection following the occurrence of the ½ DRS, defined by RFS I.3.b and constituting a prerequisite for restart of the reactors on the site, is not clearly defined. ***ASN has asked EDF to check the conformity of its facilities with RFS I.3.b. by 30th September 2012.***

Furthermore, even though a degree of training has been dispensed, the drills triggered by ASN during the inspections showed that on most sites, the operators had problems in analysing the data produced by the seismic instrumentation, which could delay shutdown of the reactors or even lead to this decision not being taken. ***ASN has asked EDF to define and monitor a training programme for its operating personnel in order to reinforce their preparedness for an earthquake (by no later than 31st December 2012 for the reactor operating personnel in charge of the seismic rack and associated operational measurements and by 31st December 2013 for the other operating personnel).***

ASN has also asked EDF to study the advantages and drawbacks of implementing automatic shutdown of its reactors in the event of seismic loading, enabling the reactor to be shutdown to the safest state, if the seismic level corresponding to a spectrum with half the amplitude of the design response spectrum, adapted to each site, is exceeded. EDF shall submit a study by 31st December 2012.

Protection against the indirect effects of the earthquake

SSC failure, "event earthquake[12]" approach

In addition to the design-basis earthquake resistance of the IPS equipment necessary in the event of an earthquake, the safety approach was supplemented by an approach called "event earthquake", the aim of which is to prevent damage to an equipment item necessary in the event of an earthquake by an item or structure not seismic-classified. This approach is implemented on the occasion of the ten-yearly outage inspections. This only considers direct mechanical damage or direct spraying of mechanical or electromechanical equipment.

The hypotheses adopted by EDF in the approach are as follows:

- equipment that is not designed to withstand an earthquake can fail and thus constitute a potential hazard;
- seismic-classified equipment must not have its function or integrity compromised by failure of an item that is not seismic-classified;
- no simultaneous occurrence of an earthquake and the following is postulated:
  - an independent incident or accident condition;
  - an independent internal hazard (for example fire);
  - another independent external hazard.

An examination must be conducted on the possible hazards that non-seismic-classified equipment represents for seismic-classified equipment by:

- considering the potential hazards representing an effective risk for the target;
- checking that none of the equipment items performing safeguard, reactor protection and their support functions is jeopardized.

The list of potential hazards identified in particular includes the structures and items (weighing more than 10 kg) not designed to withstand an earthquake (unfixed loads, handling machinery not tied down, cabinets, fans, civil engineering structures, tanks, large equipment on small piping, equipment running through the premises, false ceilings, piping with a diameter larger than 50 mm, etc.).

The event earthquake approach was extended to the potential damage to the nuclear island buildings by the turbine hall.

When the analysis leads to the need for protection, the measures taken can involve:

- relocation of the target or the hazard source;
- installation of reinforcements to ensure the hazard's ability to withstand the earthquake;
- installation of protection on the target;
- justification of the target's ability to withstand the hazard by analysis or by testing;
- modification of the operating conditions of these equipment items.

Implementation of this approach is being requested by ASN on the occasion of the ten-yearly outage inspections (as of the 900 MWe VD2). The approach comprises two parts, one national, which can lead to modifications to a plant series, and one local.

[12] The purpose of the "event earthquake" approach is to prevent an item necessary in the event of an earthquake being damaged by an item or structure that is not seismic classified.

During the course of its inspections, ASN observed the difficulty experienced by the licensee with ensuring optimum integration of this requirement on certain sites on a day-to-day basis, in particular during maintenance operations, construction site operations, the use of scaffolding and the utilisation and conservation of handling resources. ***This is why ASN has asked EDF to ensure on each site the effective and efficient implementation of the "event earthquake" approach by 31st December 2013.***

Loss of off-site electrical power supplies:

The PWR safety demonstration studies the simultaneous occurrence of a major earthquake and the loss of off-site power supplies, insofar as they are not designed to withstand a major earthquake.

At the same time, EDF introduced the "LOOP combination" which simulates the consequences of an earthquake during an accident transient. Therefore, as described in the safety analysis report, these transients are only managed with seismic-classified equipment.

The total loss of electrical power supplies (SBO situation) to a single unit on the site is included in the baseline safety requirements. It is the result of the loss of off-site power supplies associated with the impossibility of restoring the panels backed up by the back-up generators in each unit. These back-up sources comprise autonomous and functionally independent diesel generators. In the event of the failure of these unit diesel generators to start or connect, it is possible to connect a site emergency generator or a diesel generator belonging to a neighbouring unit.

There is only one emergency generator per site, which is not designed to withstand an earthquake. In the event of a common mode affecting all site back-up diesels, only one of the site units could be backed up. In the event of an earthquake, the availability of this emergency generator cannot be guaranteed. *ASN sees this as a weak point in the ability of the facilities to deal with an on-site SBO situation, in particular if resulting from an earthquake. ASN duly notes the measures envisaged by EDF to improve the robustness of its facilities vis-à-vis these situations, which in particular consist in ensuring the earthquake robustness of the additional measures defined for the on-site SBO situation. These aspects are also described further in § 2.*

ASN considers that the reinforcement objectives proposed by EDF are satisfactory. ASN has thus asked EDF, by 31st December 2014, to increase the life of its batteries and supplement the electrical back-up by emergency diesels, allocated to each reactor, which will have to be a part of the hard-core (see 1.1.3) and will therefore have to withstand significantly higher seismic levels than the DBE.

Conditions for access to the site following an earthquake:

In the event of major disruption to roads and structures, the emergency response organisation calls on the public authorities who, in addition to triggering the off-site emergency plan (PPI) if necessary, take special measures. These measures allow on-call personnel to be brought in.

The plant safeguard systems requiring external supplies (fuel, oil, etc.) have an autonomy of several days, varying according to the systems and described in the safety analysis report.

ASN observes that EDF has not demonstrated site autonomy for a period of fifteen days (time considered by EDF for restoration of the off-site power supply) in all circumstances, in particular following an earthquake or flooding leading to the site being isolated (these aspects are detailed in § 2 of this report).

ASN has asked that EDF secure its on-site stocks of fuel and oil and ensure that they can be replenished in all circumstances, to guarantee an autonomy of at least 15 days.

Earthquake-induced fire risk:

The buildings consist of sectors to prevent the propagation of a fire. These sectors comprise a seismic strength requirement.

The buildings and premises housing IPS equipment are subject to general equipment installation requirements to prevent the loss of the safety function in the event of a fire (in particular, redundant systems must not be installed in the same sectors, cables must be geographically separated whenever possible, and so on).

Fire-fighting systems are subject to seismic strength requirements and they are separated from non-seismic-classified parts by seismic-classified isolating devices.

However:

- the sectoring, fire detection and fixed extinguishing systems are designed to withstand half of the DBE for the 900 MW and 1300 MW plant series;
- operating experience feedback mentions outbreaks of fire in normal operating situations on IPS equipment;
- fire detection and fixed extinguishing systems are not electrically backed-up by seismic qualified equipment;
- seismic qualification of fire detection only applies to equipment installed within the context of the study of the reference accidents in the safety analysis report.

ASN has asked EDF, by 31st December 2012, to reinforce the fire sectoring, fire detection and fixed extinguishing systems, so that they can withstand a SSE.

Earthquake-induced explosion risk:

Application of the SSE design requirement to the hydrogen systems and inclusion of the "event earthquake" approach for lines carrying hydrogen in the nuclear island, is in progress on the N4 plant series, and is scheduled:

- between 2009 and 2019 for the 900 MWe reactors;
- between 2015 and 2023 for the reactors of the 1300 MWe plant series.

ASN has asked EDF to speed up application of the SSE design requirement to hydrogen systems and the implementation of the "event earthquake" approach for lines carrying hydrogen.

The hydrogen presence detectors and the shut-off valves situated outside the reactor building are not covered by seismic strength requirements. ***ASN has asked EDF to guarantee the ability of this equipment to withstand a SSE and to supplement the forthcoming safety requirements.***

ASN considers that management of the explosion risk, for these lines, also entails correct application of a maintenance programme and ensuring that there are no deviations.

1.1.1.3 - Conformity of facilities with existing safety requirements

The conformity of nuclear facilities with the safety requirements that are applicable to them is a key component of their safety and their robustness to accident initiators or hazards. For ASN, this conformity must be continuously managed and be based on a systematic search for possible deviations, which must be dealt with in a way commensurate with the safety stakes. The detection, notification and processing of deviations are now the subject of ASN requirements defined in the order of 10th August 1984[13] and in the general operating rules for nuclear power plants which, for example, specify the time within which the reactors must be shut down according to the importance of the deviation. These deviations may be the result of errors in the initial design, the construction, the modifications made during the course of operation or during maintenance operations, but also following reassessments of the safety requirements stipulated by ASN during the periodic safety reviews. They may for example concern equipment whose ability to resist an earthquake to be withstood by the facilities is not guaranteed.

EDF's general organisation for guaranteeing conformity

The review of the seismic conformity of the equipment, conducted by the licensee and checked by ASN, comprises a number of complementary parts:

- the detection of deviations, particularly during maintenance and scheduled periodic tests,
- examination of unit conformity (ECOT) and the complementary investigation programme (PIC), performed as part of the periodic safety reviews,
- incorporation of international operating experience feedback,
- performance of specific studies or inspections dedicated to evaluating the seismic robustness of the facilities (robustness diagnosis, implementation of the Seismic Margin Evaluation-SMA method, etc.).

The basis of this examination is the updated safety requirements, both for the hazard and for justification of the seismic strength of equipment and structures.

The conformity evaluation of the equipment and structures is an opportunity for a regular review of the adequacy of their initial design, based on specific checks and studies. ASN considers this organisation to be pertinent.

Processing of seismic deviations:

Seismic-classified equipment undergoes maintenance in accordance with the maintenance programmes, as do the anchors and supports.

The main deviations detected and being processed concern:

- locking the threaded fasteners of certain valves,
- cracking of electrical relays or their sockets,
- mounting defects of certain PCBs,
- sensor qualification faults,
- excess lubricant on the contacts of certain relays,
- strength defects of lines, exchangers, catwalks or access towers.

Not all these deviations are simultaneously present on all the reactors.

Similarly, two design anomalies are being processed:

- sufficiency of emergency feedwater system (EFWS) reserves to deal with a loss of off-site power (LOOP);
- modelling of the physics of hydraulic flows under the reactor vessel dome (which has an impact on the definition of the safe shutdown times of the reactor when facing loss of power supply).

[13] Order of 10th August 1984 concerning the quality of design, construction and operation of basic nuclear installations.

These deviations are the subject of significant event notifications and are being processed accordingly with ASN oversight.

Conformity examinations on the occasion of the ten-yearly periodic safety reviews:

The periodic safety review conducted by EDF is an opportunity on the one hand to carry out a detailed examination of the situation of the facility, in order to check that it in fact complies with all the rules applicable to it (conformity review) and, on the other, to improve its safety level (safety reassessment) in particular by comparing the applicable requirements with those in force for facilities with more recent safety objectives and practices and by taking account of changes to available knowledge and national and international operating experience feedback.

The conformity review consists more precisely in comparing the state of the facility with the safety requirements and the applicable regulations, in particular its authorisation decree and all ASN prescriptions. This conformity review aims to ensure that any evolution of the facility and its operations, due to modifications or to ageing, complies with all the rules applicable to it. This ten-yearly review does not however relieve the licensee of its permanent obligation to guarantee the conformity of its facility.

In addition, the licensee implements a complementary investigation programme to consolidate the hypotheses adopted concerning the absence of damage in certain zones considered not to be susceptible and thus not covered by a preventive maintenance programme. The checks carried out under the complementary investigation programme are spot-checks and differ from one reactor to another, in order to cover all the areas concerned by maintenance.

For the safety reassessment, the conformity of the equipment, structures and components is checked in terms of the compliance of their seismic strength with the reassessed baseline level.

Detection of a seismic strength nonconformity during the ten-yearly outage inspections may lead to a significant event notification, processed accordingly with ASN oversight.

Incorporation of international operating experience feedback:

In its approach, EDF incorporated some of the operating experience feedback from the July 2007 earthquake in the Japanese power plant at Kashiwasaki-Kariwa, especially by defining the scope of seismic inspections it performed and studying the consequences of a transformer fire.

Following the Fukushima accident, EDF conducted an initial series of field reviews on all its sites, which included earthquakes (specific reliability review: WANO SOER 2011-2). A number of observations were made, but none called into question the reliability of the systems.

ASN considers that the process to search for deviations during normal operation, maintenance, conformity reviews and safety reassessments, during the complementary investigations (event earthquake approach, specific seismic inspections, etc.), and on the occasion of the inspections performed following the Fukushima accident, is satisfactory.

The deviations identified during the CSAs do not directly compromise the safety of the facilities concerned but they can, in particular if combined, constitute factors such as to weaken the facilities. ***ASN has asked EDF to reinforce the detection and processing of deviations. The regulatory requirements on this topic were in particular strengthened by means of the order of 7th February 2012 setting out general rules for basic nuclear installations, especially with regard to an assessment of the cumulative impact of the various deviations present in a facility. These requirements will be reinforced by means of ASN prescriptions.***

Deployment of mobile resources after a DBE.

The post-earthquake deployment procedures do not require the use of mobile resources up to the design-basis earthquake. The issue of replenishment of consumables (fuel, oil, etc.) is dealt with in the chapter on site accessibility after an earthquake (§ 1.1.1.2).

1.1.2 Evaluation of safety margins

On the occasion of the complementary safety assessments, ASN asked EDF:

- *based on the available information, to give an evaluation of the level of earthquake beyond which the loss of fundamental safety functions or fuel damage (in vessel or pool) was inevitable,*
- *to identify the weak points and cliff-edge effects, according to the scale of the earthquake*
- *to propose measures to prevent these cliff-edge effects and reinforce the robustness of the facility.*

On the basis of an analysis conducted in a very short period of time, EDF reviewed the seismic strength margins of the structures and equipment important for safety, in order to determine the level of acceleration for which, with a high level of confidence, the facility has a very low probability of failure.

EDF supplemented its general study with studies of equipment for which there could be performance discontinuities, based on an analysis performed in a very short period of time, and proposed modifications or reinforcements as applicable.

Finally, EDF carried out the seismic inspection of a sample of the equipment needed to operate the unit in the event of total loss of off-site and on-site power supplies, whether or not seismic-classified, for all the nuclear power plants in service.

In its overall margin study, EDF identifies three margin sources:

- margins between the MHPE and the SSE and between the SSE and the DBE;
- response of the structure;
- design criteria for the structures and equipment.

Seismic loading margin:

EDF stated that using a plant series spectrum for all the reactors of the same series as the design response spectrum, is an envelope approach in that this spectrum is broad-band and designed to cover the characteristics of all the sites. In the frequency ranges of the structures, it therefore considers acceleration levels higher than those which would be transferred to the structures in the case of the spectrum of a site SSE.

For each site, EDF proposed a table of margin factors between the reassessed site SSE and the DBE, between 1 and 6 or 10 Hz (because this is the frequency of interest for the structures). It considers it a fixed penalty to take account of the rest of the unfiltered seismic signal.

EDF adopts margin values between 1 and 1.7 depending on the sites and the buildings considered.

Margin on the structure response:

EDF mentions an attenuation on the structures of the free-field signal measured, owing to their significant foundation depth, the interaction between the soil and the structures and inertial effects conservatively incorporated into the models.

Margin on the design criteria of structures and equipment:

EDF stated that the design of the facilities and their construction are based on codified or standardized methods and that these codes or standards comprise considerable conservative safety margins in that the design rules remain within the linear elastic domains, for a fraction of the elastic domain.

In addition, EDF regularly conducts multipartite design and R&D actions to characterise the behaviour of structures in the post-elastic domains. As part of its ageing projects and the "operating lifetime" project, EDF carries out R&D work on the conformity criteria and the implicit margins usable. EDF has also carried out or taken part in destructive tests on components and structures comprising defects, in order to study the margins and phenomenology of collapse mechanisms.

According to EDF, seismic operating experience feedback (for flexible lines and light cableways) or tests on a vibrating table (equipment or structure mock-ups) or on anchor pull-out, show considerable margins.

EDF focused in particular on the behaviour of:

- large components,
- flat-bottomed tanks,
- pipes,
- supports,
- ventilation ducts,
- relay cabinets and I&C panels,
- cableways.

The margin factors identified by EDF are higher than 2, except for the tanks and relay and I&C cabinets (where there is enough strength but not the functionality in the event of an earthquake greater than the design-basis earthquake).

In any case, there is a margin in relation to the design-basis earthquake.

Performance of specific studies or inspections dedicated to evaluating the seismic robustness of the facilities:

For the Tricastin site, as a means of assimilating the method, the licensee carried out an SMA (Seismic Margin Assessment).

This method was developed by the American electricity utilities and their safety regulator and aims to study the robustness of the facility to an earthquake larger than the design-basis earthquake.

This evaluation concerns the deterministic study of the strength of equipment, systems and structures necessary for shutdown of the unit to a safe state, considering as fixed a small RCS break and a loss of off-site power.

It is performed using hypotheses different from those of the safety analysis report (earthquake larger than design-basis, conformity criteria based on "average" behaviour of the equipment).

This method complements the studies and includes a field cross-check of the actual condition of the equipment, systems and structures necessary for reactor safe shutdown (design, qualification, anchors, foundations, etc.).

This type of inspection also allows identification of the points which, if improved, would reinforce the robustness (construction measures, protection, relocation of equipment and so on).

It is a different but complementary review of the approach for checking the design-basis earthquake conformity of the equipment.

With regard to the Tricastin site, the study shows the robustness of the facility and the conservative nature of the engineering practices used in the construction, which are consistent across all the power plants in service.

Over and above the search for a higher hazard margin, one benefit of this type of study lies in the cross-checking of the real condition of the equipment and the implementation of good practices in addition to the conformity baseline.

Another advantage is that, on the basis of hypotheses, methods and criteria that are different but which are consistent with those adopted at the design, this type of method makes it possible to check that all or part of the safety objective has been met.

When processing a deviation on the FPCS[14] tanks at Bugey, EDF carried out a CP0 robustness study which was in some ways similar to the SMA approach. Following these studies, anomalies were detected in the design of the anchors, leading to appropriate corrective actions. This confirms the potential benefits of these methods.

ASN considers that using SMA type assessments for verification of the French nuclear power plant reactors, is of very real interest and considers that the development of review methods for equipment, systems and structures, in order to implement the best practices resulting from these assessments or from operating experience feedback should be generalised. ASN asked EDF to include this topic in the forthcoming periodic reactor safety reviews.

In addition to the SMA approach, on the occasion of the 1300 MW periodic safety review, EDF proposed an experimental seismic probabilistic safety assessment (EPS) for the Saint Alban site.

This subject is today being investigated and cannot therefore be implemented in the complementary safety assessments.

EDF seismic inspections on equipment necessary for reactor operation in the event of total loss of off-site and on-site power supplies beyond the design-basis earthquake.

EDF carried out a study of the seismic behaviour (guaranteed functionality, satisfactory anchors, absence of interactions with nearby equipment and structures) of the main equipment items not seismic-classified and necessary in this situation.

EDF identified a deficiency on the SER[15] and FPCS tanks, the CRF[16] valves on certain sites, some electrical cabinets and a number of interactions to be considered. In its reports, EDF stated that it will be initiating studies into reinforcing the robustness of these items. Furthermore, some equipment requires special studies and, as applicable, modifications (valves on certain SAR[17] tanks, etc.).

As a result of these inspections, EDF identified the following areas for vigilance and complementary improvement measures for a hazard beyond the design-basis earthquake:

- Electrical equipment: Some equipment is not seismic-qualified or, if so qualified, its functional behaviour beyond the DBE is not guaranteed. EDF will thus be identifying the equipment required to manage loss of heat sink, loss of electrical power, severe accident situations and topping up the spent fuel pools. It will be proposing a programme of action to render them robust.

[14] FPCS: reactor cavity and spent fuel pool cooling and treatment system. The FPCS acts as a tank for the safety injection system (SIS)
[15] SER: Conventional demineralised water distribution system
[16] CRF: Circulating water system
[17] SAR: Regulating air distribution system.

- Seals between buildings: some seals between buildings are filled with materials such as expanded polystyrene, which no longer corresponds to current practice in paraseismic engineering. A large part of these materials is removed during the ten-yearly outage inspections. If it is to be retained, an assessment of the impact of interaction between buildings at 1.5 SSE will be performed.
- Venting-filtration system for the containment in the event of a severe accident: this equipment is currently not covered by any seismic resistance requirement. EDF is initiating a complementary analysis to assess the seismic resistance of this equipment.
- EDF will be studying additional measures necessary for unit safe shutdown in the event of a loss of off-site power caused by an earthquake larger than the design-basis (which requires a study of the adequacy of the steam generator back-up system water inventory and the speed of connection to the residual heat removal system).
- EDF envisages speeding up the conformity work on the CCWS section that is not seismic-qualified.

<u>EDF conclusions concerning the seismic margins</u>

Based on all the margins studied (seismic loading, structural response, design criteria for structures and equipment) and the seismic inspections it carried out, EDF concludes that the seismic capacity of the containment and of the structures and equipment which, in the event of failure, would compromise the safety functions, is 1.5 times greater than the spectrum corresponding to the SSE. EDF considers that this level easily exceeds the seismic context of the sites, up to hazard values that are relatively to completely implausible for these sites.

<u>ASN position statement</u>

The licensee's assessment did not identify the level of earthquake leading to the gradual loss of the various basic safety functions on the basis of a hazard increasing progressively beyond the DBE.

EDF studied the consequences of an earthquake with a value of 1.5 times the SSE, which it considers to be relatively to completely implausible and which enabled it, within the allotted time, to use seismic verification methods according to the industrial state of the art and not requiring any lengthy studies or research.

ASN considers that, within the allotted time, the principle of studying the consequences of an earthquake significantly larger than the design-basis earthquake allows robustness studies to be conducted to identify the weakest points beyond the design-basis earthquake.

ASN considers that EDF's performance of targeted inspections on the seismic behaviour of equipment for a hazard level higher than that used in the design, and EDF's commitment to performing a systematic review of the equipment necessary in loss of heat sink or loss of electrical power supply situations are sufficient.

ASN considers that the margin review supplemented by inspections, enabled equipment modifications or reinforcements to be defined for an earthquake larger than the facility's design-basis earthquake and beyond the initial design hypotheses.

ASN asked EDF that a programme to ensure that the modifications and reinforcements identified (strengthening of tanks and anchors, interaction limitation, additional seismic qualification studies, etc.) be performed rapidly.

ASN considers that these studies complement the periodic review approach for the seismic part, which hitherto did not exceed the design-basis and only concerned the conformity of the equipment and structures as described in the safety analysis report.

However, although ASN does not question the general approach adopted in identifying the various conservative values beyond the initial or reassessed regulation design basis earthquake, ASN does believe that the margin values presented and evaluated on the basis of an analysis performed within a very short period of time, are thus inadequately justified and should be consolidated and taken further in greater detail.

ASN considers that some of the margins proposed by the licensee correspond to provisions used in the design to offer protection against the uncertainty and variability of the seismic hazard, in the same way as the variability of the behaviour of materials or uncertainties linked to modelling or construction. Consequently, ASN considers that these design provisions cannot be simply amounted to margins in the absence of a detailed justification concerning the uncertainties mentioned above. Furthermore, the margin values proposed by the licensee were established according to expert opinions in the light of the deadline for the complementary safety assessments.

While duly noting the conservative nature of the approach beyond the initial or reassessed regulation design-basis earthquake, ASN thus considers that the overall margin evaluation needs to be consolidated and taken further in greater detail, in particular during the forthcoming periodic safety reviews.

ASN also considers that the identification of the equipment liable to experience behaviour discontinuities, given the time available for the exercise, cannot be exhaustive, particularly for those points that are hard to check or modify (for example: the fuel transfer tube between the reactor building and the fuel building).

ASN asked EDF to complete its review of the items liable to experience behaviour discontinuities and initiate the necessary corrective measures as applicable.

1.1.2.1 Seismic level leading to significant damage of the fuel assemblies

The robustness study performed by EDF for a hazard equivalent to 1.5 SSE identifies no failure of the systems performing fundamental safety functions.

On this point, ASN has no remarks in addition to those made concerning the application of the robustness analysis approach by EDF beyond the design-basis earthquake.

1.1.2.2 Seismic level leading to a loss of containment

The robustness study performed by EDF for a hazard equivalent to 1.5 SSE identifies no failure of the containment.

On this point, ASN has no remarks in addition to those made concerning the application of the robustness analysis approach by EDF beyond the design-basis earthquake.

1.1.2.3 Seismic level leading to non-design-basis flooding

<u>Combination of a seismic risk and an off-site flooding risk:</u>

In the initial design and following the partial flooding of the Le Blayais plant, EDF's flood safety margin level calculations took account of the dam which, if it failed, would entail the highest water level on the site.

In its CSA reports, EDF took account of the topography of each of the sites and identified the water reserves above the site (and thus liable to create flooding in the event of a break) which are not considered robust to a SSE. EDF evaluated the volumes of water that could flood the platform.

The examination performed in principle identifies no risk not already covered by the existing or planned protection measures. Nonetheless, in order to consolidate this assessment, EDF proposed complementary studies for certain sites:

- concerning an earthquake initiating a dam failure, to confirm that the protections for the sites concerned against the flooding created by this dam failure cannot be damaged by the earthquake;
- concerning an earthquake liable to lead to several dam failures, to confirm that the flood protections for the sites concerned are sufficient.

In the light of the geographical situation of the structures concerned, the critical effect is the arrival of water on the nuclear island platform, exceeding the building access thresholds. The potential consequences of this scenario are presented in the flooding part (§ 1.2) of this report.

For each of its sites, EDF also studied the plausibility of the scenarios leading to cliff-edge effects. EDF examined the consequences of the collapse of all the tanks and pipes leading to spillage of the entirety of their contents. Conservatively, EDF considered the tanks to be filled to their maximum capacity and evaluated the total volume poured onto the nuclear island platform on each site and compared the water level reached with the building access and platform access thresholds. EDF concludes that the off-site flooding risk created by an earthquake exceeding the level for which the facility is designed cannot be ruled out for several sites.

For those sites on which the off-site flooding risk created by an earthquake and exceeding the level for which the facility is designed, cannot be ruled out, EDF proposed a study to determine how real the water risk on the nuclear island platform actually is. In the light of the results, EDF will determine whether or not additional protection is necessary.

In addition, for the Gravelines site, the retaining walls along the sides of the intake channel need to remain stable in order to guarantee the heat sink flow. This point was evaluated on the occasion of the VD3.

ASN however considers that additional studies going beyond the SSE need to be carried out by EDF.

1.1.2.4 Measures envisaged to reinforce the robustness of the facilities to the seismic risk

With regard to earthquakes, the complementary safety assessments concerned an evaluation of the conformity of the facilities with their safety requirements and a study of their robustness beyond the design-basis earthquake, up to 1.5 SSE.

Beyond the current safety requirements, EDF proposed additional measures to prevent the serious consequences of extreme situations, on a deterministic basis, regardless of their plausibility.

EDF proposed defining a hard core of reinforced equipment such as to prevent severe accidents and avoid significant radioactive releases into the environment, over and above the current safety requirements, for the deterministic situations studied in the complementary safety assessments.

By June 2012, EDF intends to draw up a list of the main hard core items and the robustness requirements to be applied to them, both for the fleet in service and for the EPR.

ASN considers that the approach proposed by EDF is appropriate and required that before 30th June 2012, EDF submit for ASN approval the requirements associated with this hard core, which shall include significant fixed margins in relation to the current design-basis earthquake.

1.1.3 Summary: earthquake

The complementary safety assessments showed that there are sufficient seismic margins on EDF's nuclear reactors to avoid cliff-edge effects[18] if the current safety baseline is limitedly exceeded. These assessments confirmed the benefits of periodic revision of the seismic risk on the occasion of the ten-year safety reviews. This process of periodic revision of the seismic risk should be continued on the occasion of each periodic safety review. Moreover, following analysis of the EDF CSA reports and the targeted inspections it carried out in the summer of 2011, ASN identified a number of areas for improving safety, linked to the seismic robustness of the facilities.

Therefore, with regard to the seismic risk, ASN asked EDF:

- *to ensure that the equipment used to control the fundamental safety functions is better protected against fire in the event of an earthquake. The main fire protection provisions of the facilities are not all today designed to withstand the design-basis earthquake of the facility, with the margins of this design baseline;*

- *to improve how this risk is integrated into the day-to-day operations of its reactors: improved operator training, improvements in how the "event earthquake" issue is addressed, compliance with the fundamental safety rule concerning seismic instrumentation (maintenance, operator familiarity with the equipment, calibration). In a number of nuclear power plants, ASN observed shortcomings in the application of the current seismic risk baseline;*

- *for the Tricastin, Fessenheim and Bugey sites, to provide a study analysing the level of seismic robustness of the embankments and other structures protecting the facilities against flooding, and to present the consequences of the failure of these structures.*

<u>Definition of a hard core</u>

Furthermore, following the complementary safety assessments (CSA) of the nuclear facilities, conducted in the wake of the Fukushima accident, ASN considers that the safety of the nuclear facilities must be made more robust to highly improbable risks not so far considered in the initial design of the facilities, or following their periodic safety review.

This involves giving these facilities the means to enable them to deal with:
- ***a combination of natural phenomena of an exceptional scale and greater than the phenomena considered in the design or the periodic safety review of the facilities;***
- ***very long duration loss of electrical power or heat sinks capable of affecting all the facilities on a given site.***

ASN thus asked EDF to define by 30th June 2012 and then deploy a "hard core" of material and organisational measures enabling the fundamental safety functions to be controlled in these exceptional situations and to specify the procedures it has implemented.

These steps would thus guarantee ultimate protection of the installations, with the following three objectives:
- *prevent a severe accident or limit its progression,*
- *limit large-scale releases in an accident scenario which could not be controlled,*
- *enable the licensee to perform its emergency management duties.*

[18] Cliff-edge effect: major discontinuity in the scenario, leading to a significant and irreversible worsening of the accident

To define the requirements applicable to this hard core, EDF shall adopt significant fixed margins compared with the current baseline safety requirements. The systems, structures and components (SSCs) which are included in these measures shall be maintained in a functional state in the extreme situations studied by the CSAs. In particular, these SSCs shall be protected against the on-site and off-site hazards induced by these extreme situations, for example: falling loads, impacts from other components and structures, fires, explosions. The proposals to be transmitted by EDF will be reviewed by ASN and its technical support organisation.

Regarding the Flamanville 3EPR reactor, EDF proposed several measures to increase its robustness. ASN considers that these propositions are relevant and that they should be implemented. As with the other reactors, ASN asked EDF to identify the equipment to be included in the hard core, including the existing or complementary systems to ensure control of pressure in the containment building in the event of a severe accident.

1.1.4 Summary table – Topic 1: Off-site events – earthquake

Activities	Activities of the Licensee			ASN activities		
	Activity Completed In progress? Envisaged	**Calendar** Or steps for the activities envisaged	**Result** Obtained Yes? No?	**Activity** Completed In progress? Envisaged	**Calendar** Or steps for the activities envisaged	**Conclusions available** Yes ? No?
Topic 1: Off-site events – earthquake						
Creation of a "hard core" of reinforced material and organisational measures to ensure that in the extreme situations studied by the CSAs, an accident with core melt is prevented or its progress limited, minimising large-scale releases and enabling the licensee to perform its emergency management duties The requirements applicable to this hard core will provide significant margins in relation to the current safety baseline, with regard to the hazards considered in the CSAs	In progress,	Proposed definition of scope and associated requirements in 2012	Yes	In progress	Examination of EDF proposals in 2012	No
The robustness of the associated electrical equipment to the situations envisaged following Fukushima experience feedback will be consolidated up to a seismic level of 1.5 times the SSE. Modifications will be proposed as necessary	In progress	Studies and possible programme of modifications in 2012	No			
Robustness studies at 1.5 times the SSE will be consolidated in 2012 for the Fessenheim and Bugey sites (FPCS tanks, CRF isolation valves, behaviour of buildings, etc.)	In progress	Studies and possible programme of reinforcements in 2012	No			
Improvements to the existing venting and filtration system will be studied (seismic resistance, filtration efficiency)	In progress	Studies and possible programme of reinforcements in	No			

		2012				
Check the conformity of the facilities with the provisions of fundamental safety rule I.3.b, the application of which is stipulated in the safety analysis report	In progress	30/09/2012	No	Completed		
Re-definition and implementation of the steps necessary to prevent potential damage, by other equipment, of items which the safety analysis report requires to be available following an earthquake.	In progress	31/12/2012 for definition of steps 31/12/2013 for implementation review	No	Completed	Requirement 2012	
Improve operating personnel training to enhance their level of preparedness for an earthquake	In progress	31/12/2012 for the reactor operating personnel in charge of the seismic rack and associated operating measurements 31 December 2013 for the other operating personnel	No	Completed	Requirement 2012	
Fessenheim and Tricastin: Study analysing the level of seismic robustness of the embankments and other structures protecting the facilities against flooding and presenting the consequences of the failure of these structures according to this level of robustness.	In progress	30/06/2013	Yes	Completed	Requirement 2012	
Study evaluating the safe shutdown earthquake resistance of the fire sectoring, fire detection and fire extinguishing systems, required by the safety analysis report to withstand half the DBE. For items for which the ability to withstand the SSE cannot be proven, a programme of modifications to guarantee protection of fire safety functions in the event of a SSE.	In progress	31/12/2012	No	Completed	Requirement 2012	
Study of the advantages and drawbacks of implementing	In progress	31/12/2012	No	Completed	Requirement	

automatic shutdown of its reactors in the event of seismic loading, enabling the reactor to be shutdown to the safest state, if the seismic level corresponding to a spectrum with half the amplitude of the site's design response spectrum is exceeded.					2012	
The functional seismic resistance of the water injection system in the "basement" between the basemats of the Cruas units ("U4" system linked to the specific double basemat with anti-seismic pads) will be studied for the end of 2011.	Completed	Studies completed late 2011.	Yes			
The possible acceleration of the handling of certain points to be reviewed in terms of seismic strength will be examined.	Completed end March 2012	Definition of a calendar of possible accelerations by March 2012	Yes			
Spent fuel pool: presentation of the possible measures for safe positioning of a fuel assembly being handled.	In progress	Presentation planned for June 2012	No			
Spent fuel pool: consolidation of robustness demonstration of transfer tube and possible countermeasures	In progress	Studies and possible programme of modifications in 2012	No			
Provide additional information to check that, for the seismic levels associated with the various conceivable earthquake scenarios, the fundamental safety functions are guaranteed.	Envisaged	Next periodic safety reviews		Completed	ASN request 2012	
Speed up application of the SSE design requirement to hydrogen systems and the implementation of the "event earthquake" approach for lines carrying hydrogen.	Envisaged	Next periodic safety reviews		Completed	ASN request 2012	
Guarantee the SSE resistance of the hydrogen presence detectors and shut-off valves located outside the RB, in addition to the future safety baseline requirements on this point.	Envisaged	Next periodic safety reviews		Completed	ASN request 2012	
Complete the review of equipment liable to suffer cliff-edge	Envisaged	Next periodic safety		Completed	ASN request 2012	

effects in the event of an earthquake and initiate the necessary corrective measures.		reviews				
Implement targeted SMA analysis or seismic PSA measures to evaluate the robustness of the facilities beyond the SSE	Envisaged	Next periodic safety reviews		Completed	ASN request 2012	
Study of the risk created by activities taking place near the facilities, in beyond design-basis situations, in conjunction with neighbouring operators responsible for these activities (nuclear facilities, installations classified on environmental protection grounds or other facilities liable to constitute a hazard). Proposal of any modifications to be made to the facilities or their operating procedures as a result of this analysis.	In progress	31/09/2012 for Tricastin 31/12/2012 for Gravelines and Saint-Alban 31/12/2013 for the other sites	No	Completed	Requirement 2012	
Revision of the applicable ASN guidelines covering the effects of earthquakes on BNIs				Envisaged		

1.2 Flooding

Floods are events liable to lead to failures that can impact all the facilities on a site. The risks generated by flooding and high water are in particular:

- the loss of water supply by flooding of the pumping equipment or a large-scale arrival of detritus;
- the loss of off-site electrical power supplies owing to flooding of the switchyard;
- loss of equipment important for safety as a result of flooding;
- prolonged isolation of the site, making it impossible to relieve the personnel, obtain fuel supplies for the back-up generators or bring in mobile emergency systems.

Flooding is a risk that is taken into account in the design of the facilities and reassessed on the occasion of the periodic safety reviews or further to certain exceptional events, such as the partial flooding of the Le Blayais nuclear power plant during the storm on 27th December 1999. This reassessment in particular concerns the maximum water level considered in the design of the site protection structures, called the flood safety margin level (CMS), but also all the phenomena and combinations of phenomena that can be the cause of a flood (high river level, storm, rainfall, rising groundwater level, failures of water retention systems and structures, etc.).

1.2.1 Design of the facilities

1.2.1.1 Floods for which the facilities are designed

In its CSA specifications, ASN asked EDF to give:

- *the characteristics of the flood for which the facility is designed (in particular the water level considered), their justification, as well as the values of these parameters taken into account for the facility's initial authorisation decree;*
- *the methodology selected for evaluating the characteristics of the flood for which the facility is designed (return period, past events considered, their location and the reasons for this choice, the margins added, etc.); flooding sources considered (tsunami, tide, storm, dam burst, etc.); validity of historical data.*

ASN also asked the licensee to state its position regarding whether the facility flood level design is adequate.

For the design of the flood protections, the sites use fundamental safety rule RFS I.2.e of 12th April 1984 ("Consideration of the off-site flood risk"). This text in particular defines a method for determining the water levels to be considered when designing the facilities. This method is based on the definition of the flood safety margin level (CMS) and differentiates between three cases:

1. For coastal sites, the CMS corresponds to the combination of the maximum calculated tide (coefficient 120) and the thousand year storm surge.

2. For river sites, the CMS (or CBMS) is the higher of the following two levels:
   - Level reached by a river whose discharge is obtained by increasing the thousand year flood level by 15%;
   - Level reached by a combination of the highest known flood waves, or the hundred-year flood level if higher, and collapse of the most restrictive retaining structure.

3. For estuary sites, the CMS is the highest of the following three levels:
   - Level reached by a combination of the thousand year river flood level and the tide of coefficient 120;
   - Level reached by the combination of 2.b and a tide of coefficient 70;

- Level reached by the combination of the thousand-year marine surge and the tide of coefficient 120;

Following the partial flooding of the Le Blayais nuclear power plant in December 1999, EDF updated its CMS evaluation of all the sites and systematically took account of other hazards liable to cause flooding:

1. For all the sites:
   - the deterioration of a water storage structure (pipeline, air cooling tower ponds, water storage ponds, etc.) close to the site, for which the waterline is higher than the platform of this site;
   - the intumescence[19];
   - high intensity rainfall (hundred-year return period) and regular and continuous rainfall (maximum hundred-year averages over 24 hours);
   - a rise in the groundwater level;
   - failure of a system or equipment item.

2. For river sites:
   - influence of the wind on the river or the chop (determined for a hundred-year wind).

3. For coastal sites:
   - wave swell

EDF also considered certain hazard combinations taking account of the degree of interaction between these phenomena, the order of magnitude of the frequency of occurrence and the potential risks associated with the various hazards or combinations thereof. The following were thus taken into consideration:

1. For river sites:
   - thousand-year flood and chop;
   - high-intensity rainfall and medium discharge river;
   - regular and continuous rainfall and hundred-year flood level;
   - intumescence and various flood situations.

2. For coastal sites:
   - the CMS (as defined by RFS I.2.e for coastal sites and recalled previously in this report) and a hundred-year wave swell;
   - high-intensity rainfall and mean tide high water level (coefficient 70);
   - regular and continuous rainfall and overall hundred-year sea level (including storm surge and tide);
   - intumescence and various flood situations.

EDF has also taken into account the possible damage to structures (located above the sites or on the platform, such as channel embankments, reservoirs, dams, tanks, etc.) as well as damage to systems or equipment (mainly those associated with the pumping station, the circulating water intake and discharge channel and the CRF[20] system) which could lead to the presence of large volumes of water on the site platforms). For the channel embankments and reservoirs, EDF is studying their behaviour in response to the following hazards: earthquake, airplane crash and off-site hydrocarbon explosion.

This method complementing RFS I.2.e was evaluated by IRSN. After obtaining the opinions of the advisory committees in December 2001 and March 2007, ASN considered this methodology to be on the whole satisfactory.

[19] Free surface deformation wave caused by a sudden variation in the speed of (discharge) flow. Phenomenon comparable to fluid "hammers" in a pipe. Known as "positive" intumescence when there is a sudden reduction in speed, and conversely "negative" intumescence when there is a sudden increase in speed. It can be observed at sudden stoppage/startup of the units on a run of river hydroelectric plant, or CRF pumps on a once-through PWR nuclear power plant intake channel.

[20] CRF: circulating water system

However, ASN did ask EDF to revise its studies concerning a system or equipment break hazard and to supplement the methodology for characterising the high-intensity rainfall hazard, to ensure that the protection measures for these two hazards are sufficient.

Additionally ASN has submitted specific requests concerning the sites of Belleville and Tricastin:

- *The Belleville CMS considered by EDF does not cover the significant influence of the Strickler coefficient*[21]*. If the calculation does take account of this influence, then it leads to a higher water level, estimated at 47 cm by EDF. However, EDF did not update the CMM value accordingly. ASN asked EDF to update the Belleville CMM value to take account of the uncertainty surrounding the Strickler coefficient.*
- *The Tricastin CMS needs to be revised to take account of failure of the Vouglans dam. EDF presented new studies in 2008 giving the water level at the Tricastin site in the event of failure of the Vouglans dam. In its hypotheses, EDF postulated a median water level (in other words reached 50% of the time) in the Vouglans dam at the time of its failure. ASN considers this hypothesis to be insufficiently conservative and asked EDF to take account of a higher water level in the Vouglans dam at the time of its failure in its CMS calculation for the Tricastin site.*

The following table presents the current CMS level with regard to the elevation of the nuclear island platform:

	Current design							
	Ref Level	**Current CMS level**	**Location**	**Current design hazard**	**Elevation of the nuclear island platform**		**Elevation of lowest access threshold for buildings classified important for safety (IPS)**	
Blayais	NGFN	5.11		Thousand year storm surge + tide 120	4.50	On 30/06/2011	4.41	With infinite settling
Belleville	NGFO	142.06	At the NI	CMM	141.55	on 30/06/2011 (settling stabilised)	141.73	on 30/06/2011 (settling stabilised)
Bugey	NGFO	197.37		REB	197.00	on 30/06/2011 *(no settling of the PF)*	196.92	on 30/06/2011, settling stabilised
Cattenom	NGFN	155.61	At the NI	CMM	171.00	On 30/06/2011	170.90	On 30/06/2011
Chinon	NGFO	37.40	At the NI	CMM + failure of Val d'Authion dyke	37.20	On 30/06/2011	37.22	With infinite settling
Chooz	NGFN	109.54	At the NI	CMM	114.7	on 30/06/2011	114.65	on 30/06/2011 (settling stabilised)
Civaux	NGFN	75.80	At the NI and water intake	REB	76.7	on 30/06/2011 (settling stabilised)	76.77	on 30/06/2011 (settling stabilised)
Cruas	NGFO	80.60	Cruas Plain	REB	80.50	on 30/06/2011 (settling stabilised)	80.50	on 30/06/2011 (settling stabilised)
Dampierre	NGFO	125.69		CMM	125.50	on 30/06/2011	125.46	With infinite settling
Fessenheim	NN	206.26 215.89	Alsace Plain GCA	CMM	205.50	on 30/06/2011	205.47	on 30/06/2011, settling stabilised
Flamanville	NGFN	7.79		Thousand year storm surge + tide 120	12.40	on 30/06/2011	-	N/A
Gravelines	NGFN	6.12		Thousand year storm surge + tide 120	5.52	on 30/06/2011 (settling stabilised)	5.51	With infinite settling
Golfech	NGFN	61.38	At the NI	CMM	62.22	on 30/06/2011	62.17	on 30/06/2011

[21] Coefficient representative of the roughness of the river bed

Nogent	NGFN	66.07	At the NI	REB	68.15	on 30/06/2011	68.05	With infinite settling
Paluel	NGFN	7.40		Thousand year storm surge + tide 120	25.30	on 30/06/2011	-	N/A
Penly	NGFN	7.74		Thousand year storm surge + tide 120	12.00	on 30/06/2011	-	N/A
Saint-Alban	NGFO	147.46		REB	147.00	on 30/06/2011	147.05	With infinite settling
Saint - Laurent	NGFO	83.47		CMM	83.65	on 30/06/2011	83.58	With infinite settling
Tricastin	NGFO	50.90 59.56	Rhone low water channel[22] Donzère Canal	CMM	52.00	on 30/06/2011	51.85	With infinite settling

NGFN: French normal general datum system / NGFO: Orthometric datum system / CMS: flood safety margin level / CMM: maximum thousand year flood / REB: dam burst or collapse / GCA: Grand Canal d'Alsace / NI: Nuclear Island / N/A: not applicable

In parallel, ASN and IRSN launched a revision of RFS I.2.e concerning the inclusion of the flooding risk, taking account of all the work done since the flood at the Le Blayais nuclear power plant. The new guide for BNI protection against the flooding risk will concern the choice of hazards liable to lead to flooding of the site and the methods for characterising them all. This draft guide was the subject of a consultation in June 2010, broadened to include the general public (www.asn.fr). After consideration of the remarks collected, the guide will be submitted to the advisory committees for their opinion. They will be meeting in May 2012. ASN aims to distribute this new guide in 2012.

1.2.1.2 - Measures to protect facilities from the flooding risk, included in the design process

In its CSA specifications, ASN asked EDF to describe the steps taken to protect the facility in the event of a CMS.

ASN in particular asked EDF to identify the structures, systems and components (SSC) which must remain available after a flood to ensure a safe state, including the steps taken to ensure the operation of the pumping station and the measures to guarantee the back-up electricity supply.

ASN also asked EDF to identify the main design measures to protect the site against flooding (level of the platform, of the embankment, etc.). In addition, ASN asked EDF to clarify the main operating provisions (including emergency procedures, mobile equipment, etc.) for issuing an alert of an imminent flood and then for mitigating the consequences of the flooding.

Material provisions

In its CSA reports, EDF indicates that the elevation of the site platforms was set according to the water height initially calculated. It should be noted that RFS I.2.e was published in 1984 and certain elevations were therefore calculated using different methodologies. Since the design of the sites, these heights have thus been re-evaluated to take account of:

- evolution of the calculation rules (publication of RFS I.2.e for example);
- a broader range of data;
- changes in available knowledge (modelling techniques for example);
- operating experience feedback from the incident at Le Blayais in 1999.

The following table shows some of the steps taken by EDF to protect the plants against the risk of flooding (flood, dam burst, rainfall, etc.):

[22] The low-water channel, or ordinary bed designates the space occupied permanently or temporarily by a water course. The flood plain is differentiated from the low-water channel, which is the zone limited by the banks. The flood plain is the space occupied by the water course when in flood.

	Existing protection
Blayais	Embankments
Belleville	Peripheral embankments
Bugey	Protective embankments and walls
Cattenom	Platform elevation
Chinon	Flood gates (cofferdams)
Chooz	Platform elevation
Civaux	Platform elevation
Cruas	Banks of the Rhone + Northern periphery wall
Dampierre	East and South protection embankments
Fessenheim	GCA Protection bank and embankment
Flamanville	Platform elevation
Gravelines	Intake channel walls and embankments
Golfech	Platform elevation
Nogent	Platform elevation
Paluel	Platform elevation
Penly	Platform elevation
Saint-Alban	North and East wall
Saint-Laurent	Platform elevation
Tricastin	"Gaffière" stream protections and Donzère canal embankments

In its CSA reports, EDF presented the steps taken to protect the sites against flooding. These steps are based on the approach adopted by all the sites following the partial flooding at Le Blayais ("Le Blayais operating experience feedback" approach). EDF conducted a safety analysis for each site, drawing up a list of systems and equipment necessary to reach and maintain a safe state.

For all of the sites, EDF also took account of all the support systems contributing to their operation (electricity sources, I&C, fluids) and certain air-conditioning or ventilation systems. The CSA reports give the list of these systems and equipment for each of the sites.

EDF has differentiated between two equipment categories: that of the nuclear island and that of the pumping station. In order to reach a conclusion on the absence of water in the premises housing the equipment to be protected in the event of flooding, EDF has adopted a two-step approach:

1. EDF compared the water height liable to be reached at the various possible water inlet points (or by-pass);
2. EDF mentioned the material and operating measures aimed at protecting the facility against the flood level for which it is designed.

The material provisions concern the following fields:

- civil engineering: construction of protective walls, raising or reinforcement of embankments, installation and repair of seals between buildings, installation of pumping systems, raising of equipment, installation of thresholds, etc.
- mechanical: installation of specific equipment (sluice gates, watertight doors, closures), modification of existing equipment (for example increase in pump capacity or installation of non-return valves), and so on.
- electrical and I&C equipment: raising or relocation of the electrical equipment (in particular I&C), installation of automatic systems or shutoffs (for example for the closures), installation of electrical backups for certain equipment, transmission of alarms to the control room, etc.

Subsequent to the evaluation of this "Le Blayais operating experience feedback" approach, and the opinion of the advisory committees in March 2007, ASN considered that the steps planned or already in place on the sites represented significant progress in terms of safety and should provide the power plants with a sufficient level of protection against off-site flooding.

However, certain modifications and tasks defined by the "Le Blayais operating experience feedback" approach have yet to be carried out. These modifications primarily concern work to guarantee the peripheral protection of the Cruas and Tricastin sites in the event of the maximum thousand year flood and dam burst, finalisation of the peripheral protection work on the Saint-Alban site, raising and strengthening of the wave protection at Gravelines, installation of an automatic pumps shutdown controller for the circulating water system (CRF) on certain sites, electrical back-up for the plant sewer system (SEO) pumps on the Gravelines and Le Blayais sites and installation of door threshold sills at the entrance to certain buildings on some of the sites.

To ensure that this work is completed as rapidly as possible, this issue is the subject of an ASN requirement which demands conformity by all the sites no later than the end of 2014.

Furthermore, in order to prevent any ingress of water into a perimeter encompassing the buildings containing equipment required to guarantee reactor safety (equipment necessary for emergency shutdown and for maintaining a safe shutdown state in the event of off-site flooding), EDF has set up volumetric protection (VP) on all sites. This perimeter encompasses at least the infrastructures of the premises to be protected (in this case, the perimeter of the VP excludes level +0.00 m); on certain sites, it is extended above level +0.00 m. The choice of the contour takes account of the specificities of each site or the construction constraints. The perimeter of the VP consists of the outer walls as a whole: walls, floors and ceilings. These walls may comprise openings which could compromise the role of the VP if not watertight (doors, openings, hatches); measures are thus taken accordingly to ensure their watertightness.

Operating measures

In addition to the material provisions, EDF presented its operational measures for each site, aimed at protecting the facility against the flood level for which it was designed. The operating measures comprise:

- alert systems in the event of a foreseeable hazard (failure of a retaining structure upstream of the site, riverside or coastal flooding, possibly combined with extreme winds, rainfall) liable to lead to flooding of the site. These alert systems comprise several surveillance levels: maximum of four phases (watch, vigilance, pre-alert and alert). Depending on the risk to the site, there are not always 4 phases;
- agreements with organisations within or outside EDF (Météo France, prefecture, etc.) in order to obtain forecasts concerning the above hazards.
- special operating rules in the event of a flood (flood RPCs) which are based on alert systems in order to anticipate the steps to be taken to protect the sites in the event of a flood (during the flood rise and fall phases) as well as to prepare for the possible transition to emergency shutdown state. These RPCs in particular make it possible to anticipate and manage the possible isolation of the site;
- local procedures (in particular clarifying the flood RPCs).

These operating measures are determined according to both the vulnerabilities of the sites and the feared events in the case of flooding, that is isolation of the site, loss of off-site electrical sources, loss of the pumping station and flooding of the site platform.

Given the lack of vulnerability of some sites, EDF concluded that it was not necessary to install an alert system on them.

For those sites concerned by flood RPCs, ASN checked their implementation during targeted inspections between June and October 2011; on this occasion, ASN observed that the flood RPCs had not been applied on certain sites (Chooz, Cruas, Nogent, Tricastin, Dampierre, Gravelines)[23], even though they radically alter the flooding hypotheses (for example, at Tricastin, the site is now considered potentially subject to isolation and exposed to a LOOP), which is not the case in the current procedures.

ASN required that EDF adapt the organisation on the Cruas and Tricastin sites to deal with isolation in the event of flooding, by 31st December 2012.

Finally, in its CSA specifications, ASN asked EDF to clarify whether other effects, either linked to the flood itself or to the phenomena which triggered the flood (such as very poor meteorological conditions) were considered, in particular the loss of off-site electrical power, the loss of the water intake (effect of debris, of hydrocarbon slicks, etc.) and the situation outside the facility, including complete blockage or delay in access to the site by personnel and equipment.

In the CSA reports, EDF stated that loss of off-site electrical power (in particular as a result of a storm) and of the water intake (which could result from the massive arrival of clogging material or hydrocarbon slicks) were taken into account. The analysis led EDF to propose additional studies and material and operating measures for certain sites (for example: raising the level of the switchyard on certain sites).

1.2.1.3 Conformity of facilities with existing safety requirements

In its CSA specifications, ASN asked EDF to describe the general organisation set up to guarantee conformity (periodic maintenance, inspections, tests, etc.); ASN in particular asked EDF to describe the organisation enabling EDF to ensure that the mobile equipment outside the site, provided for in the emergency procedures, is available and remains in good working condition. Any anomalies observed, and the consequences of these anomalies in terms of safety, as well as the programming of remedial work or compensatory measures, were to be specified. Finally, ASN asked EDF to submit the conclusions of the specific conformity examinations already initiated following the accident in the Fukushima nuclear power plant.

In its CSA reports, EDF stated that the flood protection conformity of its facilities is based on:

- periodic surveillance through periodic tests or inspections as part of the preventive maintenance programmes on equipment contributing to protection, identified in the design studies;
- monitoring and management of VP.

With regard to the periodic inspections carried out on the equipment contributing to flood risk protection, EDF has stated that the monitoring or maintenance programme for certain equipment items was in the process of being deployed on certain sites. The equipment concerned constitutes the lines of defence against off-site flooding.

ASN thus considers that these monitoring and maintenance programmes must be implemented as early as possible, in order to guarantee the availability, integrity and correct operation of the measures adopted in the event of a flood.

EDF stated that the monitoring and protection of the VP, designed to provide a long-term guarantee of its watertightness at all times, is based on the following two checks:

- verification that there is no deterioration of the watertightness of the VP over time: the various components of the VP undergo maintenance, as identified in the basic preventive maintenance programmes (PBMP).
- a VP management rule, which must be applied to all the sites, in order to ensure real-time monitoring of VP tightness breaks: both planned and unforeseen.

During the targeted inspections conducted in June and October 2011, ASN observed numerous deviations regarding the monitoring, maintenance and perimeter of the volumetric protection. For example:

- *the conformity work decided on subsequent to the Le Blayais operating experience feedback, which was to have been completed in 2007, is not finished on all the sites;*

[23] For Chooz, the notification of modification pursuant to article 26 of decree 2007-1557 of 02/11/2007 was filed by EDF and is currently being examined by ASN. For Nogent and Tricastin, the process is ongoing.

- *some sites notified deviations observed between the VP perimeter identified in the EDF national level report and the actual situation on the site;*
- *some sites notified the fact that it was impossible to test the "waterstop"[24] seals which are a key part of the VP. For example, the Cattenom site declared a significant safety-related event (ESS) regarding flooding of the fuel oil tank room, partly owing to a loss of tightness of the "waterstop" seals;*
- *the identification of equipment and structures at the VP limits is absent on some sites;*
- *the day-to-day management and monitoring of the VP are not always carried out correctly, sometimes even not at al.*

Following the submission of the CSA reports, EDF has made the following commitment:

"The VP conformity remediation work will be completed on all the NPPs before the end of 2011.

With regard to the operational monitoring of the volumetric protection components, EDF confirms that the national VP management requirements will be effectively applied on all sites by end of March 2012.

The problem of the WATERSTOP seals observed at Cattenom has already been dealt with by a conformity remediation action. The maintenance programme for these seals will be reviewed on the basis of this experience feedback.

EDF has also conducted an initial analysis of the feedback from the inspections on the Flooding topic. Based on this initial analysis, EDF considers that the nature of the findings is not such as to compromise the safety of the units concerned.

By the end of March 2012, EDF will carry out an overall analysis of the findings of the "Post-Fukushima" inspections or the points raised by the NPPs regarding volumetric protection. EDF will then present:

- the reactive measures already taken by the NPPs,
- the strategy for dealing with findings of a generic nature,
- the solutions provided to the requests for extension of the current volumetric protection perimeter."

ASN considers that the measures proposed by EDF are satisfactory.

Given that VP plays a key role in protecting the plants against the off-site flooding risk and that the deviations observed are such as to compromise certain conclusions of the CSAs, ASN will be requiring that EDF implement rapid conformity remediation work.

In particular, with regard to the waterstop seals, EDF considers that these cannot be subjected to watertightness testing. EDF therefore presented a strategy consisting in examining the stresses and displacements generated by differential settling of the buildings, for all the seals. Where the design of the seals does not enable them to deal with the corresponding displacements and stresses, EDF installed additional tightness strips on the inner wall side.

ASN considers that EDF did not take account of seal ageing in its approach. ***Monitoring of the "waterstop" seals is a key factor in ensuring the effectiveness of volumetric protection, so ASN asked EDF to demonstrate the effectiveness of its strategy and draw up a list of the sites for which an additional system needs to be deployed.***

EDF has also initiated a specific reliability review in accordance with the conclusions of the 2001-2 SOER report (*Significant Operating Experience Report*) issued by WANO (*World Association of Nuclear Operators*). *ASN noted that when the licensee identified particular findings, it presented corrective measures.*

[24] Tightness of the expansion joints in the concrete walls (water stop strip)

ASN considers that these corrective measures are satisfactory; however, EDF needs to set a deadline for each one.

1.2.2 Evaluation of safety margins

1.2.2.1 Estimation of margins in the event of flooding

In its CSA specifications, ASN asked EDF to state the flood level the facility could withstand without damage to the fuel (in the reactor vessel or in the pool) and the levels leading to the initiation of accident situation measures. EDF was able to call on the available information (and take account of the studies to confirm the engineer's assessment).

In its CSA reports, for the various hazards considered for each site, EDF presented the margins - when available - between the flood level reached and the level of the protections, for the purposes of the current design and, as applicable, reached a conclusion regarding any additional measures to be taken.

This information offers a satisfactory response to the ASN request.

EDF also studied a number of situations which it feels are representative when evaluating cliff-edge effects. These cases are summarised below. They assume hypotheses going beyond the design-basis, contrary to what was presented hitherto in this part of the report devoted to flooding.

In its CSA reports, EDF analysed three types of cliff-edge effects that could be triggered by a flood:

1. Flood causing the loss of site heat-sink (LUHS situation), initiated by a rise in the water levels leading in turn to loss of the back up circulating water filtration system (CWFS) then submersion of the essential service water system (SEC) pumps. For certain sites, the loss of the SEC pumps occurs before the loss of the filtration system. In its CSA reports, EDF stated that:
   - the loss of the filtration system on the sites equipped with rotating drum screens would imply long-term unavailability of some devices on the filtration system, although without leading to a certain loss of the function,
   - the loss of the chain screen drive motors could lead to long-term unavailability of filtration. In this case, the risk of an LUHS situation through clogging cannot be ruled out. For the Fessenheim plant, the pumping station is situated at a higher altitude than the site platform, so the essential back up service water system can function by gravity in the event of flooding.

2. Flood causing a LOOP (loss of off-site power) situation resulting from a loss of equipment through submersion initiated by at least one of the following events:
   - loss of all the off-site power substations (HV line outgoing feeders) through equipment submersion. This scenario can directly affect an entire site (except if special corrective measures are taken).
   - loss of transformers supplying the safety auxiliaries from the off-site grid, these transformers being located inside the site:
     i. directly at the output from the generation unit (main transformers and step-down transformers),
     ii. auxiliary transformers (supply circuit separate from that of the main and step-down transformers).

3. Flood causing total loss of the electricity sources (SBO situation) associated with the possible loss of the reactor back-up systems, this type of effect being initiated by the presence of a layer of water on the nuclear island platform.

With regard to flooding caused by an earthquake bigger than design-basis, EDF identified critical cliff-edge effects owing to the positioning of the structures concerned, which are liable to constitute potential sources of flooding following an earthquake of intensity higher than the SSE. Depending on the sites, these cliff-edge effects are the arrival of a layer of water on the nuclear island platform exceeding the building access thresholds, which would lead to an SBO situation, or the arrival of a layer of water causing submersion of the auxiliary transformers, which would lead to a LOOP type situation.

In its CSA reports, in order to evaluate the robustness of the facility to cliff-edge effects, EDF:

- identified the cliff-edge effects caused by off-site flooding and calculated the corresponding water levels;
- conducted "beyond design-basis" sensitivity analyses, by increasing certain current design scenarios by a fixed amount;
- compared the water levels reached for each of the increased scenarios with the water levels leading to cliff-edge effects;
- proposed studies to confirm the existence of the cliff-edge effect or the steps to be taken to reinforce the robustness to such a cliff-edge effect.

Scenarios adopted

EDF considered the following scenarios, according to the geographical situation of the site:

1. For all the sites:

Scenarios adopted by EDF	***ASN standpoint***
Maximum high-intensity rainfall (PFI): PFI rainfall intensity used in the design, doubled	*ASN considers that a factor of 2 corresponds to a correct order of magnitude for reaching a hazard that is significantly more penalising than that of the current safety requirement baseline. However, ASN considers that the duration adopted is in principle not sufficiently penalising, given the saturation of the rainwater networks.* *ASN considers that EDF's commitment to a sensitivity study for rainfall times longer than the network concentration time is satisfactory.*
Combination of a PFI lasting 60 minutes with complete blockage of the site's SEO rainwater drainage network outlets	*ASN considers than in the CSAs, this combination can go significantly beyond the rainfall levels currently adopted for the sites. This combination is a means of identifying the flooding levels as of which cliff-edge effects appear and thus meets the requirements of the CSA specifications.*
Flooding caused by an earthquake bigger than design-basis: identification of the structures present on or directly above the platform and liable to constitute potential sources of flooding following an earthquake of an intensity greater than the SSE, if the structure or equipment is not considered robust to an earthquake beyond design-basis. During the investigation, EDF made the following commitment: "In order to complete the analysis of the flood risk caused by an earthquake "beyond baseline safety standards", presented in the RECS (complementary safety assessment report), EDF will by the end of 2012 evaluate the risk of damage to the walls surrounding the cooling towers on the four sites concerned, on the basis of: • the effective distance between wall and cooling tower, • the possibility of justifying the absence of significant damage to the cooling tower shell for earthquakes bigger than the SSE If damage of the wall following collapse of the cooling tower under the effect of an earthquake "beyond baseline safety standards" cannot be avoided, the effects in terms of induced flooding will be analysed. As applicable, additional measures will be proposed in order to guarantee protection of the equipment in the "CSA hard core".	*ASN considers that the study approach proposed by EDF would appear to be satisfactory.* *ASN considers that the approach adopted by EDF and the undertaking made, provide a satisfactory response to the CSA specifications.*

2. For coastal sites, EDF chose a CMS scenario (combination of the maximum level of the astronomical tide and the thousand year storm surge) plus an additional increase of 1 metre (which, according to EDF, corresponds to a storm surge with a return period between one hundred thousand and one million years). *ASN considers that the additional 1 metre adopted by EDF to characterise the marine hazard for coastal sites in the CSAs goes significantly beyond the marine levels currently utilised for these sites and thus meets the requirements of the CSA specifications.*

3. For river sites:

Scenarios adopted by EDF	***ASN standpoint***
Augmented river flood: 30% increase of the CMM rate of flow Moreover, following submission of the CSA reports and on the occasion of the examination of these reports by IRSN, EDF made the following undertaking: "For sites on which the platform is currently considered to be above water level in the case of a maximum river flood scenario, particularly Tricastin and St Alban, EDF will examine (by end 2012) whether any phenomena induced by this type of flood on the behaviour of hydraulic structures are liable to lead to a revision of the levels adopted in the initial evaluations. The conclusions of this complementary analysis will be taken into account for the protection of the equipment in the "CSA hard core". For the particular case of the Tricastin NPP mentioned in the IRSN recommendation, EDF underlined the fact that the planned modifications to the Donzère-Mondragon hydraulic facility, to guarantee site protection against the CMM, provides for the creation of a emergency safety device (lateral spillway on the right bank) designed to limit the level in the canal, including in the event of a malfunction of the facility's hydraulic systems."	*ASN considers that the 30% increase in the river flood adopted by EDF in its CSA reports goes significantly beyond the river flood levels currently used for its sites and thus meets the requirements of the specifications.* *The results given in the CSA reports are however to be considered in the light of significant uncertainties surrounding these initial evaluations. The behaviour of hydraulic structures in the case of the maximum river flood scenarios would need to be examined in greater detail, in particular for the Tricastin and Saint-Alban sites.*
Earthquakes initiating dam bursts (including Le Blayais): EDF proposes performing additional studies on an earthquake initiating a dam burst (to confirm that the site protections against the flooding caused by this dam burst cannot be destroyed by the earthquake) and on an earthquake liable to cause several dam bursts (to confirm that the site flood protections are sufficient). During the investigation, EDF made the following commitment: "For the purpose of the studies concerning the effects of dam bursts caused by an earthquake "beyond baseline safety standards", mentioned in the RECS, EDF will consider the induced risks to the equipment in the "CSA hard core" by multiple dam bursts situated in the same valley."	*ASN considers that the approach adopted by EDF and the undertaking made, provide a satisfactory response to the CSA specifications.*

4. EDF also studied other augmented scenarios when considering the flooding induced by an earthquake beyond design-basis or specific site characteristics, in particular flooding caused by the loss of integrity of the SEA circulating water ponds (Flamanville, Penly and Paluel); concerning the collapse of the SEA ponds on the three sites, EDF considers that the stability of the ponds is guaranteed for an earthquake bigger than the SSE.

ASN considers that this approach is satisfactory, provided that the tightness of these ponds is guaranteed, in particular as EDF considers the SEA pond to be the emergency make-up source.

Water heights resulting from the augmented rainfall scenarios and earthquakes beyond design-basis

EDF calculated the water level resulting from the augmented scenarios, considering the protections implemented on the site for protection against the design-basis hazards, including those for which implementation is planned subsequently (for example 2014 for Cruas and Tricastin).

ASN considers that this approach does not conform to the CSA specifications and that EDF needs to take account of the real status of the facilities as at 30th June 2011.

The consequences of the reference flood augmentation scenarios vary widely. The nuclear island platforms of some sites would remain above water level. For the others, the flooding could reach up to about two metres on the nuclear island platforms. For a certain number of riverside sites, EDF considers that the water height estimates, based on extrapolations from existing studies or models, would need to be consolidated.

The consequences of each of the two rainfall scenarios are on the centimetre scale. Depending on the site, EDF considers that the volumes of water associated with each of the two maximum rainfall scenarios are either contained by the roadways or liable to cause a layer of water a few centimetres high on the nuclear island platforms.

With regard to the flood scenarios induced by an earthquake beyond design-basis, the water levels obtained are of the centimetre or decimetre scale, in certain cases. However, depending on the sites, EDF estimates that:

- either the risk of flooding can be ruled out because the platform on which the failed structure is situated is well below the nuclear island platform,
- or the associated water volumes are contained by the roadways,
- or the associated water volumes are liable to create a layer of water a few centimetres high on the nuclear island platform.

EDF was unable to issue a final statement for all the sites concerning the consequences of this type of hazard in the situations considered. Further studies are still required.

Evaluation of the water heights induced by these three scenarios is based on the principle of calculating the spreading of the volume of rainwater not evacuated by the network.

ASN considers that certain hypotheses need to be checked (hydraulic, topographical hypotheses) and that the studies are not sufficiently conservative to cover the dynamic flow effects. Additional data would seem to be necessary to justify the spreading hypotheses as well as the hydraulic hypotheses utilised in the studies, in particular those concerning blockage of the drains[25].

For certain sites, EDF considers that the volumes of water induced by these three scenarios will be contained by the roadways of the site platforms. For the others, the water elevation is compared with the building access thresholds. In the event of an LUHS, LOOP or SBO risk, EDF proposes studying the plausibility of a water layer risk on the nuclear island platforms and, as applicable, the main/step-down transformers. During the investigation, EDF specified that these studies will retain the water layer spreading hypothesis, but will enable the conservative nature of the current evaluations to be reduced.

[25] System primarily designed to collect run-off water and channel it to the sewer network

However, ASN considers that the uncertainties surrounding the hydraulic and spreading hypotheses adopted by EDF can lead to flood heights in excess of those presented, therefore the margins should not be calculated down within one centimetre.

At the meeting of the advisory committees in November 2011, EDF made the following undertaking, which offers a satisfactory response to the CSA specifications:

"The influential parameters listed (duration of precipitation, absorption and drainage capacity) are considered beyond the baseline safety standards with a view to verifying protection of the "Hard Core" equipment". In order to initiate the studies announced in the RECS, aimed at providing a more detailed characterisation of the layers of water induced by the "PFIx2", "PFI+SEO blockage", and "flooding induced by an earthquake bigger than design safety standards" scenarios, EDF intends to define and justify the various hypotheses utilised (land absorption capacity, evacuation flows to off-site land, spreading hypotheses, consideration of dynamic effects, consideration of topographical data). Furthermore, concerning the maximum scenario "PFIx2", a sensitivity study concerning the duration of precipitation greater than the network concentration time will be performed".

With regard to the envelope nature of the scenarios utilised, ASN considers that the approach adopted by EDF clearly aims to define maximum augmented hazards covering all the phenomena which could lead to or contribute to flooding, by examining supplementary scenarios for certain sites.

The analysis supplied by EDF in the CSA reports, presenting cliff-edge effects induced by the flooding risk, complies with the ASN request.

Special case of embankments

Following the meeting of the advisory committees in July 2011, the purpose of which was to examine the methodology proposed by the licensees for performance of the CSAs, ASN asked EDF to examine the consequences of a failure of the embankments along the Grand Canal d'Alsace close to the Fessenheim site, as well as those of the Donzère canal close to the Tricastin site.

Concerning the consequences of a failure of the Donzère-Mondragon canal embankment for Tricastin and the failure of the Grand Canal d'Alsace embankments for Fessenheim, EDF provided an answer which should be considered preliminary owing to the lead-times associated with the CSAs.

With regard to Tricastin, whether the failure is on the left bank or the right bank of the Donzère-Mondragon canal embankments, EDF considers that the existing peripheral protections (sluice-gates, watertight screen) would prevent flooding of the NPP platform.

With regard to Fessenheim, the consequences of a failure of the Grand Canal d'Alsace embankments would be the presence of a layer of water on the site, liable to lead to a scenario involving total loss of the off-site and on-site power supplies, as well as the potential loss of other nuclear island equipment.

Whether for Fessenheim or Tricastin, EDF underlines the absence of any precise study data today available for the height of this layer of water. In the RECS, EDF proposed:

- conducting a detailed examination of the ability of the embankments to withstand a level higher than the SSE and to determine a flood flow to be considered beyond the design-basis,
- in the light of the results, initiating calculation of the corresponding flood fields,
- If necessary, defining and implementing the appropriate material and organisational countermeasures to prevent the feared situations considered in this kind of analysis, namely significant releases into the environment (for the reactor building case), and fuel uncovering (for the fuel storage building case).

ASN considers that EDF's undertaking responds in part to its request and that EDF will need to conduct studies giving a precise indication of the water level on the Tricastin site in the event of failure of the Donzère-Mondragon embankments and on the Fessenheim site in the event of failure of the Grand Canal d'Alsace embankments and to evaluate the resulting consequences. ASN has asked EDF to submit a study to it before 30th June 2013, stating the level of seismic robustness of the embankments and the other structures protecting the facilities against flooding and, according to this level of robustness, presenting:

- ***the consequences of a failure of these structures,***
- ***the technical solutions envisaged to protect the hard core equipment.***

<u>Strength of the Tricastin embankments</u>

The Tricastin Nuclear Power Plant (NPP) is situated alongside the Donzère canal in Mondragon (right bank), to the east of the Rhone river, within the Tricastin nuclear site, which in particular comprises various facilities devoted to the fabrication of nuclear fuel. Cooling of the Tricastin NPP relies on a once-through circuit supplied by the water of the Donzère - Mondragon canal diverted from the Rhone river.

EDF has identified two hazards liable to lead to flooding of the site, following failure of the embankments of this canal: earthquake and CMM.

<u>In the event of an earthquake</u>, the studies performed by EDF prior to the meeting of the advisory committee in March 2007 concluded that the embankments were stable, subject to effective monitoring and maintenance by their owner, the Compagnie Nationale du Rhône (CNR). Following examination of the dossier, IRSN on the whole confirmed the EDF diagnosis and considered that the two phenomena which could compromise the stability of the embankments are liquefaction and internal erosion at the singularity level of the embankment body. Concerning the liquefaction risk, piezometry (water height in the embankments) is an essential parameter.

ASN considers that the current level of embankment monitoring is inadequate and incapable of accurately characterising the piezometry of the canal embankments.

Consequently, ASN considers:

- *with regard to the internal erosion risk, EDF will need to identify the local singularities (pipes or buried structures, transition sector between two different types of embankments, etc.) and, as necessary, work will need to be carried out to eliminate the risk of internal erosion in these sectors;*
- *pending a study on the vulnerability of the section of the right bank of the embankment, EDF will have to conduct a geotechnical[26] survey of its component materials and monitor its piezometry;*
- *given the safety issues associated with the resistance of the embankments of the Donzère-Mondragon structure, EDF must check with the CNR that the monitoring and upkeep of these embankments guarantees the long-term effectiveness of their drainage, along with the absence of any disorders. EDF shall in particular ensure that this monitoring is able to confirm the effectiveness of the piezometric device.*

These actions also aim (in addition to covering the behaviour of the embankment in the event of an earthquake) to ensure the ability of the embankment to withstand a maximum thousand year flood (CMM).

In the event of an SSE and the CMM, ASN considers that the Tricastin NPP is not immune to flooding due to failure of the canal embankments.

<u>In the event of a CMM</u>, the main issue for protection of the Tricastin NPP against the flooding risk concerns the integrity of the Donzère-Mondragon canal structures and maintaining an acceptable water level in the canal, to avoid stressing the embankments beyond their design loadings. The hydraulic facility was designed on the basis of a project flood (9,900 m^3/s) corresponding to a flow rate far lower than the flow rate at present used for protection of the Tricastin NPP (flow rate of 13,700 m^3/s).

[26] Soil survey: in-situ survey and laboratory study to define all the physical, chemical and mechanical characteristics of the soils in place.

Thus, in 2006, EDF and the CNR defined a strategy to protect the Tricastin site, consisting of a combination of several material and operational countermeasures within the Donzère-Mondragon facility.

They consist in:

- raising the low points and locally consolidating the embankment on the left bank upstream of the guard dams and bund walls in the Donzère reservoir, opposite the town of Donzère;
- raising and reinforcing the new navigable channel through the guard dams at the entrance to the canal;
- installation of a cofferdam rapid removal system on a reservoir dam sluice-gate;
- extension of the operating setpoint beyond the "project flood";
- installation of a canal emergency safety device (DSU). This would consist in creating a lateral spillway on the right bank of the canal.

ASN considered this strategy to be satisfactory in principle, provided that the work to implement the countermeasures was performed rapidly. However, ASN asked EDF to provide a certain number of complements and justifications in particular regarding the stability of the structures and the embankments.

These data have not yet been provided and the countermeasures implementation work has not yet started; however, an agreement between CNR and EDF was signed and the work is scheduled for completion by late 2014.

Pending the performance of this work, ASN considers that protection of the Tricastin NPP cannot be guaranteed in the event of a CMM.

On 27th May 2011, in its opinion on the continued operation of Tricastin reactor n°1 after thirty years of operation, ASN issued a requirement for performance of this work before 31st December 2014.

The Fessenheim NPP is located below the right-bank embankment of the Grand Canal d'Alsace (GCA). In the Fessenheim CSA report, EDF recalled that a number of studies had been performed. EDF analyzed four embankment failure modes in these studies, and carried out the following reinforcement work:

- failure by slippage: consolidation of the intake channel closure plug;
- loss of tightness at the seals: protective embankments built around the site (to divert leaks), reinforcement of the site drainage network (to recover any water that percolated through these protective embankments and discharge it downstream) and monitoring of the body of the embankment (to check that there is no saturation, to prevent and detect leaks in a normal situation and after an earthquake) with predetermined alert levels allowing appropriate intervention;
- failure by internal erosion: injections into the embankment;
- failure by overtopping[27] due to settling caused by an earthquake.

ASN considers that the approach adopted by EDF for studying embankment failure is satisfactory. With regard to the state of the embankment and its general understanding, ASN considers that the permanent monitoring and seismic alert measures are appropriate. Similarly, ASN considers that the preventive work completed improves the stability and watertightness of the potentially fragile areas.

[27] Overtopping is the river flowing over the top of the embankment. This generally leads to external erosion and rapidly entails breaching of back-filled structures.

1.2.2.2 Measures envisaged to reinforce the robustness of the facilities to the flooding risk

Based on the results presented above, ASN asked EDF:

- *to state whether additional protection measures can be envisaged or implemented (depending on the time between the alert and the flood);*
- *to indicate the weak points;*
- *to specify any cliff-edge effect [28];*
- *to identify the buildings and equipment that would be flooded first;*
- *to state whether steps could be envisaged to prevent these cliff-edge effects or reinforce the robustness of the facility (design modification, procedural modifications, organisational measures, etc.).*

In its CSA reports, EDF envisages various solutions according to the cliff-edge effect identified and the maximum scenario which led to this cliff-edge effect. The following table identifies the various EDF proposals:

	Maximum flood scenario	**Maximum rainfall scenarios and structural failure scenarios for an earthquake bigger than design-basis**
When a cliff-edge effect linked to an SBO situation is identified	EDF proposed studying a solution to reinforce the protection of the equipment necessary for operation in an SBO situation.	EDF proposed studying the plausibility of a risk of the presence of water on the nuclear island platform. In the light of the results, EDF will determine whether or not additional protection is necessary.
When a cliff-edge effect linked to an LUHS situation is identified	for some sites, EDF proposed studying the need for reinforced protection of the pumping station.	EDF identified no measures allowing reinforcement of the robustness of the facilities.
When a LOOP cliff-edge effect is identified	EDF proposed no measures allowing reinforcement of the robustness of the facilities.	EDF proposed studying the plausibility of a risk of the presence of water on the transformer platform. In the light of the results, EDF will determine whether or not additional protection is necessary.

In its CSA reports, EDF also proposed other measures to reinforce the robustness of the facility:

- a study of the consequences:
  - of a rise in the groundwater level on the structural resistance of the buildings of units 1 and 2 on the Penly site;
  - of a karst flood[29] flood on the lack of buoyancy of the buildings on the Paluel site;
- studies to confirm the ability of the protective embankments to withstand a CBMS+1m under the effect of wave swell;
- studies on the seismic behaviour of the protections in the event of an earthquake initiating dam bursts and studies concerning multiple dam bursts;

[28] Cliff-edge effect: major discontinuity in the scenario, leading to a significant and irreversible worsening of the accident
[29] Flood from the karst (limestone formation in which water has excavated numerous cavities)

- study on the seismic resistance and electrical back-up of the SEO lifting[30] pumps.

For the Tricastin site, EDF proposed carrying out studies on seismic strength and electrical back-up of the SEO rainwater lifting device.

ASN considers that the approach proposed is satisfactory.

For three sites (Tricastin, Fessenheim and Bugey), on which the heat sink is at a higher elevation than the site platform, there is a risk of a major leak in the event of rupture of the cooling systems (CRF) for the facilities connected to them. Although in the examination EDF stated that the valves can isolate the system from the heat sink in all circumstances, a study programme was initiated to improve the robustness of these isolation valves up to a level beyond design-basis, yet to be defined. EDF also stated that "appropriate reinforcement of the door counterweight arms will then be implemented". EDF concluded that as things currently stand, this point does not compromise the safety of the facilities. *However, given the risk of the channel emptying, ASN considers that all the elements (sensors, automation, valves, part upstream of the valves, etc.) preventing the channel draining to the site in the event of a rupture of the cooling system, must be included in the above-mentioned study.*

With regard to the consequences of the various scenarios, IRSN indicated that the orders of magnitude of the water levels obtained on the nuclear island platform are of a few centimetres for the maximum rainfall and flooding scenarios induced by an earthquake beyond design-basis, and up to about two metres on the site platforms for the maximum river flood scenarios.

ASN considers that neither the CSA reports, nor the complementary data presented by EDF during the examination clearly describe EDF's strategy with regard to the cliff-edge effects identified and that the solutions envisaged by EDF to reinforce the robustness of the facility are primarily solutions that would be such as to mitigate the accident (strengthening of the equipment necessary for operation in an LUHS or SBO situation).

ASN estimates that this approach does not offer a satisfactory response to the CSA specifications and that the prevention of cliff-edge effects needs to be strengthened. For example, ASN considers that sufficient raising of the VP would, in most cases, be able to prevent LUHS/SBO cliff-edge effects for the maximum rainfall and flooding induced by an earthquake beyond design-basis scenarios. ***ASN has asked EDF to present, no later than 31st December 2013, the modifications it envisages in order to reinforce the protection of the facilities against the risk of flooding beyond the current baseline safety standards, for example, by raising the volumetric protection, to prevent the occurrence of total loss of heat sink or electrical power supply situations for the maximum rainfall and flooding induced by an earthquake beyond design-basis scenarios.***

In particular on the occasion of the targeted inspections, ASN noted the vulnerability to flooding of the diesel halls on certain sites. For example, on some sites, EDF claims that there are kerbs of about ten centimetres in front of the diesel hall access points. However, on the site, ASN observed that these kerbs are not always present. ASN will be formulating a request on this subject.

Case of embankments on the Tricastin site

EDF states that the seismic resistance of the embankments on the Donzère Mondragon canal are significantly robust beyond the SSE. Given the time available, EDF presented the results of an existing study concerning failure of the embankments along the Donzère-Mondragon canal. According to EDF, the potential consequences are the presence of a layer of water on the site, liable to create an SBO type situation. Among the measures that could be envisaged to reinforce the robustness of the facility, EDF proposed initiating studies defining the steps to be taken as necessary for an earthquake bigger than the SSE.

[30] Pump transferring fluid from one elevation to a higher one.

EDF stated that in the event of a CMM scenario plus 30%, the water in the canal would reach a level very close to the top of the embankment. EDF checked that there would be no overtopping of the embankments in this situation.

As regards the CMM plus 30% scenario, ASN considers it acceptable for EDF to assume that the embankments would be stable in this scenario, provided that:

- *the material and organisational measures planned to guarantee the protection of the Tricastin site against a CMM are carried out;*
- *the embankments are well-maintained and the reservations applicable to them have been lifted (including their guaranteed ability to withstand to a CMM), as requested by ASN in 2007 and 2008;*
- *there is no low point at the top of the embankment below the level reached by the water in this scenario;*
- *there is no internal or external erosion.*

EDF justifies its guarantee of the ability of its embankments to withstand 1.5 times the SSE by the presence in the embankment SSE behaviour studies of choices that EDF qualifies as "conservative margins". However, an analysis of these choices shows that these hypotheses are in fact more realistic than pessimistic.

To conclude, ASN considers that all the elements associated with the embankment studies involving the SSE cannot rule out failure of the embankment for earthquakes with a 50% higher spectrum. To obtain a pertinent opinion on the behaviour of the embankments for an earthquake bigger than the SSE, ASN considers that specific studies are needed.

ASN has asked EDF to submit a study to it before 30th June 2013, stating the level of seismic robustness of the embankments and the other structures protecting the facilities against flooding and, according to this level of robustness, presenting:

- ***the consequences of a failure of these structures,***
- ***the technical solutions envisaged to protect the hard core equipment.***

Concerning the proposal for the Tricastin embankment behaviour studies beyond the SSE, ASN considers that this approach is satisfactory, because it is such as to ensure that there is no cliff-edge effect beyond the SSE. It should be noted on this point that the SSE is not a design-basis case for the embankments. These were not designed and built on a paraseismic basis, but their resistance was verified subsequently. There is thus in principle no particular reason for the SSE associated with the Tricastin NPP to constitute any threshold whatsoever for the seismic behaviour of the embankments.

EDF proposed action meeting the ASN requests and which also concerns the resistance of the embankments to the earthquake included in the baseline safety standards. These elements will be examined.

"Concerning the detailed examination of the behaviour of the Tricastin embankments for earthquake levels higher than the SSE, EDF will indeed take account of the elements mentioned by IRSN, that is:

- the impact of uncertainties concerning the actual composition of the embankments,
- the impact of any local singularities in the embankment deterioration mechanisms,
- the stability of the guard dams in the event of a significant drop in the canal waterline following a left-bank breach.

In this respect, the complementary investigations felt to be necessary (geotechnical survey, improvement of the monitoring system including piezometry of the zones considered to be sensitive) will be initiated subject to prior agreement by the Donzère hydraulic facility concession-holder.

The study sector will also be adapted according to the embankment failure scenarios liable to generate an actual risk of flooding of the platform."

Case of Fessenheim embankments

On the basis of the information in the CSA reports for the Fessenheim NPP, ASN considers that the behaviour of the embankment following an earthquake of a level equal to 1.5 times the SSE, should be acceptable in terms of stability and any leak rates, insofar as the studies have already established satisfactory justification for earthquakes set at 0.2g (far-field quakes) and 0.25g (near-field quakes) and in that preventive work to improve stability and leaktightness has already been carried out in the potentially fragile areas.

With regard to the state of the embankment and its understanding by EDF, ASN considers that the permanent monitoring and seismic alert systems are satisfactory and appropriate. For seismic levels ranging from 0.2g to 0.5g, ASN considers that the countermeasures in place are sufficient so that the consequences of any damage to the embankment, in terms of leaks, remain acceptable for the facility.

ASN also points out that because of the particular behaviour of this type of facility (a localised breach leads to complete failure of the embankment) and over and above any demonstration by calculation, the robustness of the canal embankments is based both on their guaranteed state (good understanding of these embankments, management of any problems) and on their constant monitoring.

Given the time available, EDF presented the results of an existing study concerning failure of the embankments along the Grand Canal d'Alsace. According to this study, the potential consequences are the high water level on the site.

Concerning the embankment failure scenario, regardless of the origin, EDF proposed:

- "Initiating a detailed examination of the ability of the embankments to withstand a level higher than the SSE, and determining a flood flow to be considered above the design level (ignoring completely implausible earthquake levels, in order to define the most appropriate countermeasures.
- In the light of the results, initiating calculation of the corresponding flood fields.
- In the light of these results, defining and implementing appropriate material and organisational countermeasures to prevent the feared situations which are, for this type of analysis […], significant release into the environment by the reactor and uncovering of the fuel assemblies in the fuel building".

With regard to the risk of total collapse of the embankment, regardless of the origin, ASN considers the proposal in the CSA report to be satisfactory and notes the clarification made during the examination:

"The material measures to be taken in this context would concern reinforcement of the robustness of the embankments (prevention) and/or reinforcement of the protection of the equipment necessary for management of an LUHS/SBO situation (mitigation), EDF being unable, as the studies currently stand, to issue a definitive position on the technical solutions to be preferred".

ASN considers that EDF needs to confirm these elements.

1.2.3 Summary: flooding

The CSA analysis shows that the requirements resulting from the complete re-evaluation of how this risk is dealt with in nuclear power plants, completed in 2007, offer the facilities a high degree of protection against the risk of flooding. However, ASN observed that steps aimed at meeting these requirements have not yet all been implemented. ASN required that EDF:

- *within the time allotted following the "flood" review of 2007, and no later than 2014, complete the NPP protective works and measures;*
- *improve the volumetric protection[31] of its facilities. The ASN inspections revealed that management of volumetric protection needs to be improved on several of the sites inspected;*
- *complete the heat sink design review, particularly with regard to prevention of the clogging risks, initiated following the Cruas incident in 2009;*
- *reinforce the protection of the facilities against the risk of flooding beyond the current design baseline, for example by raising the volumetric protection. The CSAs in fact highlighted the existence of cliff-edge effects (total loss of electrical power supplies) at levels close to those adopted in the baseline requirements.*

<u>Definition of a hard core</u>

Furthermore, following the complementary safety assessments (CSA) of the nuclear facilities, conducted in the wake of the Fukushima accident, ASN considers that the safety of the nuclear facilities must be made more robust to highly improbable risks not so far considered in the initial design of the facilities, or following their periodic safety review.

This involves giving these facilities the means to enable them to deal with:

- ***a combination of natural phenomena of an exceptional scale and greater than the phenomena considered in the design or the periodic safety review of the facilities;***
- ***very long duration loss of electrical power or heat sinks capable of affecting all the facilities on a given site.***

ASN thus asked EDF to define, by 30th June 2012, and then deploy a "hard core" of material and organisational measures enabling the fundamental safety functions to be controlled in these exceptional situations and to specify the procedures it has implemented.

These steps would thus guarantee ultimate protection of the installations, with the following three objectives:

- *prevent a severe accident or limit its progression,*
- *limit large-scale releases in an accident scenario which could not be controlled,*
- *enable the licensee to perform its emergency management duties.*

To define the requirements applicable to this hard core, EDF shall adopt significant fixed margins compared to the current baseline safety requirements. The systems, structures and components (SSCs) which are included in these measures shall be maintained in a functional state in the extreme situations studied by the CSAs. In particular, these SSCs shall be protected against the on-site and off-site hazards induced by these extreme situations, for example: falling loads, impacts from other components and structures, fires, explosions. The proposals to be transmitted by EDF will be reviewed by ASN and its technical support organisation.

[31] In a flood situation, the equipment capable of guaranteeing reactor safety must remain operational. Protection systems are thus employed, when necessary, to protect against the various hazards that could lead to flooding. This protection is based on several lines of defence (embankments, walls, water drainage networks, etc.), including volumetric protection. The volumetric protection perimeter, which encompasses the buildings containing equipment able to guarantee reactor safety, was defined by EDF in order to ensure that an arrival of water outside this perimeter does not lead to flooding of the premises located inside it. In concrete terms, volumetric protection consists of walls, ceilings and floors. The protections on the openings in these walls (doors, hatches, etc.) can be potential routes for water ingress in the event of flooding.

Regarding the Flamanville 3 EPR reactor, EDF proposed several measures to increase its robustness. ASN estimates that these propositions are relevant, and considers that they should be implemented. As with the other reactors, ASN asked EDF to identify the equipment to be included in the hard core, including the existing or complementary systems to ensure control of pressure in the containment building in the event of a severe accident.

1.2.4 Summary table: Topic 1: Off-site events – Flooding

Activities	Activities of the Licensee			ASN activities		
	Activity Completed In progress? Envisaged	**Calendar** Or steps for the activities envisaged	**Result** obtained Yes? No?	**Activity** Completed In progress? Envisaged	**Calendar** Or steps for the activities envisaged	**Conclusions available** Yes ? No?
Topic 1: Off-site events - Flooding						
Creation of a "hard core" of reinforced material and organisational measures to ensure that in the extreme situations studied by the CSAs, an accident with core melt is prevented or its progress limited, minimising large-scale releases and enabling the licensee to perform its emergency management duties. The requirements applicable to this hard core will provide significant margins in relation to the current safety baseline, with regard to the hazards considered in the CSAs.	In progress	Proposed definition of scope and associated requirements in 2012	Yes	In progress	Examination of EDF proposals in 2012	No
Improvements to the local volumetric protection periodic inspection and preventive maintenance programme.	Completed	End 2011	Yes	Completed	Requirement 2012	
The plausibility of the risk of a layer of water on the nuclear island and step-down/auxiliary transformer platforms will be studied in certain high-intensity rainfall scenarios, and in the case of failure of non-seismic tanks filled to maximum capacity. As applicable, additional protections will be proposed, in particular with regard to the risk of loss of the main heat sink and loss of electrical power supplies.	In progress	Studies late 2012 and possible programme of modifications late 2012 or in 2013 depending on the sites	No			
Reinforcement of the protection of the equipment needed to control a total loss of electrical power situation in the event of flooding above the current design-basis level will be studied. In the light of the results, additional protections will be proposed.	In progress	Studies and possible programme of modifications at end 2013	No	Completed	Requirement 2012	

Implementation of the programme of work decided on for protecting the facilities against flooding, in the event of the flood safety margin level (CMS) being reached.	In progress	31 December 2014	Yes	Completed	Requirement 2012	
For Tricastin and Cruas, implementation of an organisation and resources able to deal with site isolation in the event of flooding.	In progress	31/12/2012	No	Completed	Requirement 2012	
Demonstration of the effectiveness of the "waterstop" seals			No	Completed	ASN request 2012	
Study of the risk created by activities taking place near the facilities, in beyond design-basis situations, in conjunction with neighbouring operators responsible for these activities (nuclear facilities, installations classified on environmental protection grounds or other facilities liable to constitute a hazard). Proposal of any modifications to be made to the facilities or their operating procedures as a result of this analysis.	In progress	31/09/2012 for Tricastin 31/12/2012 for Gravelines and Saint-Alban 31/12/2013 for the other sites	No	Completed	Requirement 2012	
Updating of a new guide for protection of nuclear facilities against the risk of flooding.				In progress	2012	
Study of rainfall: sensitivity to parameters including rainfall duration.	In progress	The study will be conducted on 2 test sites by June 2012	No			
Study of multiple dam failures in the same valley, beyond the design basis earthquake.	In progress	2012	No			

1.3 Extreme climatic conditions

Flooding can be accompanied by other climatic phenomena. This is why, in its decision of 5th May 2011, ASN asked EDF to conduct an analysis similar to that performed for flooding and earthquakes.

As an example, one could mention the storm which swept across France in December 1999, characterised by both high tide and strong winds, which led to partial flooding of the Le Blayais NPP platform and electrical disruption of the Nogent and Le Blayais sites.

1.3.1 Design of the facilities

With regard to the extreme meteorological conditions related to flooding (storm, torrential rain, etc.), ASN asked EDF to clarify:

- *The events or combinations of events taken into account and the reasons they were (or were not) selected for the design of the facilities;*
- *The weak points, specifying any cliff-edge effects, as well as an identification of the buildings and equipment that would be affected;*
- *whether steps could be envisaged to prevent these cliff-edge effects or reinforce the robustness of the facility (design modification, procedural modifications, organisational measures, etc.).*

EDF devoted a chapter of the CSA reports on each of its sites to the extreme meteorological conditions related to flooding. In its CSA reports, EDF considered four phenomena:

- the direct effects of wind on the facilities;
- the effects of projectiles generated by extreme winds;
- the effects of hail;
- the effects of lightning.

<u>Equipment design for these extreme climatic phenomena</u>

<u>Wind</u>

The structures were designed in accordance with the latest revision of the Snow and Wind 65[32] rules available for the construction of each plant series. On the occasion of each periodic safety review, EDF checks that the buildings important for safety (IPS) and the buildings housing IPS systems or equipment are able to withstand winds with characteristics conforming to the updated Snow and Wind rules (1999 and 1984 editions, amended in 2000).

EDF also checked the design of the buildings, in particular in the light of operating experience feedback concerning the storms which swept across France in December 1999 and more recently (Klaus in 2009 and Xynthia in 2010). EDF stated that these storms led to no damage to the nuclear island buildings and the civil engineering structures of the pumping station. The systems and equipment performing the reactor safety functions are chiefly located in these buildings and structures and the effects of wind had no impact on safety.

On the occasion of the latest periodic safety reviews of the 900 MWe and 1300 MWe series, EDF checked the wind-resistance of the equipment classified IPS-NC[33] located outside these civil engineering structures.

[32] The wind and snow 65 rules are civil engineering standards in France, which set the climatic overload values (snow and wind) and give methods for evaluating the corresponding loads on an entire construction or parts thereof.
[33] Equipment important for safety but not safety-classified, that is: equipment for which a failure is liable to prejudice compliance with the safety objectives (integrity of the pressure envelope of the main primary system, shutting down the reactor and keeping it

Projectiles were also generated by the extreme winds (gravel, antennas, parts of roofs, etc.) during the three storms mentioned above; EDF evaluated their energy at a speed of about 200 km/h. EDF considers that this is insufficient to damage the structures or civil engineering works performing a safety function or housing systems or equipment participating in such a function. Therefore, only the IPS equipment situated outside buildings is liable to be damaged by such projectiles. The majority of the equipment important for safety is situated inside the buildings and thus protected from any risk of damage. Moreover, as a general rule, light objects (weighing less than about 2 kilos) or low rigidity items (heat insulation, branches, etc.) are not likely to damage outdoor IPS equipment.

Nonetheless, on the occasion of the latest periodic safety reviews, EDF defined a baseline for safety requirements concerning protection against projectiles generated by extreme winds. This baseline defines heavy and lightweight projectiles considered at all altitudes and in all directions, according to a speed taking account of past events and the regulations. This baseline also defines "targets" to be protected and stipulates a combination of loss of site electrical power supplies with loss of the heat sink. In this respect, EDF checks the IPS-NC outdoor equipment required for management of a loss of off-site power (LOOP) and necessary in the event of a the total loss of the heat sink.

Hail

In its CSA reports, EDF stated that hail was not considered in the design of the units. According to EDF, this is a relatively rare, localised and brief meteorological phenomenon. Most of the equipment important for safety is inside the buildings, which protects it from the risk of damage by hail. No incident related to a hailstorm has been observed on the units in operation.

Lightning

In its CSA reports, EDF stated that the protection of the facilities against lightning-related risks is in conformity with the ministerial order of 15th January 2008 (concerning lightning protection of certain classified facilities) abrogated and replaced by the order of 19th July 2011[34]. According to the approach to lightning protection adopted by EDF, the preventive measures and protection systems must ensure that the consequences of a lightning strike on the safety of the facilities are encompassed by those defined in the initial design of the reactors with regard to category 2 incidents (frequency of less than 10^{-2} per reactor and per year).

In accordance with the above-mentioned order, an analysis of the lightning risk was carried out to demonstrate the environmental acceptability of the consequences of a lightning strike, using an approach based on standard NF EN 62305-2 of 2006 ("Lightning protection: risk evaluation"). EDF stated that further to this study, preventive measures and protection systems will be defined, with a view to implementation on 1st January 2012. Before this date, the equipment installed in compliance with the prior regulations[35] is monitored in accordance with standard NF C 17-100.

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in a safe state, preventing and mitigating the radiological consequences of accidents), equipment for which correct operation is only necessary in the long-term to achieve these objectives, certain equipment required in the event of a hazard (fire, flooding, etc.). Since the design stage, the IPS-NC class has been extended to include other equipment necessary for the safety demonstration.

[34] Order of 19th July 2011 amending the order of 22nd October 2010 concerning the classification and paraseismic construction rules applicable to "normal risk" class buildings

[35] Article 35 of the order of 31st December 1999 as amended, stipulating the general technical regulations for preventing and mitigating nuisances and external risks arising from the operation of basic nuclear installations

Order of 28th January 1993 concerning lightning protection of certain classified facilities

Lightning can have direct effects (when the impact is directly on the building's structure) as well as indirect effects (lightning strike in the vicinity of the structure or the building). With regard to direct effects, the buildings and structures of the NPPs comprise at least level II protection as defined in standard IEC 61024 or NFC 17-100. Protection is provided by a mesh cage. Pipes and tanks are by their very nature protected against lightning. With regard to the indirect effects, various measures are implemented by EDF (antennas and piping grounded, measurement cables shielded and connected at one end, etc.).

With regard to the lightning hazard, the EPR is designed in accordance with the "lightning safety baseline applicable to the EPR". Adequate steps are thus taken to ensure that the safety functions of the systems and equipment necessary to bring the unit to a safe state and to prevent and mitigate radioactive releases are not unacceptably affected. The chosen hazard characteristics are those concerning protection level I, as defined by standard NF EN 62 305-1 or standard NF C 17-100.

Given the lightning protection measures taken, EDF considers that the consequences of a lightning strike on the safety of the facilities are effectively covered by those defined at the initial design of the units with regard to a category 2 incident.

Snow

With regard to snow, EDF did not feel that there was any need to consider it in the CSAs when selecting other phenomena related to flooding. For this, EDF uses as its basis the contribution of the Météo France / EDF / CEMAGREF / IRSN working group to the Flooding guide. This document in particular states that the following phenomena can be associated with rainfall:

- Hail: "The phenomenon of hail is closely correlated with short-duration, high-intensity storm rains. For short time pitches, the more intense the rainfall, the greater the chance of hail being associated with it."
- Lightning: "The link between this phenomenon and short-duration storm rains is confirmed."

This document also mentions other forms of precipitation such as snow. EDF considered that there was no direct correlation between snow and rain and that snow was not one of the extreme meteorological conditions linked to flooding. Nonetheless, the design of the structures in accordance with the latest revision of the Snow and Wind 65 rules available for the construction of each plant series does protect the safety classified buildings from all snow-related cliff-edge effects.

On this point, other licensees concerned by the ASN decision of 5th May 2011 included snow in the extreme natural phenomena and there are thus disparities between operators of nearby sites.

***ASN thus asked EDF to present studies taking snow into account*.**

Combinations of extreme climatic phenomena

EDF considers that the event combinations considered can generate a risk capable of creating a common mode failure, in other words a risk of the unavailability of functionally redundant equipment or systems. A situation such as this is liable to lead to total loss of the heat sink (situation referred to as LUHS), or a loss of off-site power supplies (LOOP) on all the units of an NPP. These situations are presented in § 2.

1.3.2 Evaluation of safety margins

1.3.2.1 Estimation of margins in extreme meteorological conditions

Wind

EDF considers that the design of the buildings for the off-site explosion risk guarantees their robustness to extreme winds. EDF evaluated the existing margin by comparison with this event. EDF concludes that for all its sites, all the buildings designed for the "off-site explosion" risk are thus robust to extreme winds, with significant margins.

For buildings not covered by the "off-site explosion" design, EDF considers that the loads associated with extreme winds are not liable to have consequences for reactor safety. Concerning the direct effects of wind on the equipment necessary in an SBO, LUHS, or severe accident situation and situated outside the buildings (EFWS steam generator auxiliary feedwater system piping and demineralised water distribution tanks for the conventional SER parts), EDF concludes that the loads associated with extreme winds do not compromise their strength.

ASN considers that the profiles of the two situations ("off-site explosion" and "extreme wind") are not the same: there is a single load on the structures from an explosion, whereas gusting wind leads to several loadings. ASN also considers that the wind speed to be included in these studies should be consolidated.

EDF simply analyses the behaviour of its facilities and the possible cliff-edge effects for a wind speed value of about 200 km/h. EDF stated that this order of magnitude was based on a statistical evaluation produced by EDF R&D and presented to IRSN at the review meeting of 3rd October 2011. The main lessons learned from this evaluation are as follows:

- the values given in the 99 edition of the Snow and Wind rules used in the "Projectiles generated by extreme wind" baseline, correspond to return levels higher than a hundred-year return period.
- the 200 km/h value adopted by EDF is consistent with the objective of an annual frequency of occurrence of < 10^{-4} for the wind values to be taken into account.
- the behaviour of the statistical distribution law for the wind values is bounded by the extreme values.

Given these elements, EDF thus considered that considering a wind speed of 200 km/h was sufficient for examining the cliff-edge effect on the facility with regard to direct and indirect wind effects. This value is close to that of the 1999 modified Snow and Wind 65 values (which give speeds varying on the whole between 150 km/h and 200 km/h for the NPPs).

ASN then considers that the value used by EDF to study the cliff-edge effects does not go far enough beyond the scenarios used for the design of the facilities. Moreover, ASN considers that a speed of 200 km/h is one that is rarely observed in metropolitan France but is not the maximum speed recorded within the past thirty years (storm of 16th October 1987: observed wind speeds of 216 km/h).

On the occasion of the examination in preparation for the meeting of the advisory committees in November 2011, EDF made an undertaking to "transmit a statistical study within 6 months, allowing verification of the limited behaviour of exceptional wind speeds and confirmation of the maximum wind speed to be considered when evaluating any cliff-edge effects. The values adopted for each site will be compared with the maximum speeds recorded by Météo France's metropolitan weather stations representative of each site."

This undertaking is a partial response to ASN's request. ***ASN considers that EDF needs to conduct studies which also take account of the specific nature of gusting winds and will send EDF a request accordingly.***

ASN considers that the conclusions on the direct effects of wind are also valid for the indirect effects of wind: ASN considers that the wind speed value to be used in these studies needs to be consolidated. *ASN also considers that, for wind speeds of about 200 km/h, and in accordance with experience feedback from recent French storms, EDF should check that the only projectiles to be taken into account are indeed cladding sheets which are not liable to damage the outdoor IPS equipment, owing to their lack of rigidity.*

EDF undertook to create a "hard core" of reinforced material and organisational measures to ensure that in the extreme situations studied by the CSAs, an accident with core melt is prevented or its progress limited, minimising large-scale releases and enabling the licensee to perform its emergency management duties The requirements applicable to this hard core will provide significant margins in relation to the current safety baseline, with regard to the hazards considered in the CSAs, in particular extreme winds and associated projectiles. Through this undertaking, EDF aims to guarantee protection of the facilities against any cliff-edge effect that could be associated with extreme winds and associated projectiles.

Hail

Most IPS equipment is situated indoors, which offers it protection from hail damage. With regard to the robustness of the buildings themselves to the effects of hail, EDF considers that the maximum impact could be pitting of the cladding, but without penetration. No incident related to a hailstorm has been observed on the reactors in service.

The targets identified with respect to hail are primarily those already considered in the analyses covering wind-generated projectiles. Piping and tanks are considered to be able to withstand the impact of hail.

The consequences of blockage of the rainwater drainage networks, which could be caused by hail, are dealt with in section 1.2.2.

EDF specified that the undertaking described in the previous section also applies to hail. *The hard core requirements, in particular the "extreme hail" loading, will therefore be forwarded to ASN as part of the hard core stipulated by ASN.*

ASN considers that the elements presented by EDF concerning hail are too succinct: in particular, no hail loading value (intensity, diameter of hailstones, etc.) was mentioned. ASN asked EDF to propose a more precise definition of extreme hail loading and to conduct a more detailed analysis of the resistance of the equipment.

Lightning

EDF considers that there is no plausible cliff-edge effect liable to be created by lightning, given:

- the high robustness of the facilities required for management of an accident situation with regard to the lightning risk and its effects;
- the confirmation from operating experience feedback of the effectiveness of this robustness, up to high levels;
- the functional redundancy and the diversity of certain systems, especially those linked to the electrical power supplies.

To reinforce the robustness of the facilities, EDF nonetheless stated that a preventive maintenance programme for the "Hot non-IPS structures" and a maintenance programme for the "turbine hall" are currently being drafted. They will cover the metal cladding. EDF considers that maintenance of the cladding will limit the risk of it being damaged by a storm, for the buildings within the scope of these maintenance programmes, thus increasing the protection of the facilities against the lightning-related risks.

With regard to lightning-induced cliff-edge effects on PWRs in operation, ASN observed that EDF bases its position solely on arguments related to the design or to positive operating experience feedback at high intensity levels, but without mentioning any values which clearly indicate the absence of a cliff-edge effect.

ASN also noted that on the EPR (Flamanville 3, Penly 3), EDF mentioned an analysis of operating experience feedback which revealed the occurrence of lightning strikes of an intensity of up to 454 kA (Chooz in April 2011). EDF specified that a study will be conducted on the EPR to assess the consequences of a lightning strike in excess of 200 kA for the equipment installed outside the "mesh cage". This feedback from Chooz and this study are not however mentioned in the CSAs for the PWRs in operation.

EDF specified that the undertaking described in the previous section also applies to lightning. The hard core requirements, in particular the "extreme lightning" loading, will therefore be forwarded to ASN as part of the hard core stipulated by ASN.

ASN considers that an "extreme lightning" loading, defined on the basis of the available operating experience feedback, should be defined and taken into account for the PWRs in operation, concerning the equipment needed to manage LUHS, SBO and severe accident situations. ASN has asked EDF to conduct such studies.

<u>Combination of extreme climatic phenomena and loss of heat sink (LUHS) and loss of electrical power supply (SBO) situations</u>

Contrary to what ASN requested in its decision of 5th May 2001, EDF does not include these extreme natural phenomena in the LUHS and SBO analyses presented in the CSA reports (see § 2). However, during the examination preceding the meeting of the advisory committees in November 2011, EDF indicated that it would be including them in the analyses of the action to be taken for LUHS, SBO and severe accident situations, as well as for earthquake and flooding, and that the extreme climatic conditions linked to flooding were indeed among the requirements applicable to the hard core.

ASN considers that EDF must take account of the extreme meteorological conditions linked to flooding in the definition of the "hard core" (see § 1.2.3).

With regard to the EPR, EDF states that to prevent any cliff-edge effect beyond the baseline safety standards, the additional equipment that could be deployed following the CSAs will be designed for or protected against extreme climatic conditions.

ASN considers this approach to be satisfactory.

1.3.2.2 Measures envisaged to reinforce the robustness of the facilities to extreme meteorological conditions

In its CSA specifications, ASN asked EDF, on the basis of the conclusions of the previous analysis, to state whether measures could be envisaged for preventing these cliff-edge effects or for enhancing the robustness of the facility (modification of the design, modification of procedures, organisational measures, etc.).

Concerning the reactors in operation, during the examination in preparation for the meeting of the advisory committees in November 2011, EDF made an undertaking to study the ability of the venting-filtration system required in the event of a severe accident (U5 filter) to withstand the direct and indirect effects of wind, as well as the ability of the equipment needed to operate the emergency management centres and situated outside the building to withstand the indirect effects of wind. Moreover, to reinforce the robustness of the facilities, EDF stated that a preventive maintenance programme for the "Hot, non-IPS structures" and a maintenance programme for the "turbine hall" are currently being drafted.
They will cover the metal cladding. EDF considers that maintenance of the cladding will limit the risk of it being damaged by a storm, for the buildings within the scope of these maintenance programmes, thus increasing the protection of the facilities against the risks linked to projectiles generated by extreme winds.
In addition, ASN will ensure that the definition of the "hard core" takes account of the extreme meteorological conditions linked to flooding.

With regard to the EPR, EDF states that to prevent any cliff-edge effect beyond the baseline safety standards, the additional equipment that could be deployed following the CSAs will be designed for or protected against extreme climatic conditions. *ASN considers this approach to be satisfactory.*

1.4 Summary table: Topic 1: Off-site events – Extreme climatic conditions

Activities	Activities of the Licensee			ASN activities		
	Activity Completed In progress? Envisaged	Calendar Or steps for the activities envisaged	Result Obtained Yes? No?	Activity Completed In progress? Envisaged	Calendar Or steps for the activities envisaged	Conclusions available Yes ? No?
Topic 1: Off-site events – Extreme climatic conditions						
Creation of a "hard core" of reinforced material and organisational measures to ensure that in the extreme situations studied by the CSAs, an accident with core melt is prevented or its progress limited, minimising large-scale releases and enabling the licensee to perform its emergency management duties The requirements applicable to this hard core will provide significant margins in relation to the current safety baseline, with regard to the hazards considered in the CSAs	In progress	Proposed definition of scope and associated requirements in 2012	Yes	In progress	Examination of EDF proposals in 2012	No
Study of robustness of the facilities to snow				Completed	ASN request 2012	
Study of the robustness of the facilities to gusting wind, taking account of the specific aspects of gusting winds for all the sites.				Completed	ASN request 2012	
Study of the risk created by activities taking place near the facilities, in beyond design-basis situations, in conjunction with neighbouring operators responsible for these activities (nuclear facilities, installations classified on environmental protection grounds or other facilities liable to constitute a hazard). Proposal of any modifications to be made to the facilities or their operating procedures as a result of this analysis.	In progress	31/09/2012 for Tricastin 31/12/2012 for Gravelines and Saint-Alban 31/12/2013 for the other sites		Completed	Requirement 2012	

2 Design studies

2.1 Loss of electrical power supplies and cooling systems

Even after the nuclear chain reaction has stopped, the nuclear fuel in the reactor and the spent fuel pool must be cooled in order to remove the residual power. For this it is necessary to ensure continuity of the electrical power supply to certain key components (for example the cooling system pumps), and the supply of cooling water from a heat sink (from a river or the sea, for example).

ASN has therefore asked EDF to analyse the induced losses of the following safety systems, in relation to the experience feedback from the Fukushima accident:

- *loss of the electrical power supplies (including the case of total loss of the off-site and on-site electrical supplies);*
- *loss of the cooling sources (heat sink),*
- *the above two losses combined.*

2.1.1 Loss of electrical power supplies

Each reactor is linked to the electricity transmission system by a line called the "main line". Before delivering the electrical energy produced at the main generator to the electrical power grid, the reactor - via the step-down transformer - draws the energy it needs to supply the electrical panels that energize the equipment vital for its operation, and the equipment necessary for the safety of the facility. In the event of an incident on the main line, the reactor can isolate itself from the electricity transmission system and, via the step-down transformer, continue to supply the electrical panels; this procedure is called "house load operation".

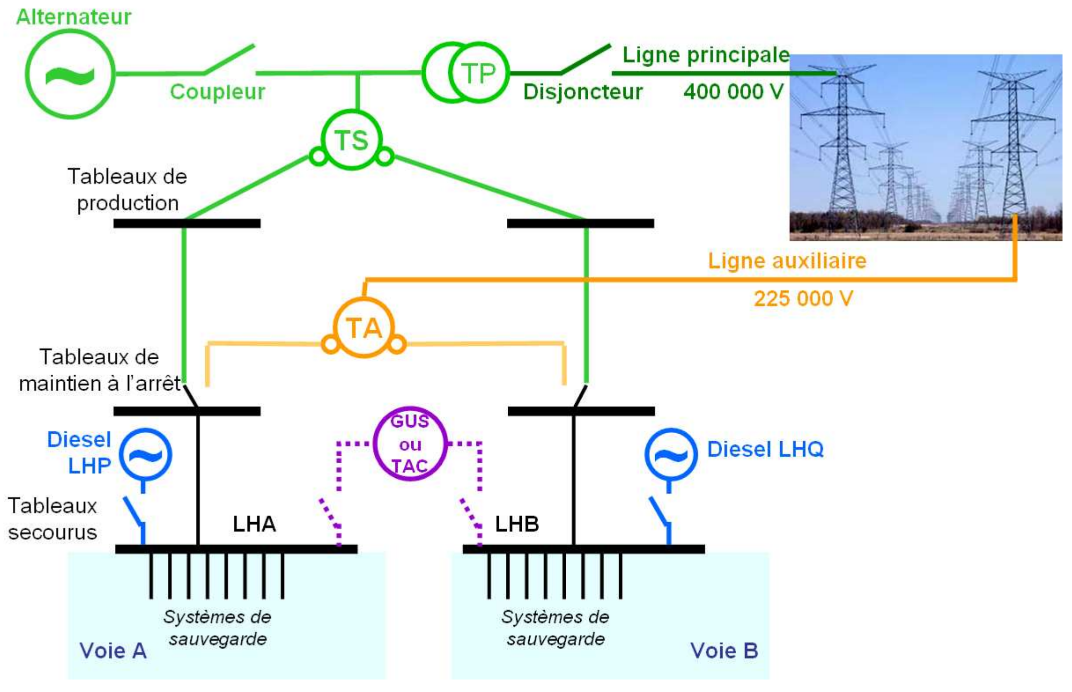
When the reactor is not producing electricity, or if the main line is out of service, the electrical panels are supplied via a second line called the auxiliary line. In this case the reactor is supplied directly by the electricity transmission system via the auxiliary transformer.

To have sufficient on-site electrical power sources, each reactor has on-site redundant conventional back-up sources capable of supplying the electrical panels vital for correct operation of the safety equipment. The conventional back-up sources for each reactor in service consist of two emergency diesel generator sets, while the EPR reactor has four main generator sets.

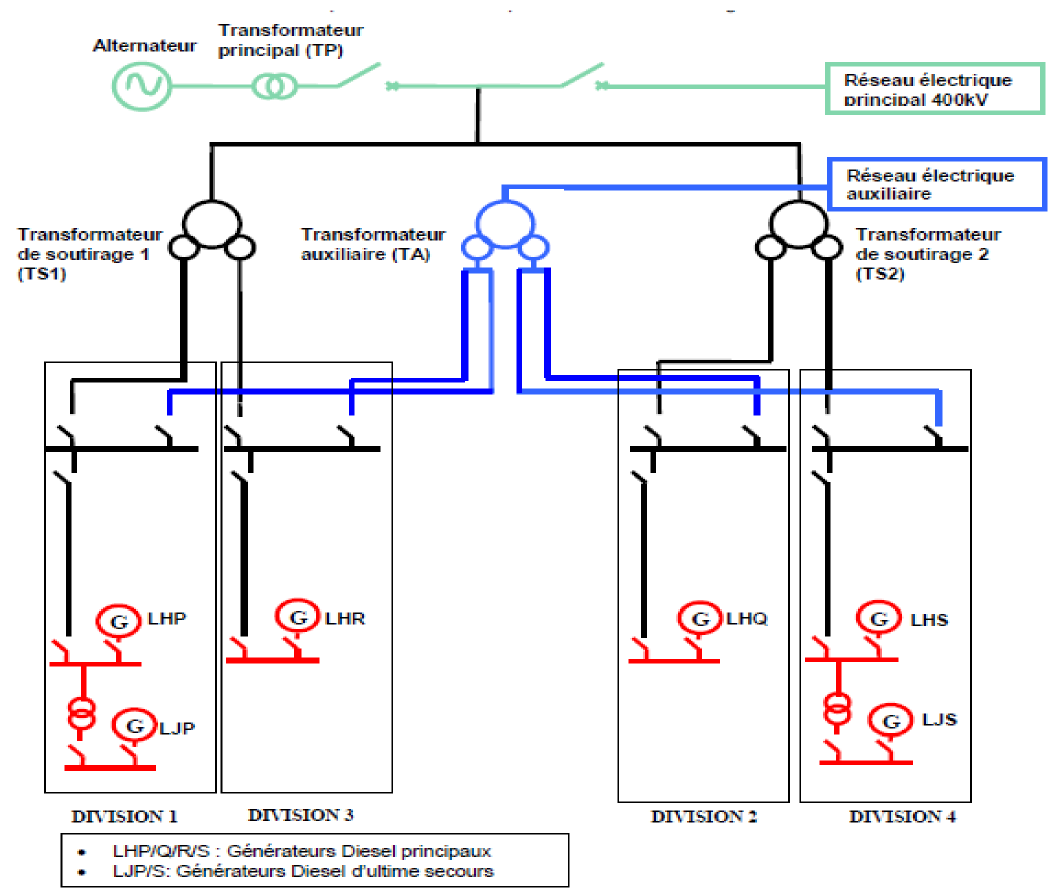
Each NPP also has an additional on-site emergency power source, whose technology differs according to the plant series involved:

- for the 900 MWe series, one ultimate back-up diesel-generator set (GUS) per site;
- for the 1300 MWe and N4 series, one combustion turbine (TAC) per site;
- for the EPR reactor, two ultimate back-up diesel-generator sets (SBO – Station blackout) per reactor.

Electric batteries with a power autonomy of one hour on the reactors in service and two hours on the EPR reactor ensure and guarantee continuity of the electrical supply to certain key equipment items when the generator sets are not operating.



Schematic diagram of electrical power supplies for a reactor in service



Schematic diagram of electrical power supplies for an EPR reactor

If the off-site electrical sources and the abovementioned on-site back-up sources should fail, specific equipment is provided to supply certain items that are critical for managing this situation:

- on each in-service reactor, one ultimate electrical power source provided by a turbine generator (LLS) driven by steam from the steam generators (SG);
- on the EPR reactor, two batteries dedicated to this situation (called "12-hour" batteries).

ASN has asked EDF to study the successive loss of all these electrical power sources in the complementary safety assessments, considering initially that only one reactor is concerned, and secondly that all the facilities of a given site are affected simultaneously.

The targeted inspections carried out by ASN in 2011 found that the state of the electrical power supplies was generally satisfactory, though a number of shortcomings exist on certain sites. Generally speaking, the consistency of the operating and maintenance documents, the physical condition of certain items relating to fuel storage, the periodic management of generator set fluids and the periodic inspections of the combustion turbines (TAC) are areas in which many sites could make improvements.

2.1.1.1 Loss of off-site electrical power supplies

For each reactor, ASN has asked EDF to:

- *describe the facility's design measures that take into account this power loss situation, the back-up means provided, and their conditions of use;*
- *indicate the length of time the on-site electrical power supplies can function without external back-up;*
- *specify the measures taken to extend the utilization time of the on-site electrical power supplies (refuelling of the diesel generator sets, etc.);*
- *indicate any measures envisaged to increase the robustness of the facility (design change, change in procedures, organisational arrangements, etc.).*

Loss of the off-site electrical power supplies of a reactor is a situation analysed for the baseline safety standard; it corresponds to loss of the main and auxiliary lines and failure of house load operation.

In a situation of off-site electrical power supply loss:

- the reactor is supplied by its on-site sources, i.e. the back-up diesel generator sets; these generator sets start automatically in the event of simultaneous loss of the main and auxiliary systems or a significant voltage drop on the backed-up electrical panels;
- the control rods drop under gravity, which terminates the nuclear fission reaction and controls the reactivity;
- the reactor core continues to emit heat, called residual power, which must be removed from the core to prevent its temperature from rising and ultimately damaging it;
- the reactor coolant pumps (RCP) are no longer supplied with electricity, as their power demand is too great for them to be supplied by the generator sets; the flow in the primary system decreases rapidly; after complete stoppage of the RCPs, natural circulation in the primary loops removes the residual power which decreases as a result of decay further to automatic reactor shutdown;
- on the secondary side, reactor shutdown trips the turbine and closes the turbine inlet valves; as the steam generator main feedwater pumps (feedwater flow control system - ARE) have stopped due to the initiating event, the feedwater supply drops until the auxiliary feedwater system (EFWS) starts up; the residual power is removed by the steam generators with opening of the main steam safety relief valves to the atmosphere (MSB-a/VCD-a for the reactors in service, or MSRT for the EPR reactor);
- the spent fuel pool cooling systems are backed up by the reactor emergency generator sets.

In the complementary safety assessment (CSA) reports, EDF pointed out that starting the emergency generator sets gives the management team the electrical power sources necessary to bring the reactor to a safe condition if the off-site electrical power supplies are lost.

In the scheduled and systematic actions to identify any deviations on its facilities (periodic tests, maintenance, regulatory inspections, installation conformity reviews carried out as part of the periodic safety reviews), EDF identified a number of deviations directly or indirectly affecting the generator sets of the reactors in service.

ASN considers that although these deviations do not represent an immediate safety hazard, they do affect the robustness of the back-up generator sets. EDF notified ASN of these deviations and they are being monitored specifically.

Regarding the autonomy of the on-site electrical power supplies, EDF pointed out in the CSA reports that the reference case studied to determine the robustness of the facility considers a situation where the off-site electrical power supplies for the entire site are lost for two weeks. The following procurement measures have been planned on the basis of this situation:

- fuel autonomy is guaranteed for 3.5 days; procurement is covered by a national contract that requires delivery within 24 hours in emergencies and 3 days in normal situations; EDF also pointed out that strategic fuel reserves are reserved for its needs;
- oil autonomy is 3 days for the reactors in service and 10 days for the EPR reactor; beyond this, procurement is possible in accordance with provisions specific to each site. Whatever the case, EDF considers that the availability of resources is ensured for two weeks;
- the diesels are air-cooled. The initial cooling water reserves for the generator sets of the reactors in service provide two weeks of autonomy. For the EPR reactor, the initial cooling water reserves ensure at least 10 days of autonomy for the "high temperature" water and 22 days for the "low temperature" water;
- the compressed air reserves required to start each generator set allows five start-ups and can be replenished by compressors; the diesel engines have a stand-alone air-water cooling system.

EDF indicated in its CSA reports that the ultimate back-up generator sets (SBO) of the EPR reactor provide an additional electrical power supply of at least twenty-four hours.

ASN considers that the supply management methods are satisfactory in guaranteeing 3 days autonomy for the generator sets of the reactors in service and 4 days for the EPR reactors.

ASN noted that EDF has not demonstrated that the site can be autonomous for two weeks under all circumstances, and notably after an earthquake or a flood leading to isolation of the site. ASN will require that EDF secure its on-site stocks of fuel and oil and ensure that they can be replenished in all circumstances, to guarantee an autonomy of at least 15 days.

Regarding the measures taken to extend the utilisation time of the on-site electrical power supplies, EDF specified in the CSA reports that:

- on the reactors in service, the use of independent thermostatic valves, i.e. controlled only by the fluid passing through them, instead of electropneumatic valves to regulate back-up generator set cooling, guarantees the operation of these generator sets if the compressed air distribution system (SAR) fails;
- on the EPR reactor, ensuring the long-term operating reliability of the back-up generator sets depends on the activation of additional protection mechanisms in the event of problems that risk causing rapid destruction of the generator and that can be repaired in a relatively short time. The aim is to limit the consequences of a possible failure that could damage the generator set by preventively shutting it down: long-duration failures can thus be avoided by making short-duration shutdowns for repair work;
- as a single generator set suffices for the safety systems, the others could be shut down, to save fuel for example.

ASN considers that EDF's proposal to draft an operational procedure for "economising" a generator set when necessary should be put into application.

Regarding the measures that can be envisaged to enhance the robustness of the facility, EDF proposed in the CSA reports that the protection logic of the 1300 MWe series generator sets be modified by manually restoring the "non-priority" protection mechanisms that are disabled automatically in the "short-term" operating phases (this modification is currently being deployed on the 900 MWe and N4 series generator sets). The aim is to limit the consequences of a possible failure that could damage the generator set by preventively shutting it down: long-duration failures can thus be avoided by making short-duration shutdowns for repair work.

ASN considers that the proposed improvements, which meet the CSA specifications, should be implemented.

Regarding extension of the off-site electrical power supply loss to the entire site, which is not analysed for the baseline safety standard, EDF specified in its CSA reports that this does not change its analysis; this is because in this situation, reactor management does not require any particular equipment or equipment that is common to several reactors.

ASN considers that EDF must take into account this off-site electrical power loss scenario when ensuring the reliability of on-site fuel and oil stocks and their resupply.

2.1.1.2 Loss of off-site electrical power supplies and conventional back-up supplies

For each reactor, ASN has asked EDF to:

- *provide information on the capacity and autonomy of the batteries;*
- *indicate for how long the site can cope with loss of the off-site electrical power supplies and the back-up energy sources without external intervention, before serious damage to the fuel becomes inevitable;*
- *indicate what (external) action is planned to prevent fuel damage:*
    - *equipment already on the site, for example equipment from another reactor;*
    - *equipment available off the site, assuming that all the reactors on a given site have suffered damage;*
    - *generators that are geographically very close (e.g. hydroelectric generators, gas turbines, etc.) which can be used to power the facility via dedicated connections;*
    - *the time necessary for each of these systems to be operational;*
    - *the availability of competent human resources, in particular to make these exceptional connections and render them operational;*
- *identify the moments when the main cliff-edge effects occur;*
- *indicate whether measures can be taken to prevent these cliff-edge effects or to reinforce the robustness of the facility (design change, change in procedures, organizational arrangements, etc.).*

Loss of the off-site electrical power supplies and the conventional back-up supplies of a reactor is a situation analysed for the baseline safety standard; it results from loss of the off-site electrical power supplies combined with failure to resupply the electrical panels that are backed up by the reactor's back-up generator sets.

In this situation of loss of the off-site electrical power supplies and the conventional back-up supplies of a reactor in service:

- the residual power of the core is removed by thermosiphon natural circulation if the primary system is closed, or by evaporation if the primary system is open;
- if the reactor is initially under power or in hot shutdown condition, the rod cluster control assemblies (RCCAs) are inserted into the core and cooling of the reactor coolant pumps (RCP) seals is ensured by the test pump (SIS on 900 and CVCS on 1300 and N4) (common to a pair of reactors for the 900 MWe series) and supplied with electricity by the back-up turbine generator (LLS);
- if the primary system is partially or sufficiently open, the ultimate back-up diesel-generator set (GUS) for the 900 MWe series or the combustion turbine (TAC) for the 1300 MWe and N4 series can supply the charging pumps of the CVCS, thereby providing make-up water to the primary system;

- for the secondary system, the steam generators are supplied if necessary via the auxiliary feedwater system (EFWS) by one turbine-driven pump (900 MWe series), or two turbine-driven pumps (1300 MWe and N4 series), supplied with the steam from these same steam generators; the residual power is removed to the atmosphere by the main steam safety relief valves (MSB-a/VCD-a);
- the spent fuel pool cooling systems are no longer supplied with electricity, which can result in evaporation of the pool water and possibly uncovering of the fuel (within a time specified further on), and can ultimately lead to meltdown of the stored fuel.

For the EPR reactor, in the event of loss of the off-site electrical power supplies and the conventional back-up power supplies:

- an ultimate back-up diesel-generator set (SBO), which is started manually from the control room, supplies the pumps of the EFWS system; the "2-hour" and "12-hour" batteries are charged automatically by the SBO generator when it is in operation;
- if the reactor is initially under power or in hot shutdown state, the rod cluster control assemblies are inserted into the core; the residual power is removed by thermosiphon natural circulation; the tightness of the RCP shaft seals is ensured automatically by the standstill seal system (SSSS) supplied by the "2-hour" batteries;
- for the secondary system, the steam generators are supplied if necessary via motor-driven pumps of the EFWS system which are supplied with electricity by the SBO generators; the residual power is removed by the atmospheric steam dump valves (MSRT);
- if the reactor is shut down and the primary system is partially or fully open, the residual power is removed by evaporation; a low-head injection channel of the safety injection system (IRWST - internal water refuelling storage tank) supplied by the SBO generator enables primary system make-up to be accomplished and a channel of the ultimate heat removal system in the containment (CHRS/UCWS) removes the residual power from the containment;
- a cooling system of the spent fuel pool can be supplied with electricity by an SBO generator.

Regarding the capacity and autonomy of the batteries of the reactors in service, EDF recalled in the CSA reports that the storage batteries:

- ensure automatic switchover of power sources;
- supply power for at least one hour to the instrumentation & control necessary to diagnose the problem and orient the operating team during an electrical power failure.

EDF also specified in the CSA reports that operating procedures for lost external and on-site electrical power supply situations provide for operation in "battery saving mode", enabling high-priority parts of the functions to be powered for as long as possible by load-shedding lower-priority parts.

For the EPR reactor, EDF recalled in the CSA reports that:

- four "2-hour" batteries can supply the instrumentation & control, the man-machine interfaces and the containment internal isolation valves for at least two hours;
- two "12-hour" batteries can supply the instrumentation and control (I&C) dedicated to severe accidents (CCAG), the severe accidents console (PAG), the iodine filtration of the inter-containment space, the 900 t/h pressuriser relief valves, the containment external isolation valves and the emergency lighting of the control room, of the crisis technical room and of the fallback station, for at least twelve hours.

On the EPR reactor, as the "2-hour" batteries are necessary to couple the main generators and ultimate back-up generator sets (SBO) to the electrical system, the following cliff-edge effects were identified during the examination prior to the meeting of the advisory committees in November 2011:

- a common cause failure affecting the four "2-hour" batteries in a situation of off-site electrical power supply loss would lead to total outage of all the generator sets and a severe accident;
- the measures necessary for confinement of the containment and switching over to the severe accidents console must be carried out before these "2-hour" batteries become discharged.

For the EPR reactor, ASN therefore considers that EDF must propose measures to give the "2-hour" batteries the diversification that meets the same requirements as for the generator sets. This point is currently being examined as part of the detailed design analysis of the Flamanville 3 EPR reactor generator sets.

Given the cliff-edge effects that battery discharge creates for all the reactors, ASN will instruct EDF to significantly increase the autonomy of the batteries used in the event of loss of the off-site and on-site electrical power supplies, by 31st December 2014.

Regarding the time lapse before serious fuel damage becomes inevitable, in the event of loss of the off-site electrical power supplies and conventional back-up supplies for a reactor without external intervention, EDF specified in the CSA reports that for the reactors in service:

- when the primary system is closed, the autonomy depends on the volume of water reserves of the secondary system supplying the steam generators; failure to resupply the EFWS tank then unavailability of the SGs leads to heating of the primary system and a rise in pressure until the pressuriser discharge valve opens, gradually emptying the primary system; if no additional measures are taken, the fuel will become uncovered a few days after the start of the accident;
- when the primary system is partially open, as the residual power is lower, it takes longer for the fuel to become uncovered than when the primary system is closed;
- when the primary system is sufficiently open, gravity make-up of a limited fraction of the spent fuel pool water is applied to compensate for the vaporisation caused by the loss of the primary cooling system at shutdown; this is followed by a make-up from the FPCS (reactor cavity and spent fuel pool cooling) system tank:
    - on the 900 MWe series, by the charging pumps of the CVCS system of the neighbouring reactor; if no additional measures are taken, the fuel will become uncovered more than a day after the start of the accident;
    - on the 1300 MWe and N4 series, by the mobile motor-driven cooling pump; if no additional measures are taken, the fuel will become uncovered several days after the start of the accident;
- for the spent fuel pool, make-up by the fire-fighting water distribution or production system (JPD or JPP) pumps of the neighbouring reactor prevents the fuel from becoming uncovered.

For the EPR reactor, EDF specified in the CSA reports that:

- the reactor presents no risk of core meltdown or radioactive release for at least the twenty-four hours of operation of the SBO generator sets; when cooling is ensured by the SGs, the auxiliary feedwater system (EFWS) tanks run dry after about two days, but they can be replenished from the tanks of the classified fire-fighting water production system (JAC) by the EFWS system resupply pumps (which can be backed up electrically by the SBO generator sets), giving a total water autonomy of a little more than about seven days: the fuel would start suffering damage about nine days after the initiating event;
- if the reactor is not in cold shutdown state with the reactor cavity full, the spent fuel pool cannot be cooled because the SBO generator set is dedicated to reactor management; one of the JAC system pumps can make-up water to compensate for the evaporation and avoid exposing the fuel during the twenty-four hours of autonomy of the SBO generator set; the fuel will become uncovered about 5 days after the initiating event;
- if the reactor is in cold shutdown state with the reactor cavity full, cooling of the spent fuel pool is ensured for twenty-four hours; the fuel will become uncovered more than 2 days after the initiating event.

Regarding loss of the off-site electrical power supplies and the conventional back-up supplies for the entire site, which is a situation that is not analysed for the baseline safety standard, EDF specified in its CSA reports that, for the reactors in service:

- as the GUS and the TAC are common to the site, they will only be able to supply one reactor on the site;

- when the primary system is closed, the core will become uncovered more than 24 hours after the start of the accident
- when the primary system is partially open, if the primary system vents fail to close, the fuel will become uncovered after about ten hours; this situation is similar to loss of the off-site electrical power supplies and all the back-up supplies of a reactor;
- when the primary system is sufficiently open:
    - for the 900 MWe series, the chemical and volume control system (CVCS) charging pumps are no longer available; if no complementary measures are taken, the fuel will become uncovered a few hours after the start of the accident;
    - for the 1300 MWe and N4 series, chapter III of the general operating rules (RGE) limits this situation to just one reactor on a site, always leaving the possibility of using the mobile motor-driven cooling pump; the fuel would become uncovered several days after the start of the accident;
- for the spent fuel pools, as all the pumps of the fire-fighting water production system (JPP or JPD) are out of service, the fuel will become uncovered within a day and a half.

For the EPR reactor, EDF specified in its CSA reports that the extension of the loss of off-site electrical power supply to the entire site does not change its analysis of the reactor section, but it does not give any details on the spent fuel pool section; in this situation, reactor management does not require any equipment that is specific or common to the site.

ASN considers that EDF must adopt a position regarding the missing assessment.

<u>Regarding the external measures planned to prevent the fuel being damaged</u>, EDF specified in its CSA reports that the means for managing loss of the off-site electrical power supplies and the conventional back-up supplies would be implemented by competent and qualified personnel, assisted and advised by the emergency management teams.

The planned external actions for managing loss of the off-site electrical power supplies and the conventional back-up supplies over the entire site, examined by EDF in its complementary safety assessments, correspond to the requirements of ASN decision No. 2011-DC-0213.

<u>Regarding the measures that can be envisaged to prevent cliff-edge effects or to reinforce the robustness of the facility</u>, EDF proposed in its CSA reports, for the reactors in service:

- to study and verify the resistance of the EFWS system turbine-driven pumps and the back-up turbine generator (LLS) to the temperature rise in the buildings in the absence of ventilation beyond twenty-four hours;
- to speed up the installation on each reactor of an "ultimate back-up diesel generator set":
    - with total autonomy for 48 hours, it will be able to ensure the partial electrical supply of one backed-up electrical panel, within about one hour after losing the off-site and on-site electrical power supplies;
    - it will be powerful enough to supply electricity for one primary system injection means and one motor-driven pump of the EFWS system;
    - it will also be capable of supplying electricity for the auxiliaries that isolate the reactor containment, for the ventilation systems of the control room and, for the 1300 MWe and N4 plant series, the back-up of the system for depressurising the inter-containment space;
    - it shall be designed for hazard robustness;
- pending installation of this "ultimate back-up diesel generator set", to provide one or more small emergency generator sets that will guarantee the electrical supply for the minimum necessary instrumentation & control and control room emergency lighting, to back-up the LLS turbine generator;
- to install on the 900 MWe series reactors a motor-driven pump for injecting water into the core from the FPCS system tank;

- to put in place lasting ultimate back-up means (wells, ponds, etc.) for replenishing the EFWS and FPCS systems and the spent fuel pool with water, along with the associated material and human resources; some of these material resources could be provided by the "FARN (Nuclear Rapid Intervention Force) ” - see § 3 - initially;
- to equip the sites in the short term with high-power mobile stand-alone lighting equipment to facilitate interventions on the premises;
- to draft an operating document for the situation of loss of off-site electrical power supplies and the back-up energy sources;
- for states in which the primary system is closed, to update the current operating procedure as part of a modification of the chapter VI procedures of the general operating rules:
    - anticipation of rapid cooling,
    - limiting of steam generator depressurisation;
- for states in which the primary system is partially open, to change the primary system pressure build-up procedure to remove the residual power by the steam generators, thereby having sufficient secondary pressure to supply the required turbine-driven auxiliary feedwater pump and maintain the required SG water inventory when the primary system can be repressurised;
- to modify the operating documents so that the necessary measures are taken as soon as loss of the heat sink or total loss of the electrical power supplies is confirmed, without waiting for activation of the on-site emergency plan (PUI);
- to study the complementary operating measures, notably by providing charts to evaluate the TAC or the GUS for management of the spent fuel pools in these situations;
- to study the appropriateness of having a generator set to back up the information strictly necessary for managing loss of the spent fuel pool cooling;
- to study and, as applicable, implement countermeasures to control the risk of explosion as a result of radiolysis of the water in the spent fuel pool in the absence of ventilation;
- ultimately, to study the feasibility of transferring control of the existing spent fuel pool make-up system to premises totally protected against the effects of steam propagation and improve the functioning of the steam vent.

For the EPR reactor, to prevent cliff-edge effects or to increase the robustness of the facility, EDF proposed in its CSA reports:

- to implement a mobile means of pumping fuel from the main generator set tanks to resupply the SBO generators, should it be impossible to obtain fuel from the exterior;
- to envisage resupplying the EFWS system tanks from the freshwater ponds of the demineralized water production system (SEA);
- to study and, as applicable, implement countermeasures to control the risk of explosion as a result of radiolysis of the water in the spent fuel pool in the absence of ventilation;
- to implement a passive or automatic system for opening the fuel pit area vent to improve the prevention of a pressure build-up situation in the fuel pit area;
- to implement gravity make-up of the spent fuel pool with water from the SEA ponds via an external connection with the fuel building, that could compensate for water losses by evaporation and at least maintain the water level;
- to study the measures to be taken to increase the robustness of the fuel pool instrumentation (water temperature, water level, dose rate in the fuel pit area) for managing the situation, and water top-up in particular.

ASN considers that EDF's proposals for reinforcing the electrical resources, which comply with the CSA specifications, must be implemented.

EDF has identified the need to keep information vital for operations management available in the control room and to maintain control room lighting. However, it has not assessed the risk of a cliff-edge effect associated with certain information losses in the control room, with depletion of the batteries and the absence of lighting in situations with the primary system open and LLS unavailable. *ASN notes that EDF's proposal to deploy one or more small emergency generator sets that guarantee an electrical supply for the minimum necessary* I&C *and control room emergency lighting would solve this problem.*

ASN considers that EDF's proposal to provide an additional hazard-resistant electrical power supply means called "ultimate back-up diesel generator set (DUS)" and for use in the event of loss of the other off-site and on-site electrical power supplies, and which complies with the CSA specifications, must be implemented. Pending deployment of this additional electrical power supply means, ASN also considers that EDF's proposal to provide one or more small emergency generator sets must be implemented. It has issued a requirement on this subject stipulating installation of an ultimate back-up electrical power supply system on all reactors before the end of 2018 and, in the meantime, the deployment of temporary power supply devices on all reactors by 30th June 2013.

For the EPR reactor, the SBO generator sets already have robustness features. To have a level of robustness at least equal to that of the reactors in service with the deployment of an additional hazard-resistant means of supplying electrical power,***ASN asked EDF to study the integration of the SBO generator sets in the "hard core" of the material and organisational measures, which are subject to more stringent requirements, particularly with respect to the earthquake and flooding risks.***

EDF proposed - for partially open primary system situations - to modify pressure build-up management so as to remove the residual power via the steam generators. *ASN considers that EDF must prove that the proposed change in management of the partially primary system situation will effectively result in a sufficient delay before the fuel becomes uncovered to implement external means for the medium- and long-term management of a situation of loss of the off-site and on-site electrical power supplies on a site.*

2.1.1.3 Loss of the off-site electrical power supplies and of the conventional back-up supplies and any other on-site back-up electrical power source

For the loss of the off-site electrical power supplies and of the conventional back-up supplies and any other on-site back-up electrical power source, ASN asked EDF, for each reactor, to:

- *provide information on the capacity and autonomy of the batteries;*
- *indicate for how long the site can cope with loss of the off-site electrical power supplies and the back-up energy sources without external intervention, before serious damage to the fuel becomes inevitable;*
- *indicate what (external) action is planned to prevent fuel damage:*
    - *equipment already on the site, for example equipment from another reactor,*
    - *equipment available off the site, assuming that all the reactors on a given site have suffered damage,*
    - *generators that are geographically very close (e.g. hydroelectric generators, gas turbines, etc.) which can be used to power the facility via dedicated connections,*
    - *the time necessary for each of these systems to be operational,*
    - *the availability of competent human resources, in particular to make these exceptional connections and render them operational;*
- *identify the moments when the main cliff-edge effects occur;*
- *indicate whether measures can be taken to prevent these cliff-edge effects or to reinforce the robustness of the facility (design change, change in procedures, organizational arrangements, etc.).*

Loss of the off-site electrical power supplies and all the back-up supplies of a reactor results from the loss of the off-site electrical power supplies combined with failure to resupply the electrical panels that are backed up by;

- the emergency generator sets of the reactors in service or the main generator sets of the EPR reactor;
- for the 900 MWe series, the ultimate back-up diesel-generator set (GUS);

- for the 1300 MWe and N4 series, the combustion turbine (TAC);
- for the EPR reactor, the ultimate back-up generator sets (SBO);
- for the reactors in service, the back-up turbine generator (LLS).

In the CSA reports for the reactors in service, EDF also considered the loss of the auxiliary feedwater system (EFWS) turbine-driven pumps, even though they function independently of the electrical power sources.

For the reactors in service, this is not a situation analysed for the baseline safety standard. For the EPR reactor, as this situation is included in the baseline safety standard, the "2-hour" and "12-hour" batteries are available.

In this situation of loss of the off-site electrical power supplies and all the back-up supplies of a reactor:

- if the reactor is initially under power or in hot shutdown state, the rod cluster control assemblies (RCCAs) drop down into the core; the residual power is removed by thermosiphon natural circulation if the primary system is tight, and by evaporation if the primary system is fully open;
- the primary system is no longer provided with water make-up;
- the thermal barrier and shaft seals of the reactor coolant pumps (RCP) are no longer cooled;
- on the secondary system, the steam generators are no longer supplied;
- the spent fuel pool cooling systems are no longer supplied with electricity.

For the reactors in service, EDF has carried out a conservative analysis of this situation for all the reactors on the site, rather than on each reactor individually. In its CSA reports, EDF considered the EPR reactor to be isolated from the other reactors on the site.

For the case of loss of the off-site electrical power supplies and all the on-site emergency power supplies, EDF specified in its CSA reports that the capacity and autonomy of the batteries were the same as in the preceding case of loss of the off-site electrical power supplies and the conventional back-up supplies.

<u>Regarding the time lapse, without external intervention, before serious fuel damage becomes inevitable</u>, in the event of loss of the off-site electrical power supplies and all the back-up supplies for the site, EDF specified in the CSA reports that, for the reactors in service:

- when the primary system is tight, considering deterioration of the RCP seals leading to a significant breach in the primary system, the core would become uncovered after about one day;
- when the primary system is partially open, the accident operating procedures currently demand maximum cooling of the primary system, resulting in complete emptying of the SG; if no water make-up is provided, the fuel would become uncovered in about ten hours;
- when the primary system is sufficiently open, gravity make-up of a limited fraction of the spent fuel pool water is applied to compensate for the vaporisation caused by the loss of the primary cooling system at shutdown; this is followed by a make-up from the FPCS (reactor cavity and spent fuel pool cooling) system tank:
    - for the 900 MWe series, the chemical and volume control system (CVCS) charging pumps are no longer available; if no additional measures are taken, the fuel will become uncovered a few hours after the start of the accident;
    - for the 1300 MWe and N4 series, chapter III of the general operating rules (RGE) limits this situation to just one reactor on a site, always leaving the possibility of using the mobile motor-driven cooling pump; if no additional measures are taken, the fuel would become uncovered several days after the start of the accident;
- for the spent fuel pools, as all the pumps of the fire-fighting water production system (JPP or JPD) are out of service, the fuel will become uncovered within a day and a half.

For the EPR reactor, EDF specified in the CSA reports that in the event of loss of all the off-site and on-site electrical power supplies:

- if the reactor is at full power, the fuel in the core will suffer damage after a few hours;
- if the core is unloaded, the fuel in the pit will become uncovered more than one day after the initiating event (more than four days after the event if the core is in the vessel).

In this situation of loss of the off-site electrical power supplies and the conventional back-up supplies and of all other on-site emergency electrical power sources, *ASN observed that the CSAs reveal short-term cliff-edge effects characterised by a shorter time before core uncovering than that specified for deployment of the FARN resources.*

Regarding the external measures planned to prevent the fuel being damaged, EDF specified in its CSA reports for the reactors in service that the measures are identical to the preceding case of loss of the off-site electrical power supplies and the conventional back-up supplies.

For the EPR, EDF specified that the design measures (redundant, diversified and robust electrical power sources) and the associated external measures help prevent damage to the fuel.

The external actions for managing loss of the off-site electrical power supplies and the conventional back-up supplies as well as all other back-up electrical sources on the entire site, examined by EDF in its complementary safety assessments, correspond to the requirements of ASN decision No. 2011-DC-0213.

Regarding the measures that can be envisaged to prevent cliff-edge effects or to increase the robustness of the facility, apart from the measures proposed in the event of loss of the off-site electrical power supplies and the conventional back-up supplies and described earlier, EDF proposed in the CSA reports:

- for the 900 MWe series, to study resetting of the EFWS system turbine-driven pumps from the control room (for the states in which this is possible);
- for the 1300 MWe and N4 plant series, and for states in which the primary system is partially open, to change the primary system pressure build-up procedure to remove the residual power by the steam generators, thereby having sufficient secondary pressure to supply the required turbine-driven auxiliary feedwater pump and the LLS turbine generator and maintain the required SG water inventory when the primary system can be repressurised;
- for the EPR:
    - o to extend the electrical supply for the functions supplied by the "12-hour" batteries and required beyond 12h00 for managing the feared situation, by implementing supplementary fixed or mobile electrical power sources;
    - o to put in place a means of restarting the severe accidents I&C in the event of it being cut-off;
    - o to put in place devices and mobile electrical power supply means necessary to:
- ▪ ensure the habitability of the control room,
- ▪ for the spent fuel pool, supply one cooling channel of the FPCS system or water make-up from the tank of the JAC system;
- to integrate the essential information concerning the development of the situation in the fuel building (fuel pool temperature, water level measurement, etc.) on the severe accidents I&C and the severe accidents console (PAG) which are supplied by the "12-hour" batteries.

ASN has observed that EDF proposed measures to increase the times before the core becomes uncovered, including:

- *deploying additional pumping means to make-up the primary and secondary systems;*
- *operating procedure studies and changes to limit the risk of a breach at the RCP seals if their cooling is lost;*
- *increasing the autonomy of the feedwater supply for the steam generators and the primary cooling system.*

ASN considers that it is necessary for EDF to effectively increase the time lapses before the core becomes uncovered. ASN considers that the supplementary measures proposed by EDF, which will increase robustness to the loss of the electrical power supplies and the loss of heat sink, must be implemented.

2.1.1.4 Conclusion on the planned measures to protect the facilities against the risk of electrical power supply loss

In its conclusions to the CSA reports, EDF considers that the back-up means provided to cope with total and combined loss of the electrical power sources ensure good robustness of the facilities, particularly given the number of lines of defence included in the design and assumed to be lost in a deterministic manner in the required scenarios.

ASN observed that, in the CSA reports, EDF has performed the assessment relative to electrical power supply losses according to the existing safety baseline requirements, without considering that they could be caused by an external hazard (earthquake, flooding, etc). Yet such a hazard can lead to failure of the equipment planned to be used to counter the loss of the electrical power supplies.

ASN therefore considers that the times before the fuel suffers damage in the event of electrical power supply loss could be shorter than those indicated by EDF in the CSA reports, particularly if the power loss was induced by an earthquake or a flood.

ASN considers that EDF must improve the hazard robustness of some of the proposed supplementary measures for managing electrical power loss situations. ASN asked EDF to submit a proposal before 30th June 2012 for a "hard core" of material and organisational measures, which are subject to more stringent requirements, particularly with respect to the earthquake and flooding risks (see § 1.2.3).

2.1.1.5 Measures envisaged to enhance facility robustness with respect to electrical power supply losses

In the CSA reports, EDF has summarily proposed the following measures to counter the risk of a loss of the electrical power supplies for the reactors in service:

- a hazard-resistant generator set called the "ultimate back-up diesel generator" will be installed on each reactor; it will be able to deliver electrical power for:
  - the minimum necessary reactor I&C and control room lighting,
  - the information required in case of loss of spent fuel pool cooling,
  - the ultimate water make-up pump for replenishing the EFWS system tank, the FPCS system tank and the spent fuel pool,
  - the information necessary in core melt situations,
  - the containment isolation valves, the ventilation filtration of the control room and the ventilation filtration of the intercontainment-space,
  - a motor-driven pump of the EFWS system and a make-up for the primary system;
- initially, pending installation of the "ultimate back-up diesel generator", two small fixed generator sets will be provided:
  - one to supply the minimum reactor I&C and control room lighting,
  - the other to supply the ultimate water top-up pump for replenishing the EFWS system tank, the FPCS system tank and the spent fuel pool,
- the possibility of resupplying power in the short term to the functions necessary for managing losses of spent fuel pit cooling shall be studied;
- enhancing the operating reliability of the LLS in the event of a temperature rise in the buildings beyond 24 hours without ventilation will be studied, and modifications will be proposed if shown to be necessary by the studies.

For the EPR reactor, EDF proposed the following measures in the CSA reports:

- extending the autonomy: mobile means of pumping fuel from the main generator set tanks to replenish the SBO generator sets;
- extension of the duration of electrical supply for essential functions by deploying supplementary fixed or mobile electrical power sources;
- means of restarting the severe accidents I&C.

During the examination of the CSA reports by IRSN, ASN's technical support organisation, EDF made the following undertakings:

- in order to ensure simultaneous injection at the seals on the 900 MWe series reactors, where there is only one pump for two reactors, EDF will carry out a study to determine the appropriateness of the flow that supplies the primary pump seals of each of the two reactors, in the event of loss of the off-site electrical power supplies and the site back-up energy sources; the results of this study should be available by the end of the first half of 2012;
- to avoid a breach at the RCP seals in a situation of total loss of the off-site and on-site electrical supplies for the reactors in service, EDF has started examining the implementation of robustness tests on the new high-temperature seals installed on the reactors in service in place of the O-rings; a programme will be defined by the same deadline.
- EDF will examine the RCP shaft standstill seal systems that exist or are under development across the world; on the basis of the results, EDF will adopt a position at the end of the first half of 2012 on a design modification allowing simultaneous injection at the seals on the two neighbouring reactors of the 900 MWe series;
- EDF will carry out a study of operation with accelerated cooling to reach a state where injection at the RCP seals is no longer necessary;
- as with the 1300 MWe and N4 series, EDF will shortly install on the 900 MWe series a motor-driven pump that ensures adequate make-up of the primary system when the latter is sufficiently open; in the short phase of direct opening of the reactor vessel with the closure head loosened, EDF will by March 2012 check on the reactors in service that this motor-driven pump can be used for make-up operations, pending installation of the resupply by the "ultimate back-up diesel generator" to a means of make-up the primary system ;
- on the EPR reactor, EDF will present an analysis of the situations of generalised electrical power failure by the end of 2012, and decide whether additional provisions are necessary;
- to define the requirements of the hard core equipment, EDF will take account of common mode failure risks affecting the existing equipment and the new equipment installed, aiming to ensure diversification and independence.

ASN considers that the electrical power supply reinforcement objectives proposed by EDF must be implemented.

In order to set the objectives for these reinforcements and the corresponding deadlines, ASN asked EDF to install an ultimate back-up electrical power supply and, in the meantime, to implement temporary electrical power supply systems on all the reactors by 30th June 2013.

EDF has undertaken to carry out studies on the output of the test pump for injection at the RCP seals on the two neighbouring reactors simultaneously. If the pump output cannot be demonstrated as being sufficient, *ASN considers that EDF should in the short term define a modification that makes simultaneous injection at the seals of the two neighbouring 900 MWe series reactors possible. Moreover, if a breach at the RCP seals cannot be avoided in a situation of loss of a site's off-site and on-site electrical power supplies, ASN considers that means for managing the breach must be deployed to prevent this situation degrading into a severe accident.*

ASN considers that the principle of EDF's commitment to take diversification and independence into account as a means of achieving the hard core requirements, and to verify the minimisation of common mode failure risks, is satisfactory.

2.1.2 Loss of cooling systems or heat sink

The heat sink provides the water to remove the thermal power from the nuclear fuel, to cool the systems of the nuclear or conventional facilities, and it supplies certain specific systems such as the fire-fighting system or water for industrial use. A reactor needs to be permanently connected to a heat sink, even after shutdown.

The water is taken directly from the natural environment, that is to say the sea for coastal sites, or a waterway for sites situated on the banks of a river.

The water intake structures and the pumping station pump and filter the raw water which, once collected and filtered, is used to cool the systems via heat exchangers. The pumping station is connected directly to the intake-outfall structure. Each site usually has one pumping station for two plant units. Each pumping station has two redundant and geographically separate channels.

The water intake structure varies from one site to another. For riverside sites, it usually consists of:

- a deflector panel;
- a floating skimmer boom to limit the entry of floating debris;
- waterways that can supply several under-river tunnels. Each waterway is equipped with removable trash racks.

The water intake supplies the under-river tunnels which open out into a settling pit at the entrance to the plant unit intake channel. This intake channel divides to serve the pumping stations of each pair of plant units.

Generally speaking, from upstream to downstream, the equipment used for the transit and filtration of the raw water comprises the advance grids (widely spaced bars, no trash rake), the preliminary filtration grids (more closely spaced bars, equipped with trash rake), a filtering system (chain filters or rotating drum screens), and lastly the suction pumps. The water transits chiefly through specially built channels, streams or concrete water pipes.

Raw water suction, delivery and filtration are ensured between minimum and a maximum levels called the lowest and highest safe water level respectively. The calculation of these levels takes into account the specific environment of the site. Taking the various design criteria into account ultimately determines:

- the shape and height of the dykes,
- the depth of the pipes,
- the setting and dimensions of the filtration system,
- the setting of the filtration system cleaning and disposal systems,
- the setting of the safety pumps.

The last 3 points determine the form and depth of the pumping station.

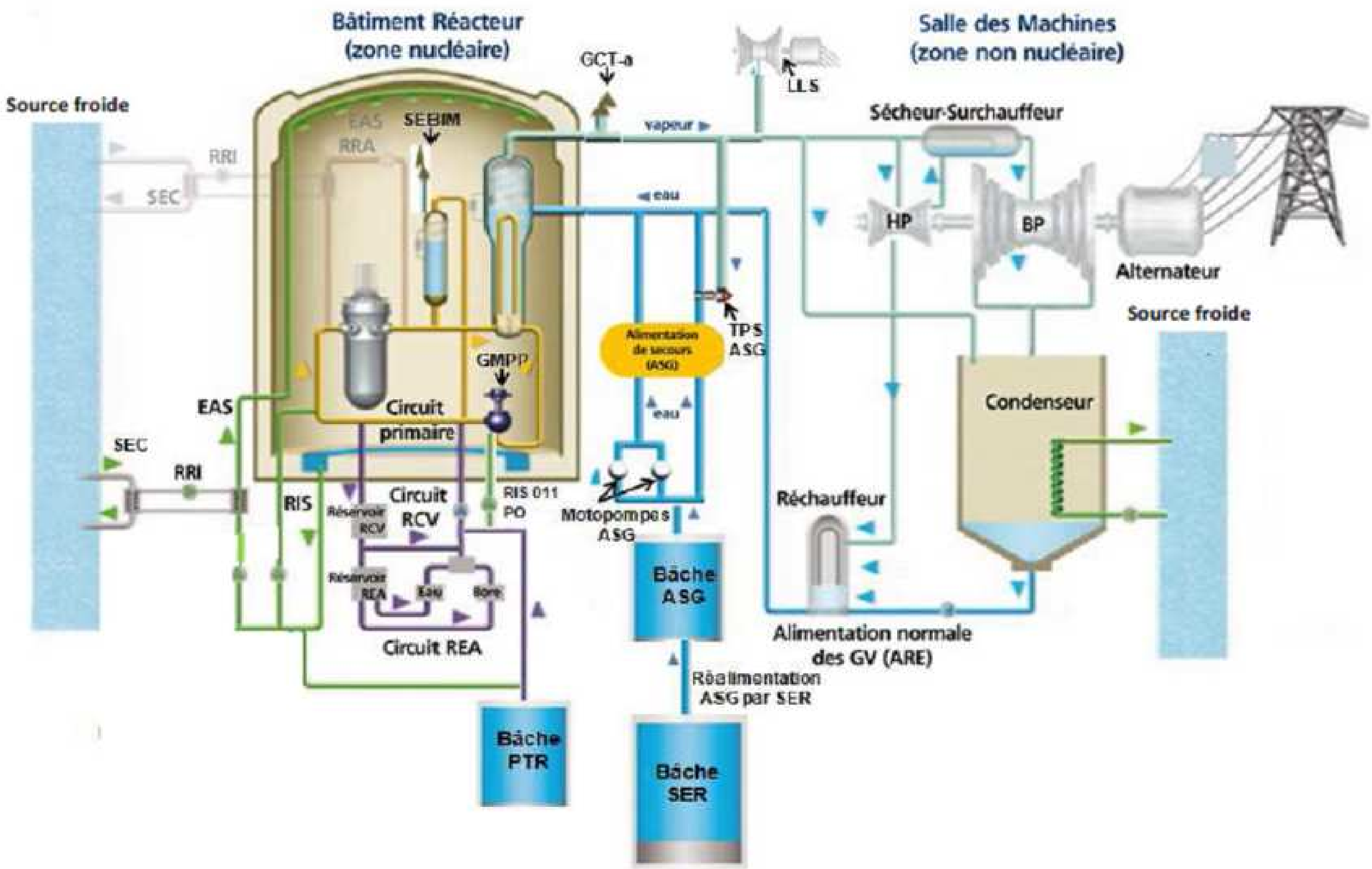
The reactors in service are designed to have an autonomy of at least 100 hours after a heat sink loss.

If the heat sink loss affects all of a site's reactors simultaneously, the targeted autonomy announced by EDF is 24 hours for coastal sites and 60 hours for riverside sites in the case of an unpredictable hazard (e.g. sudden influx of clogging material), and 72 hours in the case of a predictable hazard (e.g. a climatic event such as extreme cold + frazil ice) in which case the tanks can be filled to maximum level as a preventive measure.

The heat sink is usually the natural environment to which the nuclear facilities are connected, but other NPP heat sinks do exist, which are used according to the status of the plant units and also serve to cool down the core or the spent fuel pool:

Equipment or system used as "Heat Sinks":

	Equipment or systems used	Heat sink
Normal operation	Steam generators (GV)	o Normal feedwater o Auxiliary feedwater to steam generators (EFWS) and turbine bypass system (MSB -a).
Accident operation	Steam generators	EFWS water, demineralised water, raw water, turbine bypass system (MSB-a)
	Residual heat removal system (RHRS)	CCWS (component cooldown system) water cooled by the ESWS (essential service water system
	Safety injection system (SIS)	FPCS (Reactor cavity and spent fuel pool cooling and treatment system) tank water
	Containment spray system (CSS)	o CCWS water cooled by the ESWS o FPCS (Reactor cavity and spent fuel pool cooling and treatment system) tank water



The ASN specifications required EDF to describe the design measures for preventing loss of the heat sink (for example, several water intakes in different places, use of an alternate heat sink, etc.).

The pumping station equipment is subject to safety requirements defined in the heat sink baseline safety standard.

In its complementary safety assessments, EDF indicated that the water intake, the pumping station and the intake channel are monitored firstly through the periodic patrol inspections and secondly through application of the basic preventive maintenance programs (PBMP), which includes taking bathymetric measurements and cleaning channels.

The heat sink water levels are monitored permanently, and vigilance, pre-alert and alert thresholds are specified. These thresholds are set such that preventive measures can be taken, particularly regarding the need to increase feedwater supplies, and optimised management of plant unit shutdown with the aim of reducing the residual energy to be removed from the core.

In France, no nuclear power reactor apart from the Flamanville 3 EPR currently under construction has an alternate heat sink (lake, water table or atmosphere). This being said, some NPPs have a larger water reserve through their design. At the Civaux and Cattenom NPPs there are seismic-classified ponds that constitute the heat sink of the ESWS safety system[36]: dedicated ponds at Civaux giving 10 days' autonomy, Mirgenbach lake at Cattenom with 30 days' autonomy. Another particularity of the Civaux site is that the safety cooling circuit functions in a closed loop with a forced draft cooling tower associated with the reserve pond (whereas on most NPP sites the safety cooling system is an once-through configuration, with the water being taken from and discharged into its natural environment).

Lastly, EDF periodically revises the design data during the periodic safety reviews with the aim of consolidating or improving the robustness of the facility.

EDF has provided solutions for the various risks of heat sink loss:

1. <u>Extreme cold: to prevent the water intake from freezing up</u>

As soon as winter temperatures prevail, pumping station monitoring is tightened under the "Extreme Cold" procedures, and the systems involved in the heat sink are placed in "winter" configuration: infrastructures identified as sensitive are subject to closer monitoring.

2. <u>Extreme heat: to avoid loss of the heat sink due to low water levels</u>

As of springtime, riverside sites step up monitoring in order to detect abnormal heat sink temperatures or levels. In the event of an alert, "extreme heat" or "low water" procedures enable monitoring to be adjusted and measures to be taken to protect the heat sink by adapting production if necessary. The coastal NPP sites are naturally protected against this risk. In practice, the NPPs concerned by heat sink low water situations are generally shut down well before the lowest safe water level is reached, to limit their environmental impact.

3. <u>Oil spill: to avoid the water intake becoming clogged by an influx of hydrocarbons.</u>

Some NPP sites are protected from this risk by their geographical location. In such cases, a daily inspection patrol of the heat-sink related facilities suffices to check the quality of the cooling water. The other NPP sites (on the coastline, on an estuary, beside a navigable waterway, etc.) however, are exposed to the risk. In 2003 EDF carried out a probabilistic assessment of the drift of an oil slick offshore of the sites situated on the English Channel and the North Sea. This study assessed the probability of arrival of an oil slick resulting from an accident as 2.10-3/year for the NPPs on the Normandy coast.

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[36] "ESWS" system: Essential Service Water System (which comes directly from the heat sink)

Protection of the heat sink is based on design features and an operating doctrine that allows alerting of the NPP, surveillance of the oil slick in collaboration with the public authorities, and preventive shutdown of the plant units if there is a confirmed risk of an oil slick entering the intake channel. In the event of large-scale oil pollution offshore of the NPP, the alert is raised by the public authorities, and these situations generally lead to triggering of the "POLMAR" (maritime pollution) plan. Agreements between EDF, the French maritime authorities and Météo France (the French met office) enable the movement of an oil slick to be monitored and its position with respect to the water intakes of the nuclear sites to be communicated to EDF. Entry of an oil slick into the NPP surveillance zone results in the application of graded prevention actions to ensure the availability of the protection means, prepare for shutdown of the units and, if necessary, activate the on-site emergency plan:

- raw water consumption is limited as a precautionary measure to preserve the back-up heat sink. The site plant units are gradually shut down to reduce the flow drawn in at the pumping station to only the level required for reactor cooling;
- a floating pontoon equipped with vertically descending sheets situated in front of the intake waterway limits the ingress of a surface oil slick into the pumping station, subject to the preventive shutdown of the circulating water system (CRF) pumps, which reduces the inflow of water to just the essential service water (ESWS) flow required to cool the safety-related auxiliaries;
- the filters and their washing systems also help limit the hydrocarbon influx.

These instructions can also be triggered by an observation made as a result of pumping station monitoring, by the appearance of a rotating drum filter clogging or circulation pump trip alarm. EDF estimates that the ESWS system instrumentation, and the flow measurements in particular, remain operational up to a hydrocarbon level of 10%.

4. <u>Clogging agents: to avoid obstruction of the water intake</u>

All the pumping stations have designed-in protection against massive influxes of clogging agents by means of lines of defence which vary from one site to another according to the particularities of the environment, but which are typically:

- At the water intake entry point, the first element encountered is a set of movable grids with widely spaced bars;
- At the pumping station entry point, the first element encountered is the "upstream" grid which has more closely spaced bars. A few metres downstream, one or two coarse filtration grids prevent the ingress of large floating objects. These coarse filtration grids are usually equipped with trash rakes (one per grid) which raise any debris and direct it via a discharge channel to a waste collection bin.

The arrival of clogging agents in the pumping station is detected by the alarms specific to this system: monitoring of suction head loss, SEF alarms[37], head loss of the SFI[38] filtration resources. The protection systems associated with this monitoring will automatically trip the pumps that are not safety-classified, thereby significantly reducing the head loss at the bounds of the filtering elements to guarantee their integrity and reduce the influx of debris. This system protects the ESWS system safety pumps against a low level at suction and ensures their continuous supply.

Preventive measures initiated manually from the control room and followed by local verifications, can be used to stop one or more non-safety-classified pumps and start high-pressure washing and high-speed operation of the rotating drum filters. An operator will be sent to assess the situation; the operating teams have a specific procedure to assist them with management of this situation.

In response to a partial heat sink loss incident at the Cruas NPP in 2009 caused by a massive influx of vegetation debris, EDF has, at the request of ASN, initiated a design review of all the heat sinks to assess and reinforce their robustness to natural hazards. The results of this technical design review are expected in 2012.

[37] SEF : raw water coarse filtration system, i.e. the first filtration of the water drawn from the natural environment
[38] SFI : raw water filtering system (in the pumping station)

5. <u>Storms, spring tides, etc: to avoid heat sink loss due to natural phenomena</u>

Some sites manage these situations by a specific operating procedure that integrates the phenomena of storms with simultaneous presence of clogging agents that can affect the availability of the water intake. The aim of this procedure is to avoid total loss of the heat sink by maintaining the flows necessary for operation of the pumps that are important for safety, and facilitate the cleaning of clogged equipment. This procedure prescribes the monitoring of numerous parameters such as the pumping station alarms, the weather conditions - especially wind speed and direction, historical wind records, tidal coefficients and sea state, the change in operation of the neighbouring plant unit's CRF pumps, the nature of the clogging agent and the actions to be implemented. It also prescribes closer monitoring of the pumping station and envisages several cases of plant unit shutdown. Each NPP site also establishes specific instructions, such as for lashing down objects in the event of high winds.

ASN considers that the heat sink, which is an important system, requires particular vigilance. Its vulnerability was highlighted by the recent events of clogging and partial loss of the heat sink at Cruas and at Fessenheim in December 2009. This led EDF to initiate a plan of action to reinforce the robustness of all its heat sinks. ***ASN has more particularly asked EDF to conduct a design review of all its heat sinks. ASN has instructed EDF to provide detailed conclusions, by 30th June 2012, concerning the heat sink design review, site by site, along with a plan of action with completion dates.***

The inspections carried out by ASN in 2011 found the general condition of the heat sink facilities to be satisfactory, and that almost all of them are in conformity with the EDF's national baseline safety standard, though there are still some deviations on a number of sites. As a general rule, operating and maintenance rigour, equipment and structure condition monitoring, and exhaustive application of national directives, are areas for improvement on most sites. Despite noteworthy progress attributable to EDF's OEEI initiative (French acronym meaning "to achieve an exemplary condition in installations"), a number of sites still have pumping station equipment comprising leaks or showing signs of relatively advanced corrosion. Several sites in particular displayed shortcomings in the maintenance of the ESWS system, which is safety-classified and therefore merits greater attention.

The risk of heat sink loss (by clogging, freezing, etc.) is not addressed equally from one site to another, and generally requires greater attention. Recent events have shown that the means currently in place have so far been sufficient to cope with the hazards, though sometimes with difficulty. EDF has therefore started to reinforce the robustness of its heat sinks against risks such as "massive influx of clogging material".

Personnel training has occasionally displayed deficiencies, making it an area for progress included in the plan of action initiated by EDF in 2010 in response to the heat sink clogging events at Cruas and Fessenheim.

Finally, EDF plans to tighten the baseline safety standard for the heat sink, with early 2013 announced as the corresponding completion date.

2.1.2.1 Loss of the primary heat sink

In its CSA specifications, ASN asked EDF to study the induced losses of safety systems, and loss of the alternate heat sink in particular. Initially, the licensee will analyse each facility or installation individually; subsequently, it will be assumed that all the installations or facilities (reactors, pools, etc.) on a given site are affected simultaneously. For the reactors having several heat sinks (namely the Flamanville 3 EPR reactor), the successive loss of the heat sinks must be considered. For each of these situations, the time for which the site can remain in this situation without external aid, before damage to the fuel becomes inevitable, must be indicated.

The situation of total heat sink loss is called "LUHS". This situation can affect either a single reactor or all the reactors on a site. In the latter case it is referred to as a "whole-site LUHS".

Total loss of the natural heat sink leads to loss of the cooling functions of the core and spent fuel pool in the fuel building (BK[39]). It is detected in the ESWS system by appearance of the low flow alarms which will lead to first one, then two ESWS channels being declared unavailable in succession. Total loss of the heat sink renders the feedwater plant and the essential service water system (ESWS) unusable. This is followed by gradual heating of the component cooling system (CCWS). The following systems gradually become unavailable: the component cooling system (CCWS), the residual heat removal system (RHRS), the reactor cavity and spent fuel pool cooling and treatment system (FPCS), the primary pumps (loss of cooling of the bearings, motor and thermal barrier), the safety injection system (SIS) and the containment spray system (CSS).

The measures taken with equipment immediately present on the site enable the following functions to be ensured for the time necessary to restore the heat sink:

- the thermal inertia of the primary system borated water reserve (FPCS tank) is then used as a back-up heat sink under an operating procedure devised for this purpose. In the long term the component cooling system (CCWS) no longer cools the auxiliaries correctly. It is stopped manually and declared unusable when the fluid temperature exceeds its maximum operating temperature (temperature at heat exchanger output exceeding 50 or 55°C depending on the sites);
- maintaining of one charging pump necessary for injection at the primary pump seals. This pumps allows make-up of borated water and reactor depressurisation by auxiliary spraying;
- replenishing of the auxiliary feedwater system reserve (EFWS tank) to allow removal of residual power by the steam generators in the longer term, if the residual heat removal system (RHRS) becomes unavailable.

Evaluation of the impact of an LUHS situation on the reactors (affecting first one, then all the reactors of a site)

EDF identified 4 possible configurations:

- Primary system tight and residual heat removal system (RHRS) not connected;
- Primary system tight but residual heat removal system (RHRS) connected;
- Primary system partially open;
- Primary system sufficiently open.

<u>Case n°1: LUHS situation affecting a single reactor</u>

The thermal inertia of the primary system borated water reserve (FPCS tank) is used in the event of loss of the essential service water system (ESWS). It allows the following to be kept in service: one of the primary system pumps, normal spraying and letdown (CVCS). The reactor is thus taken through to shutdown status following a procedure similar to a normal reactor shutdown.

<u>In the primary system tight states</u>, a cliff-edge effect in a situation of total heat sink loss ("LUHS" situation) is associated with exhaustion of the feedwater reserves (EFWS + SER). On the basis of the SER water volumes required by the technical specifications (TS), the site has an autonomy of several days (100 hours). The SER tanks are usually filled well above the required thresholds, which means that the autonomy is greater. EDF considers this period to be long enough to restore the heat sink before the core starts to become uncovered.

<u>In the primary system open and partially open states</u>, the primary system make-up by the CVCS system is available. Water is supplied from the FPCS tank which can be replenished according to the procedures implemented on the initiative of the national emergency team. The primary system tight situation mentioned above therefore encompasses the primary system partially open situation.

[39] BK: Nuclear fuel storage building

Case n°2: Loss of the heat sink for all the plant units of a site

EDF estimates that the plausible time required to restore the heat sink is about three days for riverside sites and one day for coastal sites.

Primary system tight state*:* on the basis of the EFWS and SER water volumes commonly encountered, the feedwater autonomy is greater than the plausible time required to restore the heat sink. Consequently there is no cliff-edge effect and EDF considers that the heat sink will have been restored before the core starts to become uncovered.

Primary system partially open state: As the residual power is lower, the primary system tight situation encompasses the primary system partially open situation.

Primary system fully open state: The thermal inertia of the primary system borated water reserve (FPCS) is used and the vaporisation is compensated by topping up the primary system from the FPCS tank. The residual power to be removed is also lower than in the primary system tight situation.

EDF therefore estimates that in all cases the heat sink will have been restored before the core becomes uncovered. To reinforce facility robustness in a whole-site LUHS situation, EDF has undertaken to re-assess the minimum thresholds of the Technical Specifications (TS) for the SER tanks in order to guarantee the targeted autonomy.

Particular case of the EPR:

Loss of primary heat sink on a plant unit in state A, B or C[40] with primary system tight or partially open

In an initial situation with a reactor operating at full power, the EFWS tanks will be empty after about 2 days. Replenishing these tanks with water from the JAC[41] tanks gives a total water autonomy of 7 more days starting from the loss of the heat sink (i.e. 9 days in all). Damage to the fuel starts about 9 days after the initiating event. The other initial situations are encompassed by that described above because the residual power to be removed is lower.

Loss of the primary heat sink on a plant unit in state C, primary system not pressurisable or in state D

The study of this accident scenario shows that the core remains covered for several days and long-term removal of the residual power is ensured.

For all the plant units of the EPR site:

Extending loss of the heat sinks to the entire site changes nothing in the scenario for loss of the heat sink for a single plant unit, as the Flamanville 3 EPR has no equipment in common with the site's plant units 1-2. Given national and international operating experience feedback for coastal sites, the plausible time for restoring the heat sink has been estimated at one day.

[40] State A: under power and hot shutdown or intermediate state with all the reactor's automatic protection functions available; some functions may be disabled at low pressure;
State B: intermediate shutdown above 120°C, shut down cooling system not connected; some automatic protection functions may be disabled;
State C: intermediate shutdown and cold shutdown with cooling system in operation and primary system tight or able to be made tight rapidly;
State D: cold shutdown with primary system fully open

[41] JAC: safety-classified fire-fighting water production system.

Loss of primary heat sink, reactor in state A, B or C with primary system tight or partially open

Extension of the incident to the entire site does not change the scenario described previously. Operation of the Flamanville 3 EPR does not require equipment common to plant units 1 and 2. Damage to the fuel of the Flamanville 3 EPR starts about 9 days after loss of the heat sink..

Loss of the primary heat sink, reactor in state C, primary system not pressurisable or in state D

Extension of the incident to the entire site does not change the scenario described previously. Operation of the Flamanville 3 EPR ensures long-term removal of residual heat and does not require equipment common to plant units 1 and 2.

For the EPR, EDF therefore estimates that in all cases the heat sink will have been restored before the core becomes uncovered. When the JAC tanks are empty (about 7 days after loss of the heat sink), replenishing of the EFWS tanks of the Flamanville 3 EPR from the freshwater ponds of the SEA (demineralisation plant water supply system) is envisaged. This resource, which is shared by the three plant units and the replenishing of the EFWS and BK building tanks, could be called on at the request of the national emergency team to provide several days of additional autonomy.

To conclude, when the primary system is closed, the residual power is removed from the reactor core by the secondary system. In this case EDF identifies a cliff-edge effect related to the exhaustion of the feedwater reserves. The time this would take is evaluated at "several days". EDF considers that the heat sink (which can be restored in one or three days depending on the site) will in all cases have been restored before the core becomes uncovered. In situations where the primary system is not pressurisable, the residual power is removed by vaporisation of the reactor cavity water in the containment. In such cases, the primary system is provided with make-up via the CVCS system. The cliff-edge effect is not detailed by EDF. In the particular case of the EPR, a cliff-edge effect is associated with the feedwater autonomy, evaluated at about 2 days. This corresponds to the specified autonomy of the EFWS tanks. These can subsequently be replenished by the tanks of the JAC system which is dedicated to this, increasing the autonomy to 9 days

ASN considers that the heat sink loss accident situations analysed by EDF in its complementary safety assessments correspond to the requirements of ASN decision 2011-DC-0213 for the existing reactors and partially for the Flamanville 3 EPR. As required by the specifications, they are established considering gradual losses of the water resources, with the exception of the following cases which EDF should have studied:

- *total loss of the primary heat sinks combined with loss of the alternate heat sink on the Flamanville 3 EPR (situation only studied for the spent fuel pool in building BK)*
- *LUHS situation (total loss of the heat sink) on the Civaux NPP site. This situation was only studied for one plant unit on the Civaux site and not for the entire site.*

Apart from the LUHS situation on the Civaux site, the postulated situations are examined considering first one plant unit, then all the plant units of a site as being affected, as required by the specifications.

Pursuant to ASN decision 2011-DC-0213, the whole-site LUHS situation should be explicitly studied for all the plant units on the Civaux site.

If only one plant unit were to be affected, ASN considers the announced estimate of the time before the heat sink is restored (several days) to be plausible, as the baseline safety standard currently in effect already requires an autonomy of 100 hours for total loss of the heat sink on one reactor.

If all the reactors on a site were to be affected simultaneously, the feedwater volumes (EFWS + SER) would be reduced, as the SER tank is divided between several plant units. The last periodic safety reviews evaluated this autonomy at 24 hours (can reach 2 to 3 days on certain sites).

ASN considers that the times before the core becomes uncovered should have been clearly indicated.

ASN asked EDF to give a qualitative evaluation of the times.

In states where the primary system is not pressurisable, *ASN observed that EDF has not calculated a cliff-edge effect for the LUHS situation. ASN agrees that the time before the core becomes uncovered would be longer in an LUHS situation than in a situation of total loss of the electrical power supplies (see section § 2.1.1), due to additional possibilities of making-up the primary system from the FPCS tank. More precisely, the times calculated in the "SBO" situation are from 70 to 80 hours when the reactor cavity is full; more than one day when the reactor cavity is not full, subject nevertheless to the robustness of the equipment used for LUHS management (CVCS pumps, electrical panels, etc.). Reservations on this point are made in the following paragraph.*

In states where the primary system is pressurisable, *a cliff-edge effect associated with feedwater exhaustion is observed. ASN estimates the time before core uncovering, evaluated at several days, to be acceptable given the water quantities regularly observed and prescribed in the operating technical specifications: 100 hours of autonomy if a single plant unit is affected, and at least 24 hours (possibly more) if a whole site is affected. ASN considers that EDF's proposal to re-assess the minimum required water reserves and study long-term means of resupplying water is satisfactory.*

For the LUHS situation, EDF did not examine the case where the primary system vents did not close, whereas failure of this operation was examined for the SBO situations. Given the additional available sources of make-up for the primary system, such a situation appears to be covered by the "primary system not pressurisable" states.

Assessment of the impact of an LUHS situation on the spent fuel pools:

EDF has chosen the APR[42] or RCD[43] operating ranges at end of unloading as states that are penalising to consider for an accident situation affecting only one plant unit. This is because it is in these plant unit states that the residual power of the fuel stored in the spent fuel pool is at maximum level.

For the analysis of an accident scenario affecting the entire site, EDF has taken a situation where one of the site plant units is in APR or RCD (states penalising for the spent fuel pools) while the others are at power. EDF also studied the case where a fuel assembly is being handled in the spent fuel pool.

With a single plant unit affected:

Loss of the heat sink induces a total loss of spent fuel pool cooling. The procedure applied in this situation provides for:

- stoppage of the fuel handling operations and placing those fuel assemblies actually being handled in a safe position;
- line connection of spent fuel pool make-up, first of all by SED[44] and then by JPI[45].

The other measures aiming to guarantee the accessibility of the premises adjacent to the BK hall, and ensure that the pressure in the hall does not rise, are equivalent to those for the SBO situation - total loss of electrical power supplies.

Loss of spent fuel pool cooling results in gradual heating of the water. The JPP[46] system guarantees permanent make-up of the spent fuel pool. Throughout this period where topping up is guaranteed, the level of water in the spent fuel pool remains well above the top of the fuel assemblies. There is no risk of reaching the feared situation (uncovering of the fuel assemblies). Depending on the residual power in the pool, the autonomy is estimated to be at least one month, a duration that is easily compatible with an external intervention.

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42 APR: Refuelling shutdown
43 RCD: Reactor completely unloaded
44 SED: Reactor dimineralised water distribution system
45 JPI: Nuclear island fire protection system
46 JPP: Fire-fighting water production system

With a whole site affected:

The site's autonomy with respect to situations of heat sink loss associated with off-site natural hazards was verified during the third 10-year inspection of the 900 MW plant units. The target is to have several days' autonomy. The equipment and water reserves available are:

- the SED system and all the SED tanks;
- the JPI and JPP systems.

Operator management of the situation for each plant unit is identical to the preceding case, as the JPI and SED systems remain available.

Kinetics of the phenomenon

The JPP system guarantees permanent topping up of the spent fuel pool. There is no risk of reaching the feared situation (uncovering of the fuel assemblies). Throughout this period where topping up is guaranteed, the level of water in the spent fuel pool remains above the top of the fuel assemblies.

Conclusion for one site

As the SED and JPI systems remain available and make-up continues if the heat sink is lost, the fuel assemblies will not become uncovered in an LUHS situation affecting the entire site. If the JPP is affected (for example in case of heat sink clogging), only the SED system will be able to make up the spent fuel pool in the BK building. In this case the time before the fuel becomes uncovered is estimated at a few days in the states where maximum power is installed in the spent fuel pool (APR and RCD states), and about one week in the other less penalising cases.

For the EPR:

Loss of the primary heat sink leads to the loss of the CCWS/ESWS trains, and therefore loss of cooling of the two main FPCS trains.

In states C with the primary system not pressurisable, D, and potentially part of state E[47], two CHRS trains are required to manage the situation of the NSSS. In this case the spent fuel pool is no longer cooled. Topping up with water by a JAC pump with a line connected to one of the two JAC tanks (1000 m^3 and 2600 m^3) prevents the uncovering of the fuel assemblies. Making up by the JAC enables the water level in the spent fuel pool to be maintained for:

- about four days with the JAC tank of 1000 m^3;
- more than 10 days with the JAC tank of 2600 m^3.

The time before the fuel assemblies in the storage rack become uncovered is about 18 days, which is compatible with an external intervention.

In the other states, the third FPCS train, cooled by CHRS/UCWS, can be started with line connection on the diversified heat sink (outfall structure) in the event of loss of the primary heat sink, to ensure the cooling of the spent fuel pool.

[47] State "E" of the EPR: Cold shutdown with reactor cavity full for reloading.

2.1.2.2 Loss of the primary heat sink and the alternate heat sink

None of the reactors in operation has an alternate heat sink.

Only the EPR has an alternate heat sink. It comprises two independent systems (CHRS and UCWS) which themselves are made up of two redundant channels in the pumping station. The UCWS system can draw in raw water from the main pumping station ("normal" mode) or from the outfall structure in the sea ("diversification" mode).

In the CSA report, EDF did not study the consequences of loss of the alternate heat sink on the safety of the EPR reactor. Elements were however provided during the technical investigation.

Consequences of loss of the heat sink on the spent fuel pools:

In this scenario, the 3 FPCS cooling trains are lost due to the loss of the CCWS/ESWS and CHRS/UCWS trains.

In states A, B, C with the primary system pressurisable, the 2600 m^3 JAC tank is dedicated to replenishing the EFWS tank. Making up by JAC gives a time lapse of about four days before the fuel assemblies stored in the rack become uncovered, which is compatible with an external intervention..

In states C with the primary system not pressurisable, D, and potentially part of state E, topping up by JAC enables the level in the spent fuel pool to be maintained for:

- about four days with the JAC tank of 1000 m^3;
- more than ten days with the JAC tank of 2600 m^3.

The time before the fuel assemblies in the storage rack become uncovered is about 18 days, which is compatible with an external intervention.
In states E and F[48], make-up by JAC enables the level in the reactor cavity to be maintained for:

- more than one day with the JAC tank of 1000 m^3.
- more than three days with the JAC tank of 2600 m^3.

The time before the fuel assemblies in the storage rack become uncovered is about 5 days, which is compatible with an external intervention.

ASN observed that for the Flamanville EPR, EDF has not studied the consequences of the successive loss of first the primary heat sink, then the alternate heat sink on the safety of the reactor. This configuration was only studied for the spent fuel pools. However, in the CSA report, EDF did present the consequences of the combined loss of primary and alternate heat sinks with a total loss of electrical power supplies, both from the viewpoint of its consequences on the reactor and with regard to the spent fuel pool.

ASN asked EDF to conduct additional studies to assess the consequences of a complete loss of the primary heat sink (ESWS) and alternate heat sink (UCWS) of the Flamanville 3 EPR on the damage to the reactor core.

Regarding the assessment of the consequences of heat sink loss on the spent fuel pools, ASN observed that the time lapses before the core becomes uncovered would be longer than the time specified in the baseline safety standard: a few days with maximum residual power in the BK building spent fuel pool, and about one week in the states other than APR - RCD. These times seem compatible with an external intervention and with the means that EDF envisages implementing for additional water make-up. If the make-up means are lost, the times and consequences are identical to those for an electrical power loss situation.

[48] State "F" of the EPR: Cold shutdown with the reactor core completely unloaded. This state is used to carry out work on the primary system components. This state is not to be analysed with respect to reactor core protection..

2.1.2.3 Conclusion on the planned measures to protect the installations against the risk of losing the ultimate cooling system or the heat sink

In all the configurations studied by EDF, for both the reactors and the spent fuel pools, the estimated time before the feared situation occurs (nuclear fuel uncovering) is greater than the required time estimated by EDF for restoration of correct operation of the heat sink. The identified cliff-edge effects depend on the quantity of feedwater available. Moreover, EDF adds that the time lapse before the core becomes uncovered will be much longer in the states where the primary system is fully open than that calculated for situations of electrical power supply loss (evaluated at several days).

ASN agrees that the time lapses before uncovering occurs could be longer in states where the primary system is not pressurisable than in an SBO[49] *situation, due to additional primary cooling system make-up possibilities. Nevertheless, ASN observed that EDF's calculations and reasoning imply hazard robustness of the equipment used to manage a whole-site LUHS situation. Yet the cliff-edge effects associated with the temperature resistance of the equipment required in LUHS situations have not been investigated. Consequently, ASN considers the demonstration of EDF's ability to manage a long-duration whole-site LUHS situation to be insufficient, since the complementary measures implemented rely partly on existing equipment items used in LUHS situation management (CVCS pumps, electrical panels,* I&C*, etc.) which could have been damaged or lost, notably because in this configuration they are no longer cooled and can ultimately become unavailable.*

Similarly, in the current baseline safety standard, EDF has not defined systematic requirements relative to earthquake resistance and flood protection of the equipment used in LUHS situations. *Yet ASN observed certain weaknesses in the ability of the facilities to withstand a whole-site LUHS situation induced by an earthquake, including at the level of the current baseline safety standards earthquake, or by flooding beyond the baseline safety standard. In the event of such hazards, ASN considers that the core could become uncovered in just a few hours in an LUHS situation (for all plant unit states). Similarly, for the EPR reactor, ASN notes that the operability of the UCWS system (which is the EPR's alternate heat sink) is not guaranteed in the event of a design-basis earthquake.*

In its studies, EDF envisages examining the possibility of giving the means for guaranteeing water make up a higher hazard robustness margin than the current baseline safety standard. ***ASN considers that the proposed improvements, which meet the CSA specifications, should be implemented. It has issued a requirement on this subject. In a case of confirmed insufficiency, ASN will ask EDF to reinforce the robustness of the equipment contributing to the management of a whole-site LUHS situation.***

Similarly, the temperature resistance of the equipment situated in areas that are no longer cooled has not been exhaustively verified. ASN considers that certain key equipment items could ultimately be lost through the heating up of such areas. For the plants in operation, this includes:

- *the RCV pumps, whose rooms are cooled by a ventilation system that is no longer cooled in an LUHS situation;*
- *electrical or* I&C *equipment supporting other equipment used in LUJHS situations;*
- *the low-head safety injection (LHSI) pumps used in an LUHS situation, while their motors (1300 MWe, 1450 MWe) and the pumps themselves (1300 MWe) are cooled by the CCWS system, which will ultimately be lost in an LUHS situation.*

[49] Short-term cliff-edge effects characterised by a shorter time before core exposure than that planned by EDF for the implementation of the FARN have been identified in the SBO situation. This time is a few hours for the 900 MWe series in states with the primary system fully open - reactor cavity not full (due to the current absence of independent means of injection to the primary system), and about 10 hours with the primary system partially open (all plant units). In the primary system fully open state on the 900 MWe series with the current operating procedure, the time to core exposure in a whole-site SBO situation is about 8 hours (because the pump injecting at the primary pump seals is common to two plant units). Moreover, in the case of an SBO situation combined with loss of the LLS, TPS EFWS and TAC/GUS, the time is just a few hours with the primary system tight. In the primary system fully open states on the 1300 MWe and 1450 MWe series, and in the primary system fully open and reactor cavity full (all series), the time in an SBO situation (excluding summed effects) is longer (several days).

ASN asked EDF to supplement its demonstration with a temperature sensitivity study of the equipment items required to manage a whole-site LUHS situation and which are situated in areas that are no longer cooled. This study must be carried out considering a representative duration of utilisation of these equipment items in the event of a long-duration LUHS situation and considering that the entire site may be affected.

More specifically for the spent fuel pools:

ASN observed that the availability of water from the fire-fighting network to make up the spent fuel pools is not guaranteed in the event of an earthquake. In a situation of total loss of the electrical power supplies, this system will not function.

EDF proposed an ultimate back-up make-up means specific to each plant unit, robust to the hazards identified in the CSA report, which will draw water from the water table or large-capacity ponds using a stand-alone motor-driven pump or an electric pump backed by the ultimate back-up diesel generator (DUS). EDF specified that the study of this ultimate make-up means is planned for the end of 2012.

ASN considers that the proposed improvements, which meet the CSA specifications, should be implemented. It has issued a requirement on this subject.

More specifically for the EPR:

The cooling system of the EPR reactor spent fuel pool has a third cooling train. The heat sink of this third train is independent and should therefore remain functional if the heat sink common to the main two cooling trains is lost. In all the reactor operating ranges, the spent fuel pool can be made up by the fire-fighting system. This fire-fighting system is also used when necessary to replenish the tanks of the auxiliary feedwater supply to the steam generators. It must therefore be available in all the reactor operating ranges.

Within the framework of the Flamanville 3 EPR commissioning examination, ASN asked EDF to present its maintenance and management strategy for the systems shared by the spent fuel pool and the reactor (such as the fire-fighting water system) in order to minimise their temporary unavailability.

Ability of the site to manage an accident involving heat sink loss:

Managing an LUHS situation involves many actions, some in the control room but above all locally. EDF has provided little information on how they are performed, given the ambient conditions in the premises, their accessibility, and the human resources available to implement them all on all the plant units.

Furthermore, means evaluated in an LUHS situation are planned to be used by EDF as part of the complementary measures to prevent severe accidents.

ASN considers that EDF must back up its conclusions regarding the capability of the NPPs for managing a degraded situation (LUHS or SBO) on several plant units simultaneously, including when a plant unit suffers a severe accident. If necessary, EDF will define additional provisions for the management of this situation. ASN has issued a requirement on this subject.

These requests are applicable to the reactors in service and to the EPR.

2.1.2.4 Measures envisaged to increase the robustness of the facilities with respect to loss of the ultimate cooling system or the heat sink

ASN asked EDF to "indicate what measures could be envisaged to prevent or delay the onset of these cliff-edge effects, to improve the site's autonomy and increase the robustness of the facility (design change, change in procedures, organisational arrangements, etc.)."

For the reactors in service, EDF proposed measures to increase the time lapses before the core becomes uncovered. EDF proposed increasing the on-site water reserves (to supply the feedwater system, the primary cooling system and the spent fuel pool) as a complement to the FARN, which will then take over.

Ultimate make-up means for all the reactors:

EDF proposed implementing an ultimate make-up pump or tank type resource, robust to the hazards considered in the CSA report, by pumping water from the water table or large-capacity ponds using a stand-alone motor-driven pump or an electric pump backed by the ultimate back-up diesel generator (DUS). This system will be a fixed installation on all the sites and will allow the make-up of the EFWS and FPCS tanks and the spent fuel pools (before 2015). EDF has confirmed that the make-up means and its supporting systems will be dimensioned for the needs of the entire site. The output will be sufficient to supply the spent fuel pool building (BK) and either the EFWS tank or the FPCS tank simultaneously.

Ultimate make-up from the demineralisation plant water supply system (SEA) ponds (Paluel, Penly and Flamanville sites)

The demineralisation plant water supply system (SEA) ponds at the Paluel, Penly and Flamanville sites are situated on the cliff (total capacity of 150,000 m^3 at Flamanville, 36,500 m^3 at Penly and 36,000 m^3 at Paluel). The CSA reports for Flamanville 1-2 and 3 and Penly 3 indicate that the ultimate make-up will be from these ponds. For Penly 1-2 and Paluel, an ultimate make-up means by pumping water from the water table or tanks is mentioned but not detailed. During the examination, EDF pointed out that for these three sites (all plant units), the ultimate make-up would be provided by the existing SEA ponds.

These ponds are not included in the safety demonstration at present, therefore they are not safety-classified and have no seismic requirement. EDF nevertheless indicated that they are stable under the stresses of the SSE (safe shutdown earthquake), and even beyond. The ponds are connected to the demineralisation plants by two pipes (SEI - industrial water system) which are not designed to withstand an earthquake at Flamanville and Paluel but are at Penly (level not specified). The risk of rupture of the SEI pipes is studied for Flamanville and Paluel, as EDF considers that the consequences of complete emptying of the ponds are acceptable with respect to the flood risk (water retained in the galleries and turbine halls). As regards the ultimate make-up function of the ponds, EDF indicated that it will make the valve chamber and the SEI pipes earthquake-resistant at Flamanville (not specified for Paluel).

ASN considers that if the SEA ponds and the SEI pipes and valves are to be part of the ultimate defence against LUHS situations, or even a severe accident, including situations induced by an earthquake exceeding the baseline safety standard, they must be included in the "hard core" of tightened material and organisational provisions.

Ultimate make-up means at Civaux and Cattenom

These sites have large water reservoirs which constitute the back-up heat sink (ponds at Civaux giving an autonomy of 10 days, Mirgenbach lake at Cattenom giving an autonomy of 30 days). ASN emphasizes that the earthquake-resistance stability of the Mirgenbach lake dam at Cattenom "presents moderate margins beyond the SSE" according to chapter 4 of the CSA reports. For these sites, like the others, the CSA reports mention the implementation of long-lasting ultimate water make-up means (pumping from the water table, ponds, etc.) for the EFWS and FPCS tanks and the spent fuel pools.

ASN considers that the characteristics of the ultimate means envisaged by EDF must satisfy the requirements assigned to the systems, structures and components of the "hard core" of tightened material and organisational provisions.

Particular case of the Flamanville 3 EPR

The complementary measures envisaged by EDF concern, among other things, the ultimate make-up of the EFWS tanks and the spent fuel pool with water from the ponds of the demineralisation plant water supply system (SEA), and reinforcement of the ultimate back-up diesel generators. The ultimate water make-up solution for the spent fuel pool envisaged by EDF, by gravity feed from the SEA ponds, could compensate for the evaporation losses and enable a minimum water level to be maintained once the JAC water reserves are exhausted. The autonomy provided by the ponds considerably increases the time lapse before the fuel assemblies stored in the rack become uncovered. For the whole-site situation, pooling of water reserve utilisation is envisaged, which will reduce the gain in autonomy compared with the single plant unit situation.

ASN considers that these water supply reinforcement measures are in principle likely to enhance the robustness of the facilities. These measures have the advantage of reinforcing and increasing the autonomy of the means of making up the primary and secondary cooling systems with the aim of coping with long-duration whole-site LUHS situations, not taken into account in the current baseline safety standard. ***ASN considers that this ultimate make-up means must have substantial autonomy and function in a situation of total electrical power supply loss. ASN considers that the other safety objectives of this ultimate make-up means are:***

- ***to be functional at the natural hazard levels considered in the CSAs,***
- ***to be implementable under the particular conditions that may be present on the site, especially skyshine irradiation from the fuel stored in the BK building spent fuel pit (low water inventory),***
- ***to be implementable within a time scale compatible with the envelope scenario considered,***
- ***to allow boration of the water injected into the primary system.***

ASN has issued a requirement on this subject.

ASN draws attention to the fact that the quality of the make-up water must be compatible with its use by the safety equipment (EFWS pumps, CHRS spray nozzles on the Flamanville 3 EPR, etc.) and that the need to constitute a stock of boron for replenishing the FPCS tank will have to be studied.

The risks that wells descending into the water table could represent in the event of a severe accident will also have to be taken into account.

EDF is also taking additional measures, consistent with management of SBO situations:

- EDF has indicated that it was defining a "hard core" of equipment items comprising a limited number of structures, systems and components strictly necessary for the management of a whole-site LUHS+SBO situation, and therefore the safety objective is to prevent large radioactive releases into the environment. EDF specified: *"this hard core will include key existing and complementary equipment items (fixed or mobile), some of which serve to prevent entry into a severe accident (SA) condition (severe accident prevention)"*.
- EDF is initiating checks on the adequacy of the current water reserves of the auxiliary feedwater system (EFWS) for the steam generators (in 2012);
- EDF undertakes to reassess the minimum thresholds of the TS for the SER tanks in order to guarantee the targeted autonomy;
- EDF undertakes to implement additional pumping means for making up the primary and secondary cooling systems;
    - motor-driven cooling pump in the primary system fully open states on the 900 MWe series,
    - ultimate back-up diesel generator (DUS) to supply one CVCS pump and one EFWS motor-driven pump on all the reactor series.
- EDF envisages installing a motor-driven pump for injecting water into the core from the FPCS tank in situations of total loss of the electrical power supplies (before 2015);
- EDF envisages installing an ultimate back-up pumping unit specific to each plant unit and having an ultimate make-up means that will draw water from the water table or from large-capacity ponds to enhance the reliability of the spent fuel pit top-up function;

- EDF will conduct studies and make operating procedure changes to limit the risk of a breach at the primary pump seals if their cooling is lost;

Specifically for the EPR reactor, EDF plans:

- to reinforce the facilities' robustness against flooding;
- to limit water ingress via the slabs in the pumping station and outfall structures. This provision concerns the EFWS, JAC, SEC and UCWS systems used in LUHS situations.

ASN considers that these planned improvements will enhance the robustness of the facilities, even though it expresses some reserves or requires additional information regarding their adequacy or application in certain cases.

One ASN reserve concerns EDF's proposal to use existing equipment (CVCS or SIS pumps, electrical panels, EFWS equipment, FPCS tank, etc.) as part of the complementary measures, given that some of these equipment items may have been damaged or lost. In effect, robustness to hazards beyond the baseline safety standard is not guaranteed. As an example, the ultimate make-up means (pumping from the water table or reservoirs) powered by the new ultimate back-up diesel generator will be used to supply the secondary system via the existing EFWS tank, lines and motor-driven EFWS pump, and to supply the primary system via the FPCS tanks and the existing lines. It is important for EDF to guarantee their robustness, taking into account:

- *the reliability, hazard robustness and ease of use of the additional equipment;*
- *the risks of common mode failure (associated for example with an induced internal hazard) or common cause failure (associated with the design, production, maintenance, etc.) between the key existing equipment items and those added as part of the additional measures;*
- *the risks of failure - whether intrinsic or associated with a hazard - of the existing equipment that EDF proposed reusing as part of these ultimate defence measures (electrical panels, CVCS pumps, EFWS equipment, etc.).*

ASN considers that the complementary measures proposed by EDF for the whole-site SBO situation provide robustness with respect to the LUHS situation (less degraded) and cover failure of the means used specifically in this situation. However, with a defence-in-depth approach, it is important to prevent an LUHS situation from evolving irreversibly towards more a severely degraded situation (such as whole-site SBO) in which the consequences can no longer be mitigated by a small number of equipment items.

With this aim in view, ASN considers that EDF must start giving thought to updating its baseline safety standards, in the light of Fukushima experience feedback, to integrate the long-duration whole-site LUHS situation.

ASN considers it necessary for EDF to examine the temperature resistance of the "key" equipment situated in premises where the ventilation system is no longer cooled in the event of long-duration loss of the heat sink for the entire site.

To enable the complementary measures to provide a robust ultimate line of defence against the cliff-edge effects identified in the CSA reports for whole-site LUHS situations, and notably those induced by an earthquake or flooding beyond baseline safety standards, EDF must, when it defines the hard core equipment items, look for new measures that are independent and diversified with respect to the existing means, including in their supporting systems, in order to minimise the risks of common mode failure between the existing means and the complementary means.

In particular, EDF must look for easy-to-use and robust injection means situated as close as possible to the steam generators and the primary cooling system (rather than have the ultimate make-up means depend on the reliability of the CVCS pumps, whose temperature resistance displays uncertainties).

ASN considers it necessary for EDF to install hazard-resistant back-up systems that can continuously remove the residual power in the event of total loss of the heat sink.

ASN also considers it necessary for EDF to propose reliable and hazard-resistant means of injecting borated water into the reactor core.

For the EPR, ASN asked EDF for complementary studies of UCWS system reinforcement in "diversification" mode (that is to say with intake from the sea outfall structure rather than the main pumping station, as is the case in normal mode), given the high probability of having to switch to this mode in an accident situation.

ASN considers it necessary to implement EDF's proposal to constitute a hard core of material and organisational measures, associated with tightened requirements, to prevent an LUHS type situation (or SBO) from degrading into a severe accident. Complying with this requirement will lead EDF to:

- ***define the list of necessary structures, systems and components (SSC) to prevent core meltdown in long-duration whole-site LUHS or SBO situations;***
- ***demonstrate the earthquake and flood robustness of its SSCs and implement any necessary additional measures to ensure this robustness;***
- ***make an additional verification of the robustness and accessibility of these SSCs, considering the hazards and effects induced by an earthquake or flood beyond the current baseline safety standard.***

ASN considers it necessary for EDF's proposals relative to the equipment items included in this hard core to meet the requirements set forth above, and must notably be dimensioned to withstand hazards of a higher intensity that those considered in the existing baseline safety standards.

Once EDF has defined the targeted "hard core" elements (see § 1.1.3), robust to the risks exceeding the baseline safety standard, ***ASN asked it to revise its baseline safety standard in the light of Fukushima experience feedback and start examining the robustness - against the baseline safety standard risks - of those equipment items that are not included in the "hard core" but nevertheless used in whole-site LUHS situations.***

These requests are applicable to the reactors in service and to the EPR.

Medium- or long-term accident management:

The complementary measures proposed by EDF with respect to LUHS/SBO situations aim essentially at allowing water make-up to be made (to the secondary system, primary system and spent fuel pools) to extend the autonomy of the reactors and spent fuel pools. The fact of performing these make-ups, when it is not possible to restore a cooling system, enables core meltdown to be delayed but not necessarily prevented. In the case of the primary system, once a certain volume of water has been injected into the reactor building, the ability to restore lasting means of cooling may be compromised. *ASN insists on the necessity to ultimately restore cooling in order to reach a safe condition, on the existing plant units and the Flamanville 3 EPR alike (the "CHRS spraying of SEA water" modification only buys limited additional time), and to integrate this necessity into the strategy of the FARN (see section § 3.1.3)*

EDF must study the means for ultimately restoring long-term cooling of the reactors and spent fuel pools, using elements from Fukushima accident experience feedback, including in cases where the heat sink has been seriously damaged.

Finally, the FARN activation criteria in the event of a hazard or accident, and the dimensioning of the associated means, will have to be adapted to enable the FARN to effectively take over management of all the postulated accident situations (all reactor states considered) and thus avoid core uncovering. It would moreover be pertinent for the FARN's reflections to focus more generally on the means of ensuring or restoring the safety functions in the medium/long term, independently of specific accident scenarios.

2.1.3 Loss of the main cooling system combined with loss of the off-site electrical power supplies and the on-site back-up supplies

For each reactor, ASN has asked EDF to:

- *indicate for how long the site can withstand loss of the "main" heat sink combined with loss of the off-site electrical power supplies and the back-up energy sources, without external aid, before serious damage to the fuel becomes inevitable;*
- *indicate what external action is planned to prevent fuel damage, and the resources available:*
  - *equipment already on the site, for example equipment from another reactor,*
  - *equipment available off the site, assuming that all the reactors on a given site have suffered damage;*
  - *the availability of human resources;*
- *indicate the times within which the above resources can be available;*
- *identify the time within which the main cliff-edge effects occur;*
- *indicate which measures can be envisaged to prevent these cliff-edge effects or to reinforce the robustness of the facility (design change, change in procedures, organizational arrangements, etc.).*

ASN has asked EDF to take two situations into consideration for the loss of the off-site electrical power supplies and the on-site back-up supplies:

- *loss of the off-site electrical power supplies and loss of the conventional back-up supplies (safeguard means in particular);*
- *loss of the off-site electrical power supplies and of the conventional back-up supplies and any other on-site back-up electrical power source (including the ultimate back-up means).*

ASN has asked EDF to take into consideration the loss of the main cooling system combined with total loss of the off-site and back-up electrical power supplies, considering initially that only one reactor is affected, and subsequently that all the facilities of a given site are affected simultaneously.

Loss of the main cooling system combined with total loss of the off-site and back-up electrical power supplies is not analysed for the baseline safety standard.

EDF specified in the CSA reports that the situation of total loss of the heat sink combined with total loss of the electrical power supplies has no additional impact compared with the total electrical power loss alone: as the pumps of the intermediate cooling system (CCWS) are supplied by the backed-up electrical panels, the loss of the electrical power supplies intrinsically causes total loss of the heat sink.

EDF also pointed out that the impact of an earthquake or a flood on these combined situations has been examined in the CSA reports.

ASN observed that EDF has analysed loss of the main cooling system combined with loss of the off-site electrical power supplies and loss of the conventional back-up power supplies. Nevertheless, in its CSA reports, EDF has not analysed the loss of the main cooling system combined with loss of the off-site electrical power supplies and loss of the conventional back-up power supplies and any other emergency source. ASN considers that EDF must adopt a position regarding the missing assessment.

2.1.3.1 Site autonomy before loss of the normal conditions of core and fuel pool cooling

EDF specified in the CSA reports that from a thermohydraulic viewpoint, this situation is identical to that described in the section relative to loss of the off-site electrical power supplies and the conventional back-up power supplies (see § 2.1.1.2).

ASN does not question EDF's conclusions, but nevertheless notes that this combined situation is more penalising with regard to the recovery of the support functions, since it is not enough to simply recover an electrical power supply - it is also important to restore a heat sink.

2.1.3.2 External actions planned to prevent damage to the fuel

Regarding the external actions planned to prevent damage to the fuel, EDF specified in the CSA reports that in terms of facility management, the situation evoked is identical to that described in the section relative to loss of the off-site electrical power supplies and the conventional back-up power supplies (see § 2.1.1.2).

The planned external actions for managing loss of the main cooling system combined with loss of the off-site electrical power supplies and the on-site back-up supplies examined by EDF in its complementary safety assessments correspond to the requirements of ASN decision 2011-DC-0213.

2.1.3.3 Measures envisaged to reinforce the robustness of the facilities with respect to loss of the main cooling system combined with total loss of the off-site and back-up electrical power supplies

Regarding the measures that can be envisaged to prevent cliff-edge effects or to increase the robustness of the facility, apart from the measures proposed in the event of loss of the off-site electrical power supplies and the conventional back-up supplies and described earlier, and in addition to the measures presented in the previous sections, EDF proposed in the CSA reports:

- studying the means of guaranteeing protection of the equipment necessary for the management of this situation with a flood level (to be defined) that goes beyond the baseline safety standard;
- undertaking studies to ensure the earthquake resistance of the motor-driven cooling pump which, in the event of an earthquake, will offer the same autonomies as considered in the section relative to the loss of the off-site electrical power supplies and the conventional back-up supplies (§ 2.1.1.2);
- ensuring the earthquakes robustness of the measures envisaged in the section relative to the loss of the off-site electrical power supplies and the conventional back-up supplies (see § 2.1.1.2) to cover the present situation.

During the technical examination carried out by IRSN, ASN's technical support organization, EDF also gave a commitment to defining a hard core that will include "key" existing and complementary equipment items (fixed or mobile), some of which enable severe accidents to be avoided. The resistance of this hard core equipment with respect to certain hazards, the level of which remains to be defined, will be verified. Measures to reinforce the protection of the hard core equipment will also be envisaged if necessary.

ASN considers that EDF's proposals for reinforcing the electrical and cooling resources, which comply with the CSA specifications, must be implemented.

ASN has asked that by 30th June 2012, EDF send it proposals for this hard core of reinforced material and organisational measures, along with a definition of the requirements this hard core must satisfy.

2.1.4 Summary: Design studies

ASN considers that EDF's responses are on the whole in conformity with the specifications it issued.

Analysis of EDF's CSA reports showed that certain loss of heat sink and total loss of electrical power supplies scenarios can lead to reactor core melt in just a few hours in the most unfavourable cases.

ASN thus considers that the robustness of the facilities must be increased by a certain number of means enabling them to deal with long-duration loss of electrical power and cooling situations capable of affecting all the facilities on a site. ASN asked EDF to implement these reinforced measures, integrated into the hard core mentioned in section § 1.1.3 of this report, in particular comprising a diesel generator and an alternate water supply, capable of withstanding the on-site and off-site hazards exceeding the current baseline requirements and of dealing with the total loss of electrical power and cooling scenarios, in order to prevent core melt in these situations. Pending the gradual deployment of these measures, which will take several years, ASN has required the implementation of provisional measures this year, such as mobile electricity generating sets.

2.2 Summary table: Topic 2 – Design studies

Activities	Activities of the Licensee			ASN activities		
	Activity Completed In progress? Envisaged	Calendar Or steps for the activitie envisaged	Result Obtained Yes? No?	Activity Completed In progress? Envisaged	Calendar Or steps for the activities envisaged	Conclusions available Yes ? No?
Topic 2: Design studies						
Installation of an ultimate back-up diesel generator (DUS) on each unit. This diesel generator will in particular be able to power: - the minimum necessary reactor I&C and control room lighting, - the information required in the case of loss of BK spent fuel pool cooling, - the ultimate water make-up pump for replenishing the EFWS system tank, the FPCS system tank and the BK spent fuel pool, - the information necessary in core melt situations, - the containment isolation valves, control room ventilation-filtration, - a motor-driven pump of the EFWS system and make-up for the primary system;	Completed	Implementation on the 58 units in service before end 2018	Yes	Completed	Requirement 2012	
Pending deployment of the ultimate back-up diesel generator, implementation of a temporary system for supplying the reactor minimum I&C and control room lighting	In progress	Mid-2013	No	Completed	Requirement 2012	
Study of risk of hydrogen production linked to radiolysis of the water in the BK pool and, as applicable, proposals for study of countermeasures	In progress	2012	No	Completed	Requirement 2012	
Study of material and organisational measures for safe positioning of a fuel assembly being handled, in the event of loss of electrical power	In progress	2012	No	Completed	Requirement 2012	

Study and proposals for improvements of pool instrumentation (level, temperature, pool area dose rate, etc.) Implementation of a level measurement available in the event of total loss of electrical power	In progress	Implementation in mid-2012	No	Completed	Requirement 2012	
Implementation of a level measurement available in the event of total loss of electrical power	In progress	End 2013	No	Completed	Requirement 2012	
An ultimate water make-up (well or tanks) will be installed on each unit to supply the EFWS tank, the FPCS tank and the BK spent fuel pool, for long-term removal of residual power. This make-up will be integrated into the hard core and thus made robust to hazards (earthquake, flooding, other extreme climatic hazards) beyond the current design baseline.	In progress	Definition of calendar of modifications late 2012	No	Completed	Requirement 2012	
Installation of systems to ensure the injection of borated water into the reactor core in the event of total loss of on-site electrical power when the reactor coolant system is fully open.	In progress	Before 30th June 2013		Completed	Requirement 2012	
Changes to accident operating procedures to supplement management of total loss of electrical power situations, in all NSSS states, and for all the units on a site.	In progress	Deployment on all the sites by 2018	No			
Examination of the requirements associated with the equipment needed to manage total loss of heat sink or total loss of electrical power situations, with regard to temperature resistance, resistance to earthquakes, flooding and the effects induced on the facility by these hazards. Proposals for changes to the safety baseline and corresponding reinforcements of the facilities to deal with these situations.	In progress	End 2013		Completed	Requirement 2012	
Modifications to achieve a significant increase in the autonomy of the batteries used in the event of loss of off-site and on-site electrical power.	In progress	31/12/2014		Completed	Requirement 2012	
The possibility of resetting the TPS EFWS from the Control Room will be the subject of a preliminary study (900 MWe plant series)	In progress	Presentation of solutions in 2012	No			

BK spent fuel pool: By the end of 2012, EDF will complete its thermohydraulic studies of the spent fuel pool, taking account of the different behaviours of the various areas of the spent fuel pool.	In progress	2012	No			
BK spent fuel pool: Study of steps to counter a rapid loss of water inventory from the spent fuel pool	In progress	Presentation of studies in 2012.				
Secure on-site stocks of fuel and oil and ensure that they can be replenished in all circumstances, to guarantee an autonomy of at least 15 days.	Envisaged			Completed	ASN request 2012	

3 Severe accident management (on site)

This chapter presents the organisational and material measures implemented by EDF on the site to manage severe accidents (SA). This type of accident is characterised by significant damage to the fuel in the reactor building or the fuel building.
Operation in the event of an incident or accident is based on a state-based approach. This approach consists in establishing operating strategies according to the identified physical state of the nuclear steam supply system, regardless of the events which led to this state. A permanent diagnostic means that if the state degrades, the procedure or sequence in progress can be aborted and a more suitable one applied. At the time core damage is detected (core melt), the steps described in the severe accident intervention guide are designed to enable the containment to be safeguarded in order to minimise the consequences of the accident. Responsibility then shifts to the emergency management teams, with their respective action guides. In order to deal with these accident situations, nuclear power plants have back-up equipment (fixed or mobile) called on in emergencies.

3.1 Licensee's accident management organisation and measures

3.1.1 Licensee's accident management organisation

The local emergency organisation comprises a decision-making centre, three operational response centres and a think tank. It is a part of the national organisation described below.

- Implementation of the On-site Emergency Plan (PUI) entails the creation of 4 command posts (PC) and a local emergency team handling the various duties described above. Apart from the PCL, which is situated in the control room and the Local emergency team, located on the nuclear island, the other PCs are grouped in the BDS.
- The Local Command Post (PCL) is responsible for control and safeguard of the safety of the damaged unit. It thus provides first aid to the injured and collects information about the nature and scale of the accident, for its own purposes and those of the other PCs and the Local emergency team.
- The actions of the operations team are under the control of a safety engineer who is not a member of the team.
- The Local Strategic Management Command Post (PCD-L) is a key element and the hub of the organisation. It is run by the NPP Director (or his representative) and has sole responsibility for the decisions to be taken to ensure the safety of the facilities, protection of the personnel and safeguard of the equipment.
- On-site, it coordinates the activities of the other PCs and tells them what additional steps are to be taken. Off-site, it liaises officially with the local public authorities, especially the *Préfet* and the national management command posts of EDF, ASN and IRSN.
- The Controls Command Post (PCC Analysis and PCC Measurements) centralises the interpretation of the radiological measurements and evaluates the ongoing or foreseeable releases and their consequences for the environment.
- The Resources Command Post (PCM) deploys the intervention resources on the site (emergency response, troubleshooting, telecommunications, signposting, transportation) and the personnel protection measures (assembly, evacuation if necessary, decontamination) in the following fields:
    - Maintenance (organisation of particular interventions as required by the situation: Works - Interventions on behalf of the PCL according to priorities established by the PCD, troubleshooting, repairs, deployment of mobile security equipment);

- o Human protection – Safety – Radiation protection (monitoring assembly of the persons present on the site, information of these persons, possible organisation of evacuation from the site, setting up a rapid contamination monitoring and decontamination centre, activation of a Triage and Care Centre (CTS), assistance to the off-site emergency services for intervention in a controlled area and for evacuation of contaminated victims, monitoring of on-site intervention conditions, participation in deployment of MMS and PUI equipment, activation of the fallback centre;
- o Logistics (management of vehicles, organisation of transport and supplies for the intervention personnel, signposting of the site and on-site traffic regulation, supply and regulation of human and material resources necessary for the other PCs, management of PC shift changes, transmission of requests to the Site Protection team, liaison with the supporting entities);
- o Telecommunications (assistance to the PCs in ensuring the operability of the communication resources, activation of site telecommunication resources).

- ▪ The local emergency team (ELC), providing technical support to the PCD-L, contributes to the PCL's view of the situation and its resulting actions. On-site, and jointly with the national emergency teams, it analyses the situation and how it develops (diagnosis/prognosis), in order to issue an opinion and recommendations to the PCD-L regarding how to act in the medium term. Off-site, it supplements the information of the national emergency teams (EDF and IRSN) and takes part in drawing up the diagnosis/prognosis.

The response to an emergency situation requires mobilisation that is appropriate, ranging from customised mobilisation to automatic mobilisation (automatic messages) both locally and nationally.

In the NPP, 24h/24 and 365 days per year, the emergency organisation must be operational within 1 hour and mobilise 70 people.

At the national level, the National Emergency Organisation must be operational in its Paris premises within two hours, mobilising 50 people and alerting 300 others.

In the event of a PUI, the ramp-up of the nuclear licensee's organisation parallels that of the public authorities, who trigger the Off-site Emergency Plan (PPI) (see chapter 4 – National Organisations).

In addition to the premises used by the emergency teams, the sites have assembly stations (LR) in which the personnel assembles in the event of a PUI (Radiological Safety) and a fallback centre, located off the site and not under the prevailing winds, to accommodate the persons present on the site at the time of the accident, protect them (decontamination if necessary) and inform them. This centre thus houses the personnel the site's emergency director has decided to remove from the NPP for safety reasons. In the case of evacuation of personnel not required for management of the event, it can be used to accommodate persons so that they are available for organising work shifts.

In the CSA specifications, ASN asked EDF to present its emergency organisation for managing accident situations, including the availability of competent personnel capable of intervening, shift management, measures taken to optimise personnel intervention (consideration of stress, psychological pressure, etc.), recourse in accident situations to outside technical support (and alternative solutions should this support become unavailable), as well as procedures, training, and drills.

In its CSA reports, EDF describes the site emergency organisation planned to respond to incident, accident or severe accident (SA) situations. This organisation is described in the site's On-Site Emergency Plan (PUI), which is required by the regulations and devised to cover situations presenting a significant risk for the safety of the facilities, and which can lead to the release of radioactive, chemical or toxic substances into the environment. The PUI covers the management of SAs. It also describes the measures designed to aid and protect the persons present on the site, preserve or restore the safety of the facilities and limit the consequences of accidents for the public and the environmental impact. The PUI defines the functions necessary for managing the emergency and the conditions of shift relief.

EDF also describes the various PUI provisions for ensuring optimised personnel intervention. These provisions are of various types:

- in terms of personnel safety: the staff shall be counted and informed in assembly stations. EDF also indicated that the means implemented in normal operation to monitor radiological conditions on the site and to monitor the personnel remain operational and suitable for the conditions that can exist in SA situations, except in the event of total loss of electrical power. Lastly, if the site is contaminated, control room ventilation is switched to iodine traps to prevent it being contaminated by radioactive iodine;
- in terms of emergency team preparation and speed of response: immediate action shall be taken following the onset of the SA, in direct application of the operating procedure documents;
- in terms of intervention: the mobile devices implemented under the PUI are stored and deployed so as to limit personnel exposure during their assembly and utilisation in an accident situation.

The outside technical support resources the sites can call upon are also described in the CSA reports. They can for example be provided by Intersite Assistance, AMT-C (EDF's Thermal Maintenance Agency - Centre), Groupe INTRA, etc. The conditions of mobilisation and intervention of these resources form the subject of agreements between the sites and the entities on which they depend.
The procedures implemented in the management of SAs, the training and exercise drills are also detailed in the CSA reports. These three points form part of the SAMG (Severe Accident Management Guidelines) and the sites' PUI baseline. In practice, the initial operator training syllabus presented by EDF already includes a part devoted to "Severe Accidents", and drills simulating SA situations are held regularly. Certain national PUI drills can therefore be based on scenarios simulating entry into the SA domain. The internal PUI drills held by EDF cover all the domains, including design accidents, fuel building (BK) incidents and severe accidents.

EDF moreover indicated that it has analysed the sizing of the operating teams for application of the current severe accident management procedures, particularly for events affecting several reactors. EDF indicates that in this context it has postulated the situation where it is impossible for the on-call teams to reach the site for the first 24 hours following an unpredictable large-scale hazard affecting the entire site. EDF concludes from these analyses that the sizing of the operating teams, in conformity with the current baseline, does not always allow application of the SPE (permanent surveillance document), and notably the surveillance of the criterion for opening the pressuriser relief lines (LDP) in the event of a severe accident affecting two reactors. This finding thus led EDF to study the adequacy of the human and material resources for the activities involved in the deployment of the hard-core equipment items (including the immediate measures specified in the SAMG) and the additional equipment proposed further to the CSAs. The main steps involved in this study, the conclusions of which are scheduled for the end of 2012, are:

- identification of the duties to be performed (emergency management, control of the facilities, etc.) on all the reactors of a site;
- identification of the activities to be carried out with their main characteristics, such as duration, conditions of intervention, etc.;
- identification of the additional material resources to be implemented, taking their utilisation constraints into account as of the design stage;
- final verification of the adequacy of the human resources (numbers and skills) for all the activities to be carried out;
- identification of any additional training needs.

ASN considers that the emergency organisation implemented on the sites is satisfactory for the design-basis scenarios affecting a single installation. Nevertheless, EDF's current organisation and studies do not sufficiently address the management of a "multi-facility" emergency, possibly resulting from an external hazard, affecting all or part of the installations of a given site simultaneously and at different levels. ***In such a situation, ASN considers that the operating and emergency teams must be of adequate size to perform all their duties on all the site's installations. ASN therefore asked EDF to supplement its organisation, by 31st December 2012, to take into account accident situations affecting all or part of the facilities of a given site simultaneously****.*

ASN also considers it necessary, assuming an extreme situation of one of the types studied in the CSAs, for EDF to guarantee for each reactor the feasibility of all measures for which provision is made in the operating documents (accident operating procedures, SAMG) with the operating and emergency teams present on the site, taking into account the necessary shift reliefs. ASN has issued a requirement on this subject.

3.1.2 Possibility of using existing equipment

In the CSA specifications, ASN asked EDF to address the following aspects of severe accident management: the possibility of using existing equipment, the provisions for using mobile devices (availability of such devices, time required to bring them to the site and put them into operation), the management of supplies (fuel for diesel generators, water, etc.), the management of radioactive releases and provisions to limit them, and the communication and information systems (internal and external).

- Possibility of using existing equipment:

For the use of existing equipment, EDF indicated in the CSA reports that the equipment used is generally SA-specific equipment and, if conditions permit and its use is compatible with the containment control objective, non-SA-specific equipment. There is a limited number of equipment items specific to the SA domain on the EDF sites. The measures required by the GIAG are predetermined and limited. They are based on the use of existing equipment items which are also predetermined and limited. Any other equipment utilisation or measure that might be requested by the National Emergency Organisation shall be jointly appraised by the various emergency teams to check that it is not of a prejudicial nature (particularly with regard to containment).

ASN observed that as a general rule, the current baseline safety standard contains no hazard-resistance requirements for the SA-specific items (equipment and instrumentation). ***Consequently, EDF cannot guarantee the availability of existing equipment in the extreme situations studied in the CSAs. ASN thus asked EDF to integrate the equipment necessary for emergency management, including the SA equipment, into the "hard core" (see § 1.1.3).***

Furthermore, experience feedback from the Fukushima accident leads to questions concerning the permanent availability and operability of the dosimetry and radiological protection equipment. ***ASN considers that the operational dosimetry means, the measuring instruments for radiation protection and the personal and collective protection equipment must be permanently available on the sites and in sufficient quantity. ASN has issued a technical requirement on this subject.***

- Provisions for using mobile devices:

EDF indicated in the CSA reports that at present there is no specific national mobile device for severe accident management. There is however a local mobile device planned specifically for such situations: a processing unit for the plant unit radiation monitoring system (KRT) U5 for measuring the activity released during containment decompression by the U5 venting-filtration system. Other mobile devices not specific to severe accident management can also be used if they have been set up before entry into the SA condition and if their operation is not contrary to the severe accident management objectives. As a general rule, the mobile devices called upon to manage all types of accident situation must be made available within the specified time and in predetermined conditions. Each site defines the organisation for putting into service and operating the mobile devices and guaranteeing their availability. To guarantee the availability of these devices, each one has a specific sheet describing its identification, its purpose, where it is stored, the service responsible for it, the duty function to contact for its deployment, the time necessary for its deployment, the required assembly processes and the associated list of periodic tests. To verify the permanence of availability of these devices and the resistance of the premises in which they are stored, EDF undertakes for each site to appraise the emergency equipment storage conditions and their resistance to the various types of hazard considered in the CSAs. This study will identify the required reinforcements.

ASN considers that the study proposed by EDF will provide useful information for assessing the resistance of the emergency equipment storage premises. Moreover, during its inspections, ASN observed that the equipment necessary for emergency management, and in particular the MMS (mobile safety equipment), the PUI equipment and the MDC (complementary domain equipment), was not managed satisfactorily by the sites and that the storage conditions did not guarantee permanent availability, particularly in the event of external hazards. ***For ASN, the equipment necessary for emergency management must be included in the "hard core" of tightened material and organisational provisions (§ 1.2.3). These devices, their storage locations and deployment procedures must be identified in the site PUIs. They must be tested regularly, and training in their deployment must be provided during drills. ASN has issued a requirement on this subject.***

- Management of supplies for the diesel generators:

In the CSA reports, EDF presented information on the autonomy of the diesel generators and the provisions for extending their utilisation in the event of loss of off-site power (LOOP). This point is detailed in § 2.

The minimum guaranteed fuel autonomy is 3.5 days per generator set in the least favourable load conditions. The conditions of supply are covered by a national contract, which provides for delivery within 24 hours in emergency situations. Strategic reserves of fuel are held specifically by EDF.
The sites have sufficient oil reserves to guarantee an autonomy of more than 3 days. Beyond this, supply is guaranteed by measures specific to each site.

For all the plant series, the initial water reserves for cooling the diesel generators are sufficient to ensure two weeks' autonomy. Diesel generators have an independent air-water cooling system. Each diesel generator has a compressed air reserve that allows 5 start-ups.

ASN considers that the supply management methods are satisfactory for guaranteeing 3 days autonomy for the generator sets. ASN considers that EDF must secure its on-site stocks of fuel and oil and ensure that they can be replenished in all circumstances, to guarantee an autonomy of at least 15 days (see § 2).

- Management of radioactive releases and measures to limit them:

In the CSA reports, EDF described the measures implemented on the sites to manage and limit radioactive releases. The requirements relative to containment monitoring are thus set out in a procedure applied by the safety engineer in an accident situation before entry into a severe accident condition, and in a containment monitoring guide used by the emergency teams. In a severe accident situation, this containment monitoring guide remains applicable and takes priority over all the other measures demanded in the severe accidents management guidelines. Detection of containment deficiencies is signalled by high activity measurements on the plant radiation monitoring systems (KRT).

EDF stated that it has put in place extensive prevention means that reduce the probability of SA situations occurring, and means to mitigate their impact on man and the environment. When the residual power can be removed from the reactor containment, releases into the environment are limited. In this case the releases come from potential leaks from the reactor containment.

The pressurised water reactor containment performs two functions:

- reactor protection against external hazards;
- confinement and therefore protection of the public and the environment against radioactive products liable to be dispersed outside the reactor primary coolant system in the event of an accident; the containments are thus designed to withstand the temperatures and pressure levels that could be reached in the event of an accident and offer adequate leaktightness in these conditions.

The containments are of two types:

- the 900 MWe reactor containments, which consist of a single prestressed concrete wall (concrete comprising tensioned steel cables to compress the structure). This wall offers mechanical resistance to the pressure which would result from the most severe accident considered in the design, as well as the integrity of the structure with regard to an external hazard. Leaktightness is provided by a thin metal liner on the inner face of the concrete wall;
- the containments of the 1300 MWe and 1450 MWe reactors, consisting of two walls: the inner prestressed concrete wall and the outer reinforced concrete wall. Leaktightness is provided by the inner wall and the ventilation system (EDE) which channels the radioactive fluids and fission products that could come from the interior of the containment following an accident, into the annulus space between the walls. Resistance to external hazards is primarily provided by the outer containment wall.

This containment is designed to withstand 5 bar absolute pressure for all the plant series, and its resistance is verified every 10 years.

Furthermore, concerning the reactors in operation, the U5 venting-filtration system (described in section 3.2.2), reserved for the ultimate safeguarding of the reactor containment, once the gas plume induced by its opening has gone, enables the off-site radiological consequences to be limited. This system, designed to filter the aerosols that form in the reactor containment in the event of loss of reactor vessel or primary cooling system leaktightness, retains a large proportion of the radionuclides. If U5 is opened, the population protection measures would be implemented around the nuclear site during the radiological emergency phase. To limit iodine releases and reduce the radiological impact on the site and the populations in a severe accident situation, EDF indicates in the CSA reports that it plans studying a passive device for increasing the pH in the reactor building sumps, including in a situation of total loss of the electrical power supplies (SBO - site blackout).

As the earthquake was not considered a plausible severe accident initiating event at either the design stage or during the periodic safety reviews (see § 3.1), given all the design measures taken on the safety-classified structures, systems and components, the U5 system components - apart from the containment penetration and the isolation valves - are not therefore seismic classified. The U5 system sand bed filter was not therefore subject to specific requirements with respect to the seismic risk when it was installed. Consequently, this system could, in the event of an SA further to an earthquake, cease to be operational or even become a hazard for other safety-classified equipment items. **On this point, EDF has undertaken to conduct a study on the earthquake resistance of the U5 system. It has also announced that there will in addition be a broader reflection on the U5 system filtration that could, if necessary, lead to changes to this system in the longer term.**

Insofar as they were not subject to specific design requirements with respect to external hazards, ASN considers that at present, the means for limiting releases in the event of core meltdown are not resistant to the hazard levels adopted for the CSAs, particularly for earthquake levels exceeding the design-basis earthquake. The changes resulting from the studies announced by EDF will have to guarantee the resistance of these means. ***ASN thus required that before 31st December 2013, EDF carry out a detailed study of the possibility of improving the U5 venting-filtration system, taking into account hazard robustness, filtration efficiency if used on two reactors simultaneously, the improvement in the filtration of the fission products, especially iodine isotopes, and the radiological consequences of opening of the emergency management rooms and of the control room, especially with regard to site accessibility.***

- <u>Communication and information systems (on-site and off-site)</u>:

In the CSA reports, EDF gives the objectives and principles concerning means of communication, to ensure on-site communication between the emergency teams and the assembly areas, and communication with the off-site players. The objectives of these systems are to alert the on-site and off-site players as early as possible (EDF staff and public authorities alike), to alert the populations if a PPI (off-site emergency plan) reflex response phase criterion is attained, to exchange information with the various emergency management centres both on site and off site, and to inform the public and the media.

EDF indicated that the means of communication used when deploying the organisation can be deficient (either following immediate degradation as a result of an initiating event, or by exhaustion of the batteries powering them). To enhance the reliability of these various means of communication, EDF undertakes to study the reinforcement of the strategic connections by communication means that have greater autonomy and are resistant to earthquakes and flooding (i.e. totally independent of hard-wired communication links). The aim is to equip the emergency management premises with satellite-link telephones with greater autonomy enabling the shift operations supervisor to give the alert, the local and national players to establish or continue their communications, and the FARN (nuclear rapid intervention force) - if it should be required to intervene - to establish contact with the on-site participants. The FARN is a national EDF entity currently being set up, which will be capable of rapidly providing material and human aid to a site in serious difficulty. This entity is described in greater detail in the paragraph "*Extensive destruction of infrastructures around the facilities*" § 3.1.3.

ASN considers that communication is one of the primary elements in emergency management and that it is essential for EDF to be able to alert the public authorities and, if delegated powers by the prefect, to alert the populations in order to protect them, inform on-site personnel of the situation, particularly if the site has to be evacuated, and communicate with the on-site and off-site emergency teams, whether local or national. ***ASN has thus asked EDF to integrate the communication means vital for emergency management into the "hard core" of reinforced material and organisational provisions. These means will include the means for alerting the public authorities and the population alert systems if the off-site emergency plan is triggered in the reflex response phase. They will also have to be made resistant to the extreme situations studied in the CSAs.***

3.1.3 Identification of factors that can hinder accident management and the resulting constraints

In the CSA specifications, ASN asked EDF to evaluate the envisaged accident management measures considering the situation such as it could occur on the site:

- *extensive destruction of infrastructures around the facility, including the means of communication (making technical support and personnel reinforcement from outside the site more difficult);*
- *the disruption of work efficiency (including the impact on the accessibility and habitability of the main and secondary control rooms, the premises used by the emergency teams and any area required to be accessible for accident management) caused by high dose rates in the premises, by radioactive contamination and the destruction of certain facilities on the site;*
- *the feasibility and efficiency of the accident management measures in the event of external hazards (earthquakes, flooding);*
- *electrical power supply outage;*
- *potential failure of the instrumentation;*
- *the impact on the site of the other neighbouring facilities.*

- <u>Extensive destruction of infrastructures around the facility</u>:

With regard to the envisaged accident management measures in the event of extensive destruction of the infrastructures around the facility, EDF indicated in the CSA reports that its emergency organisation does not include specific arrangements for this situation, including for clearance of the site. In the event of major damage to roads and civil engineering structures, EDF calls upon the public authorities who, in addition to the PPIs specific to the emergency situation, implement the provisions of the "ORSEC" national emergency response plan. The aim of these provisions is to facilitate site access for the duty teams.

To cope with the extreme case of total defaulting of the duty personnel or failure of the communication means (particularly with the exterior) used during deployment of the emergency organisation, EDF indicated that it is currently conducting complementary studies on:

- reinforcing the skills of the operating team so that it can take the necessary minimum measures to prevent or delay core meltdown;

- reinforcing the communication links by having communication means with greater autonomy and which are earthquake- and flood-resistant;
- the creation of a Nuclear Rapid Intervention Force (FARN);
- taking into consideration the working conditions of the operating personnel, the on-call personnel and the FARN. They must be able to guarantee the health and safety of the workers. The psychological aspect is taken into account.

In the CSA reports, EDF presented the broad lines of the requirements applicable to the FARN. EDF thus plans for the FARN to be able to:

- intervene within 24 hours, without interruption and to take over from the operating teams that will have carried out the emergency measures for the site concerned and whose access infrastructures may be partially destroyed;
- work autonomously for several days on a partially destroyed site (non-seismic tertiary buildings, for example), whose environment could be radioactive and - on some sites - possibly affected by chemical pollution;
- deploy heavy-duty protection or intervention means within a few days;
- ensure a permanent link with company management, site management and teams, and the local authorities in order to manage and coordinate the interventions;
- prepare for continuation of the intervention beyond the first days of autonomy in the event of a long-duration emergency.

ASN considers that EDF has not finished analysing the weak spots in the organisation according to the scale of the external hazard that led to the emergency situation. Consequently, ASN has issued several requirements concerning:

- ***the definition of the human actions required for management of the extreme situations analysed in the CSAs, including situations affecting several reactors and those that could have consequences on the accessibility and habitability of the emergency management premises. EDF will verify that these actions can effectively be carried out, including for the FARN, given the intervention conditions likely to be encountered in such scenarios;***
- ***integration of the communication means vital for emergency management into the "hard core" of reinforced material and organisational provisions.***
- ***the FARN. This will be capable of responding within 24 hours, with operations beginning on the site within 12 hours from the time of call-out. It will comprise specialised crews and equipment capable of taking over from the personnel on a site affected by an accident and of deploying additional emergency response resources, including in situations involving large-scale releases. EDF specified the organisation and size of these crews, in particular the activation criteria, their duties, the material and human resources at their disposal, the organisational arrangements made to guarantee the maintenance and the permanent operability and availability of these material resources, and finally their training and skills currency processes. By the end of 2012, this system will be deployable on the site for intervention on a reactor. It will be able to intervene simultaneously on all the reactors of a site by the end of 2013, for 18 sites, and by the end of 2015 for Gravelines.***

- Disruption of work efficiency caused by high local dose rates, radioactive contamination and destruction of certain facilities on the site:

EDF presented the impact of this type of situation on the accessibility and habitability of the control rooms. In a severe accident situation, if the pressure in the reactor building rises, it may be necessary to depressurise the containment to maintain its integrity, by using the U5 system filter. EDF stated that in the light of the current preliminary studies on the habitability of the control room after opening the U5 system filter, the permanent presence of personnel in the control room is to be avoided in the period (24 hours) following this opening.

In the CSA reports, EDF also presented the impact of these situations on the various premises used by the emergency teams to manage the accident. The accessibility, habitability and operability of the

Emergency Technical Rooms (LTC) are identical to those of the control rooms after opening the U5 system filter.

EDF specified in the CSA reports that the emergency rooms (security block (BDS), emergency equipment stores, etc.) were designed without a specific regulatory requirement relative to flooding and earthquake, whereas in practice, these premises are required to remain operational in the event of external hazards. EDF's analysis of the earthquake resistance of the BDS shows that these buildings generally have structural resistance up to SSE (safe shutdown earthquake) level. The BDS is temporarily uninhabitable after opening the U5 system filter. On this latter point, EDF undertakes, further to the CSAs, to carry out a more comprehensive study on the scale of a site to assess the habitability of the control rooms and the BDS, and site accessibility after opening the U5 system filter on a reactor in a severe accident situation.

In the CSA reports action plan, EDF also announced the performance of preliminary studies to improve BDS robustness to ensure that they remain operational, particularly in the event of an earthquake and high winds. EDF also indicated that it will undertake a general reflection on the BDS to identify the needs in order to improve the organisation and habitability of the emergency rooms. Lastly, EDF undertakes to carry out a study comprising firstly a per-site appraisal of the emergency equipment storage conditions and the resistance of the storage premises to the different types of hazard considered (earthquake, climatic event, flooding, etc.) and secondly the identification of improvements for coping with them.

Moreover, managing an LUHS or SBO situation involves many actions, some in the control room but above all in the facilities. EDF's CSA reports provide little information on the conditions of performance of these tasks: the atmosphere in the rooms (particularly the temperature which can be very high if there is no ventilation), accessibility in the case of hazard damage, available human resources to carry out these tasks on all the facilities.

The information presented by EDF in the CSA reports does not guarantee the resistance, habitability and accessibility of the emergency management premises and control rooms in the extreme situations analysed in the CSAs and in the case of opening of the U5 system filter. *ASN points out that the emergency organisation on the sites relies on having premises which must be available to manage the emergency for the required duration.*

ASN therefore asked EDF to ensure that these emergency management premises, situated on or near the site and providing personnel protection (among other things), can withstand the extreme situations analysed in the CSAs and form part of the "hard core". They shall be accessible and habitable during long-duration emergencies and designed to accommodate the crews necessary for long-term site management.

ASN also considers that the control and monitoring of all the reactors on the impacted site must be ensured in the event of hazardous substance releases or opening of the venting-filtration system (U5). ASN thus considers that everything must be done so that opening of the U5 system on a reactor does not prevent the management of all the reactors on the site, considering that their condition at that moment may be degraded to varying extents. ***In this respect, ASN will attentively analyse the encompassing but nevertheless realistic nature of EDF's study to assess the consequences of opening the U5 system filter on the habitability of the control room, the emergency shutdown panel, and the management of the site as a whole.***

ASN has asked EDF to ensure the control and monitoring of all the reactors of a site in the event of hazardous substance releases or opening of the U5 venting-filtration system from the control rooms, the emergency shutdown panels or the emergency management rooms.

ASN has also asked EDF to define the human actions required for management of the extreme situations analysed in the CSAs, including situations affecting several reactors and those that could have consequences on the accessibility and habitability of the emergency management premises. EDF will verify that these actions can effectively be carried out given the intervention conditions likely to be encountered in such scenarios. EDF will take account of the relief of the emergency teams, the logistics necessary for the interventions, and will indicate any material or organisational adaptations envisaged.

Lastly, ASN asked EDF to submit a list of the necessary emergency management skills, specifying whether these skills are liable to be held by outside contractors. EDF will provide proof that its organisation ensures the availability of the necessary skills in a emergency situation, and notably when it is possible that outside contractors will be used.

- <u>Feasibility and efficiency of the accident management measures in the event of external hazards (earthquakes, flooding):</u>

EDF indicated in the CSA reports that application of the procedures by the operators in the control room is not affected by an external hazard (earthquake, flooding), as the control room is robust to the design-basis hazards. In the event of a severe accident combined with flooding or an earthquake, EDF specified that the equipment used in the reactor containment will not be damaged. The operating team has procedures for dealing with this situation and managing its consequences (loss of heat sink in particular). The actions to be carried out in the facilities must be secured, particularly if building lighting is lost. The communication means used in normal operation could be rendered inoperative by the external hazard.

As indicated earlier, ASN considers that failure of the means of communication in an emergency situation is unacceptable, therefore it is vital to reinforce them.

ASN has thus asked EDF to integrate the communication means vital for emergency management into the "hard core" of reinforced material and organisational provisions.

In the CSA reports, EDF presented the conclusions of its analysis concerning the LUHS and SBO situations. These analyses however do not consider that an external hazard can be the cause of such situations. Consequently, the times given in these reports for the LUHS and SBO situations alone are not representative of cases in which these situations are induced by an earthquake or flooding, even with the hazard levels of the current baseline safety standard. This is because the current baseline includes no systematic requirement regarding the earthquake resistance and flooding protection of the equipment used in LUHS and SBO systems.

ASN observed certain weaknesses in the ability of the facilities to withstand a whole-site LUHS or SBO situation induced by an earthquake, including at the level of the current baseline safety standards earthquake, or by flooding beyond the baseline safety standard. ***ASN duly notes the measures envisaged by EDF for improving the robustness of its facilities vis-à-vis these situations, which in particular consist in ensuring the earthquake robustness of the additional measures defined for the on-site SBO situation and studying the means for guaranteeing the protection of LUHS/SBO equipment against flooding beyond the baseline safety standard. ASN has asked EDF to provision additional evidence by 31st December 2013 of the improved robustness of the facilities to these situations.***

- <u>Loss of electrical power supply:</u>

Total loss of electrical power supplies (loss of the off-site sources and the on-site diesel generators) is a situation taken into account in the severe accident management guidelines (SAMG). This situation could moreover lead to loss of the telecommunication means used in normal operation. The dynamic containment achieved by the ventilation systems would be lost, and particularly the main control room ventilation function and the filtration of that ventilation via the iodine trap. Permanent habitability of the control room is guaranteed, unless the U5 system filter is opened, in view of the modifications presented in the CSA report. If the U5 system is used, the habitability can be temporarily compromised. In this respect, EDF plans to reinforce the electrical back-up of control room ventilation and filtration through the Ultimate Backup Diesel Generator (DUS). Pending implementation of this modification, the FARN will deploy means to ensure the electrical back-up of these equipment items for the damaged reactor.
As indicated earlier, ***ASN considers that control room habitability must be ensured if events presenting risks for operator safety should arise, such as the release of hazardous substances into the environment or opening of the U5 system filter. ASN has issued a requirement on this subject.***

As indicated earlier, ASN considers that loss of the telecommunication means in the event of electrical power supply loss is unacceptable. The telecommunication means must therefore be reinforced in this respect.

ASN has thus asked EDF to integrate the telecommunication means vital for emergency management into the "hard core" of reinforced material and organisational provisions.

- <u>Potential failure of the instrumentation:</u>

The instrumentation helps optimise management so as to delay or prevent entry into a severe accident situation if possible. In its CSA reports, EDF indicated that the situation diagnosis and prognosis are established by the emergency teams on the basis of the measurement of certain identified parameters. In the case of loss of the electrical power supplies, the instrumentation that detects entry into the SA situation is no longer available in the control room. EDF has undertaken to ensure the electrical back-up of this instrumentation by adding an Ultimate Backup Diesel Generator (DUS). However, in the event of an earthquake, the availability of the instrumentation useful in SA situations is not guaranteed because it is not earthquake classified.

In addition, as the containment pressure sensor is not backed up by the back-up turbine generator (LLS), it will be unavailable in the event of electrical power supply loss. EDF plans for the electrical back-up of this sensor by the FARN in order to counter the overall loss of the electrical power supplies.

ASN considers it unsatisfactory that the technical instrumentation necessary for managing an accident situation, and particularly a severe accident situation, should be lost due to an external hazard. ASN thus asked EDF to include the technical instrumentation necessary for emergency management in the "hard core" provisions. This requirement will also extend to the environmental instrumentation necessary for emergency management, for which the external hazard resistance is not guaranteed either.

- <u>Impact on the site of the other neighbouring facilities:</u>

Among the industrial facilities situated near the NPP sites, EDF identifies in the CSA reports the Installations Classified on Environmental Protection grounds (ICPE) which can be subject to Authorisation (A) or subject to Authorisation with public protection restrictions (AS). For the ICPE A facilities, EDF concludes that they present no hazard risk for the NPP sites. For the ICPE AS facilities, EDF uses the perimeter of the ICPE's Technological Risk Prevention Plan (PPRT) to evaluate its impact on the NPP site, and distinguishes between two cases:

- the maximum distance between the site and the ICPE AS is greater than the PPRT perimeter: in this case EDF concludes that this ICPE does not present a hazard risk for the site;
- the maximum distance between the site and the ICPE AS is less than the PPRT perimeter: in this case EDF specified the types of effects (thermal, toxic, overpressure) that could affect the site.

EDF also mentions the existence of ICPEs subject to Declaration (D) in the environment of all the NPP sites and indicates that they present no known risk for them.

With regard to the risks caused by the industrial facilities internal to the site, and depending on the site, EDF identifies the presence of monochloramine treatment plants, of hydrazine hydrate storage facilities and of plant unit diesel generators. EDF identifies the hazard potential and the nature of the hazardous phenomena associated with these facilities. It also indicates the measures that would be taken in the event of an accident.

Regarding the identification of hazard sources relating to the on-site and off-site industrial environment, EDF does not always present the nature of the hazardous substances, the maximum quantities involved and the distances separating these hazard sources from the facility's safety targets in the CSA reports. For example, EDF concludes - without giving any justification - that the ICPE A and D facilities do not present a hazard risk for the sites. Nor do the CSA reports give an assessment of the consequences that the hazardous phenomena associated with these hazard sources - potentially aggravated in the event of an earthquake or flood - could have on the facilities, which might have been made more vulnerable by said earthquake or flood.

EDF has undertaken to propose by mid-2012 a plan of action to study and deal with the risks associated with the industrial environment on and off the site, in the event of extreme situations, and to verify the robustness of the complementary safety measures and emergency management means with respect to hazards associated with the industrial environment. In the particular case of the Tricastin site, EDF has undertaken to assess the impact of the AREVA facilities on the Tricastin NPP in the accident situations analysed in the CSAs. For the Gravelines NPP, EDF has undertaken to assess the impact of the oil pipeline that crosses the NPP intake channel and its bridge on the site.

The hazardous phenomena associated with the hazard sources of the industrial facilities presented in the hazard studies were taken into account in the design of the NPPs and are reassessed periodically, in accordance with the requirements of the order of 31 December 1999[50] and the recommendations of RFS I.2.d[51] defined by ASN. ***ASN nevertheless considers that EDF must examine these hazardous phenomena in the extreme situations analysed in the CSAs and draw its conclusions as to the complementary measures required. ASN also considers that EDF must assess the consequences of the induced hazardous phenomena (explosive, thermal, toxic, etc.) on its facilities, considering their condition after a "CSA level" earthquake or flood.***

ASN has required that EDF strengthen its ties with the neighbouring operators, by means of agreements or detection and alert systems, so that it is rapidly informed of any event that could constitute an external hazard for its facilities, and to ensure coordinated emergency management with the operators of neighbouring nuclear facilities and ICPEs.

ASN also considers that EDF must examine the effects on its facilities of the hazardous phenomena that could occur on potentially hazardous industrial facilities situated near its NPPs, taking into consideration the extreme situations studied in the CSAs. ASN has issued a requirement on this subject.

Regarding the transport routes and pipelines situated in the site environment, EDF identifies them in the CSA reports and specifies the natures of the products carried in the pipelines. EDF concludes that, for all the sites, the transport of hazardous substances can present hazard risks, but that these risks are limited and that they meet the objectives of the fundamental safety rule (RFS) I.2.d relative to risks associated with the industrial environment and the transport routes. The CSA reports do not give an assessment of the consequences of these hazardous phenomena - potentially aggravated in the event of an earthquake or flood - on the facilities which could have been made more vulnerable by said earthquake or flood. EDF indicated that such assessments have already been carried out during the periodic safety reviews of the various sites in application of RFS I.2.d and that they demonstrate compliance with the RFS criteria. EDF thus considers that in view of the existing assessments and the fact that these hazardous substances are not permanently present near the site, complementary studies of the hazardous phenomena associated with the transport routes beyond the baseline safety standards are not necessary.

ASN nevertheless considers that EDF must assess the consequences of the hazardous phenomena associated with the transport routes and pipelines in the extreme situations studied

[50] Order of 31 December 1999, amended, setting the general technical regulations intended to prevent and limit the harmful effects and risks resulting from the operation of basic nuclear installations

[51] RFS 1.2.d of 7 May 1982 relative to consideration of the risks associated with the industrial environment and transport routes

in the CSAs, and draw its conclusions as to the complementary measures required. ASN will be formulating a request on this subject.

3.1.4 Conclusion on the organisational provisions for accident management

ASN considers that EDF's emergency organisation and resources must remain operational for hazard levels very much higher than those considered for the design of the facilities, and for radiological or toxic environmental conditions resulting from a severe accident affecting several facilities on a given site. Furthermore, ASN considers that these resources must be highly flexible so as to be capable of managing unforeseen situations. In addition, ASN considers that EDF's organisational and material emergency management provisions must be supplemented to manage a situation affecting several facilities on a given site, including in the event of extensive destruction of the neighbouring facilities (§ 3.1.3).

ASN also considers that EDF must analyse the applicability of the human actions required to manage the extreme situations studied in the CSAs, including the situations affecting all the facilities on the site and those that can affect the accessibility and habitability of the emergency management premises. ASN has issued a requirement on this subject.

3.1.5 Measures envisaged to reinforce accident management capabilities

In the CSA reports, EDF proposed several improvements or studies to reinforce the management of accident or severe accident situations on its sites. These improvements more particularly target:

- the adequacy of the human and material resources for the activities associated with deployment of the "hard core" equipment and the additional equipment proposed further to the CSAs. This study will take the intervention conditions into account;
- the reinforcement of the material resources and communication means;
- the performance of a study to improve the resistance and habitability of the BDS;
- the design of a Local Emergency Centre, integrating stringent habitability requirements and allowing more effective management of the emergency. The design requirements taken into account shall be consistent with those of the hard core;
- the reinforcement of the means of measurement and of technical and environmental information transmission, including meteorological information, necessary for emergency management;
- the creation of a Nuclear Rapid Intervention Force (FARN) and definition of its material and human resources (§ 4.2.4);
- the functional earthquake resistance of the U5 system.

ASN considers that all these areas for improvement contribute to the reinforcement and robustness of accident and severe accident management on the sites. ***ASN nevertheless considers that some of the points identified by EDF need to be clarified. ASN has therefore required that EDF integrate the following into the hard core:***

- ***the emergency management rooms. They must offer high resistance to hazards and allow the management of a long-duration emergency;***
- ***the mobile devices vital for emergency management;***
- ***the active dosimetry equipment, the measuring instruments for radiation protection and the personal and collective protection equipment are also included in the hard core. They must be permanently available in sufficient quantities on the sites;***
- ***the technical and environmental instrumentation for diagnosing the state of the facility and assessing and predicting the radiological impact on the workers and populations;***
- ***the communication means vital for emergency management are included in the hard core provisions. They more particularly comprise the means of informing the public authorities and alerting the populations if the off-site emergency plan (PPI) is triggered in the reflex response phase.***

The requirements concerning the FARN must be supplemented, particularly in that it must be capable of intervening on the impacted site in less than 24 hours to relieve the shift teams and deploy the emergency means of resupplying power, with operations on a site starting within 12 hours after the start of mobilisation. The FARN teams must be dimensioned to intervene on a 6-reactor site, including a site where a massive release has taken place, and have appropriate instrumentation that can be deployed on the sites on arrival.

3.2 Existing accident management measures further to loss of core cooling

In the CSA specifications, ASN asked EDF to describe the accident management measures currently in operation at the different stages of a severe accident, particularly further to loss of the core cooling function:

- *before the fuel in the reactor vessel becomes damaged;*
  - *possible actions to prevent fuel damage;*
  - *elimination of the possibility of fuel damage at high pressure.*
- *after the fuel in the reactor vessel becomes damaged;*
- *after failure of the reactor vessel (core meltdown in the reactor pit).*

3.2.1 Before the fuel in the reactor vessel becomes damaged

In the CSA reports, EDF indicated that the safety procedures for the reactor fleet in service and the EPR rely on a strategy of defence in depth, which can be summarized as follows:

- measures are taken to avoid incidents;
- if an incident occurs, the protection systems bring the reactor to a safe condition;
- safeguard systems prevent a more severe accident from leading to core meltdown.

The existing measures to prevent entry into a severe accident situation (therefore before the fuel in the reactor vessel becomes damaged), particularly further to situations of flooding, earthquake, loss of electrical power or of the heat sink, come under the operational management for incidents or accidents procedures.

The measures that can be taken on the reactor fleet to prevent fuel damage aim to restore a means of injecting water into the reactor vessel in order to cool the fuel and stabilise the situation by reflooding the core. The possible measures consist in

- if necessary, restoring an electrical panel that can energise the back-up systems;
- deploying an ultimate line connection for injecting water into the vessel of the impacted reactor.

On the Flamanville EPR, the various lines of defence (main diesel generators, ultimate back-up diesel generator sets (SBO), replenishment of the EFWS tank) limit the risk of entry into a severe accident situation.

3.2.2 After the fuel in the reactor vessel becomes damaged

Beyond this point, a severe accidents management procedure aims to limit the consequences in the event of core meltdown. If it has been impossible to avoid the onset of a severe accident, the operating priorities are turned towards controlling containment and reducing releases.

In the CSA report, EDF indicated the existing measures in response to the identified risk in a severe accident situation. They are indicated below and reviewed in detail with the planned or envisaged improvements further to the CSA, in the section relative to "Maintaining containment integrity after fuel damage in the reactor core".

- Risk due to the production of hydrogen:

Since the end of 2007, all the reactors in service are equipped with hydrogen passive autocatalytic recombiners (PAR). The Flamanville EPR has PARs and devices for monitoring the concentration and distribution of hydrogen in the containment by interconnecting the two parts of the containment and favouring mixing by convection.

- Risk of slow pressurisation of the containment:

On the reactor fleet in service, this risk is dealt with by the existence of the venting-filtration system called "U5" and an associated operating procedure allowing decompression and filtration of the reactor containment in order to maintain its long-term integrity. Filtration is divided between a container internal coarse metallic filter and a sand bed filter (common to two reactors for the 900 MWe series). The opening of this system, which is an ultimate reactor containment protection measure, takes place after 24 hours as of a minimum pressure equal to the containment design pressure (about 5 bar absolute for all the plant series).

On the EPR, the CHRS system removes heat from the containment and controls its pressure. This safeguard system consists of 2 redundant trains and has a dedicated cooling system which itself has a diversified back-up water intake. In the event of loss of the electrical power supplies, while satisfying conditions compatible with operation of the reactor building ultimate heat removal system (CHRS), this CHRS system can be returned to service for 2 days in order to preclude the risk of containment failure. Finally, the integrity of the containment is maintained for 3 days after the initiating event if the CHRS is not put into service.

- Risk of reactor containment leaktightness fault:

On the reactors in service, confirmation of the isolation of the containment penetrations is required as part of the immediate actions on entry into a severe accident situation. The activity is monitored so that restoration measures can be implemented if necessary. The U2 operating procedure, which is part of the operational management of incidents or accidents, is applicable in a SA situation. Its aim is to monitor and if necessary restore reactor containment (by isolating the areas concerned, reinjection of highly radioactive effluents, etc.).

On the EPR, the containment and the peripheral buildings are designed such that there is no direct leakage path from the reactor containment to the environment. The building ventilation systems are backed up by the main diesel generators and the ultimate back-up diesel generator sets (SBO).

- Risk of direct heating of the containment:

To avoid direct heating of the containment, which would result from rupture of the vessel under pressure, the SA operating procedure on the reactors in service requires depressurisation of the primary system by opening the pressuriser relief lines immediately as of entry into the severe accident (SA) situation.

On the EPR, two redundant primary system discharge lines enable the primary system to be depressurised, preventing the risk of reactor vessel rupture at high pressure, which could lead to loss of containment integrity by direct heating of the containment. The operator has one hour after entry into the SA situation in which to open these lines, supplied by the 12-hour batteries.

3.2.3 After reactor vessel melt-through

Added to the above-mentioned risks is the risk of basemat melt-through further to rupture of the reactor vessel containing the corium.

For the reactor fleet in service, EDF indicated in the CSA reports that restoring water make-up in the reactor vessel and depressurising the primary system - as required by the operating procedure on entry into the SA situation - enable the low-pressure make-ups to flow into the primary system and help reflood the core, which - if achieved in time – would stop core meltdown and prevent reactor vessel melt-through. Reflooding the corium in the vessel or injecting water into the reactor pit via the perforated vessel to keep the corium flooded, limits the risk of basemat melt-through, or failing this, delay its occurrence. The severe accident management guidelines (SAMG) define the water injection conditions, particularly with respect to the risks of early loss of containment. As the safeguard systems of the damaged plant unit were probably lost on entry into the SA, so-called "ultimate" line connections can be implemented by the emergency teams to flood the corium.

For the reactor fleet in service, there is also a risk of ex-vessel vapour explosion. For the reactor fleet in service, EDF specified in the CSA reports that an international research programme is in progress to characterise the conditions of occurrence and the intensity of such phenomena. EDF also indicated that the available studies show the containment to be well able to withstand the loads resulting from a vapour explosion. Its integrity would therefore probably not be compromised in this situation.

For the Flamanville EPR, the CSA report indicates that the corium catcher situated in a special compartment on the edge of the reactor pit, is designed to collect, cool and stabilise the corium. Prevention of basemat melt-through is thus based on a reactor pit and catcher that are both dry when the corium arrives, on the collection and spreading of the corium and on its passive cooling after spreading. In the longer term, the CHRS system used in spraying mode enables the residual power to be removed from the corium.

3.3 Maintaining containment integrity after damage to the fuel in the reactor core

The ASN specifications required EDF to study the means of preventing and managing:

- *loss of the core cooling function;*
- *loss of containment integrity, particularly the reactor containment.*

The ASN specifications stated that the licensee had to describe the severe accident management measures and facility design elements to protect containment integrity after the occurrence of fuel damage.

The ASN specifications also stated that it was necessary to:

- *identify any cliff-edge effects and evaluate the time before they occur;*
- *assess the adequacy of the existing management measures, including the severe accident management guidelines, and the possible complementary measures.*

The risks induced by these situations and the severe accident management means for controlling them and mitigating their consequences are presented below, through a description of the existing means and the complementary means envisaged further to the CSAs.

3.3.1 Elimination of the risk of high-pressure fuel damage or core meltdown

The ASN specifications required EDF to describe the severe accident management measures to eliminate any possibility of high-pressure damage to the fuel. This is because in a core meltdown accident situation affecting a PWR reactor, and when depressurisation of the primary system cannot be guaranteed (no breach in the primary system and no cooling by the secondary system), meltdown can take place at high pressure: this is called pressure meltdown.

In the CSA reports, EDF indicated that, for the reactors in operation, the prevention of pressure meltdown sequences is based on voluntary opening of the pressuriser safety relief valve tandems. This opening of the three valve tandems causes rapid depressurisation of the primary system which eliminates the risk of having a highly pressurised reactor vessel in the event of melt-through and the risk of loss of containment through its direct heating. Opening of the valve tandems is required in the majority of situations well before entry into a severe accident on a primary system overheat criterion. In a situation of total loss of the electrical power supplies, this opening is required in the event of loss of the steam generators supply from the turbine driven auxiliary feedwater pump (TPS EFWS). Confirmation of this valve opening is required by the severe accident operating documents.

EDF indicated that opening the pressuriser safety relief valves and keeping them open enables core meltdown to be avoided with the primary system at high pressure, which could lead to significant pressurisation of the reactor containment atmosphere by fine spraying of the fuel when vessel rupture occurs (phenomenon of direct containment heating (DCH)). EDF specifies in the CSA reports that to fulfil this "primary system depressurisation" function, the current design of the remote control of the pressuriser safety relief valves requires permanent electrical power to their electromagnets, and therefore the availability of the electrical power source and power cables. A hardware modification to improve pressuriser safety relief valve opening reliability, decided before the Fukushima accident and already applied on certain reactors, is planned for the next 10-yearly inspection of each reactor. The solution chosen by EDF to improve its robustness is to replace the monostable remote control (electromagnet) by a bistable control (magnetic latching on control by electromagnet).

The modification proposed by EDF at the end of the CSAs also aims - in a situation of total loss of electric power sources and exhaustion of the batteries - to control the valve electromagnets directly from the relaying rooms from a new stand-alone Mobile Backup Means (MMS). Operation is thus simplified and bypasses all problems of battery autonomy and radiation resistance of the electrical power supply for the valve electromagnets. *ASN considers that the proposed improvements, which meet the CSA specifications, should be implemented.*

In the CSA report for the Flamanville 3 EPR, EDF indicated that the EPR is designed with two redundant primary system discharge lines enabling the primary system to be depressurised and avoid the risk of reactor vessel rupture at high pressure, which could lead to loss of containment integrity by DCH. The licensee has one hour after entry into the severe accident situation in which to open theses lines, which are supplied by batteries with 12 hours autonomy. *ASN considers the principle of this proposal satisfactory; it will be examined within the framework of Flamanville 3 EPR reactor commissioning.*

3.3.2 Management of the hydrogen risk in the reactor containment

The ASN specifications asked EDF to describe the severe accident management measures to prevent any hydrogen deflagration or detonation (containment inerting, recombiners or igniters). For the PWR severe accident studies, the hydrogen risk is defined as being the possible loss of reactor containment integrity or of its safety systems further to a hydrogen deflagration.

In the CSA reports, EDF indicated that hydrogen can be produced during different phases of an accident:

- in-vessel, during the phase of core degradation due to the oxidation of the fuel element cladding and other materials present in the reactor vessel;
- ex-vessel, during the corium/concrete interaction.

The hydrogen thus produced is released in the containment (through the primary system breach, the pressuriser relief tank, or the corium pool) where it is then mixed by the convection movements. In the CSA reports, EDF indicated that Passive Autocatalytic Recombiners (PAR) have been installed on all the reactors in operation in order to reduce the hydrogen concentration in the reactor building (BR) in the event of a severe accident. This installation has been effective since the end of 2007. Associated operating provisions are applicable on the sites. On completion of the CSAs, EDF undertook to study the hydrogen risk in the other peripheral buildings of the reactor containment. The study of the hydrogen risk in the intercontainment-space on the 1300 MWe reactors is in progress as part of the periodic safety review associated with their third 10-yearly inspection.

In the CSA reports, EDF indicated that the potential cliff-edge effect associated with the presence of hydrogen in the containment would be a loss of reactor building (BR) containment in the case of ignition of a build-up of a high hydrogen concentration in the BR. The recombiners exclude loss of containment through slow deflagration by limiting the quantity of hydrogen in the BR in the event of a severe accident. EDF underlined that the probability of such phenomena occurring is extremely low, especially given the geometrical characteristics of the containment. The containment has a relatively "open" geometry which favours hydrogen mixing and therefore limits the risk of formation of a build-up with a high concentration of hydrogen. Installation of the PARs, by reducing the quantity of hydrogen in the containment at a given moment in time, reduces the probability and the consequences of such phenomena. *ASN nonetheless considers that the ongoing* R&D *studies must be continued to improve understanding of these phenomena.*

In the CSA report for the Flamanville EPR, EDF describes the planned design measures: hydrogen concentration monitoring is based on two types of devices: PARs installed in the reactor building, and rupture and convection flaps and disks, whose opening ensures natural convection within the BR, thereby mixing and homogenising the containment atmosphere. *ASN considers these measures satisfactory at this stage of the examination, which is continuing with a view to the commissioning of the Flamanville EPR reactor.*

3.3.3 Prevention of reactor containment overpressure

The ASN specifications asked EDF to describe the severe accident management measures to prevent reactor containment overpressure.

The slow rise in the reactor containment pressure (linked to sump water vaporisation and possibly the formation of non-condensable gases from the decomposition of the basemat concrete by the corium, in the event of corium-concrete interaction (CCI)), can lead to its design pressure being exceeded, ultimately with loss of its integrity.

EDF indicated in the CSA reports that for the reactors in operation, the time before containment is lost due to the mechanical characteristics of the reactor being exceeded, varies from one to several days depending on the assumptions adopted for the studies. EDF considers that this leaves the operator the time to take steps to avoid containment destruction while optimising control of radioactive releases. The U5 system operating rules were developed in order to avoid containment rupture by overpressure, whatever the circumstances. These rules provide a means of limiting the pressure to a value slightly below the design pressure of the reactor containments by means of the associated decompression and filtration system. Management of such a situation favours a filtered release through a device that can be closed if necessary. The reactor building is depressurised by opening two manual valves.

In the CSA report, EDF specified that to exclude any risk of hydrogen combustion in the U5 system that could be induced by condensation of the vapour in the piping, there is a preheating system (venting line conditioning). This conditioning is lost in the event of total loss of the electrical power supplies (SBO). Although steps are taken to limit the risk of hydrogen combustion in the U5 venting line (pressure reduction upstream of the line limiting the risk of condensation, recombiners substantially limiting the hydrogen concentration), EDF has undertaken to re-examine the hydrogen risk and its possible impacts on the U5 system.

ASN considers that this examination must in particular focus on the impact of the oxygen already present in the U5 pipe and on the risk of hydrogen deflagration and its possible consequences at the U5 system outlet. ASN also considers that for the 900 MWe series, EDF must study the simultaneous use of the U5 system, which is common to two reactors. ASN thus required that EDF study the possibilities of improving the U5 venting-filtration system taking into account robustness to hazards, filtration effectiveness when used simultaneously on two 900 MWe reactors and the improvement of the filtration of the fission products.

Regarding the implementation of a venting-filtration system, EDF specified in the CSA reports for the reactors in operation that the risk of overpressure in the reactor containment is taken into account in the severe accident management guide. The U5 system filter must not be opened until 24 hours after entering the SA situation to allow deposition of the aerosols in the reactor containment. This operating procedure is implemented after a joint decision (EDF emergency teams, ASN, IRSN and public authorities).

In the CSA report for the Flamanville EPR, EDF describes the CHRS system that removes the heat from the containment and monitors its pressure. The residual power is transferred to the dedicated ultimate heat sink (UCWS). The pressure is limited by the CHRS spray function, the water being drawn into the IRWST (In-containment Refuelling Water Storage Tank) via the nozzles in the reactor building dome. The CHRS comprises two independent trains in separate safeguard buildings. The ultimate heat sink (UCWS), which also comprises two independent trains, is diversified: it can draw in seawater from either the pumping station or the discharge pond if the pumping station is unavailable. Containment integrity is maintained for 3 days if the CHRS is not put into service.

In the EPR CSA, to avoid the cliff-edge effect resulting from prolonged loss of the electrical power supplies, EDF proposed adding a mobile and independent water make-up system in the reactor building via the CHRS spray nozzles. This system consists in adding remote valve controls, the deployment of a motor driven pump and the use of the water from the ponds of the demineralisation plant water supply system SEA. This system would be deployed within 48 hours, a time lapse that is consistent with the implementation of substantial mobile resources. This arrangement enables the containment integrity grace period to be extended to 5 days for recovery of an electrical power supply and a heat sink in order to restore the functions of the CHRS system. *ASN considers that the proposed improvements, which meet the CSA specifications, should be implemented.*

In view of the above information on the CHRS system, the installation of a venting-filtration system on the Flamanville EPR is not planned by EDF, either in the design or in the CSA report. *ASN nevertheless considers that over and above the modification proposed by EDF, the Fukushima accident makes it necessary to re-analyse this design choice in the event of the long-term impossibility of restoring a heat sink. This point is taken up in the paragraph "Measures envisaged to reinforce the maintaining of containment integrity after fuel damage"* (§ 3.3.10).

3.3.4 Prevention of the risk of re-criticality

The ASN specifications asked EDF to describe the severe accident management measures to prevent the risk of re-criticality. The fuel assembly geometry, the presence and arrangement of the control rods and neutron absorbers, the boron content of the water in the primary system and the FPCS tank (IRWST for the EPR reactor) were studied at the design stage to exclude the risk of re-criticality in the case of design-basis accidents.

However, in the event of a severe accident, following the loss of the primary coolant as a result of the unavailability of all the safeguard systems, the core heats up and can start to melt. If the primary coolant is not recovered rapidly, the fuel and the core structure suffer damage, the core loses its shape, gradually forming a bed of debris and/or a corium pool which subsequently moves to the reactor vessel coolant inlet plenum or perforates the bottom of the vessel to reach the reactor pit. In this case the initial margins against re-criticality could be significantly reduced.

In the CSA reports, EDF indicated that it has carried out reactivity studies to analyse the risk of return to criticality for different corium configurations - compact or fragmented - in the reactor vessel or the reactor pit, on the basis of realistic assumptions (conservative in some cases). These studies conclude:

- that the criticality risk is nil when the corium is not fragmented in the water;
- that the criticality risk is excluded when the borated water is injected at the minimum boron concentration of the FPCS tank.

Corium in reactor vessel:

EDF indicated in the CSA report that as the severe accident management guidelines (SAMG) prohibit the injection of non-borated water as long as the corium is in the reactor vessel, the re-criticality risk is excluded for the corium-in-vessel configurations. *This point does not prompt any remarks from ASN.*

Corium in the reactor vessel pit:

In the CSA reports, EDF indicated that after reactor vessel melt-through, injection of clarified water could be envisaged after analysis and if recommended by the emergency team. The re-criticality risk is excluded in the short term, as the intense vaporisation of the water on contact with the corium tends to reduce the reactivity (increase in the vacuum level).
In the longer term, when the bed of debris can be cooled and there is little or no vaporisation (low vacuum level), the strong presence of neutron absorbing fission products and the incorporation of concrete are factors favouring a substantial reduction in reactivity.
Nevertheless EDF and IRSN do not share the same opinion on the harmlessness of clarified water injection; provision must therefore be made for borated water make-up in the long term.
On the Flamanville EPR, as specified in the CSA report for this reactor, measures are taken to guarantee a dry reactor pit and a dry corium spreading area. *ASN will examine whether these provisions are sufficient within the framework of EPR commissioning.*

3.3.5 Prevention of basemat melt-through

The ASN specifications asked EDF to describe the severe accident management measures to prevent the risk of basemat melt-through.

Flooding of the corium in the vessel

In the CSA reports, EDF stated that maintaining the corium in the vessel avoids the ex-vessel corium-concrete interaction phase and thus contributes to the goal of maintaining the integrity of the containment. Stabilisation of the situation in the vessel entails restoring a means of injecting borated water into the reactor coolant system within a sufficiently short period of time to avoid vessel rupture, in other words before core damage is too far advanced to enable it to be cooled in the vessel.

The strategies for maintaining the corium in the vessel are based on:

- borated water make-up in the reactor coolant system;
- eventual use of the recirculation function to keep the core continuously flooded.

EDF stated that possibilities for retaining the corium in the vessel are envisaged for the reactor fleet in a severe accident situation, based on existing systems not specifically designed to manage accidents with core melt and depending on their availability. The considerations are as follows:

- to enable the situation to be stabilised in the vessel, in-vessel injection must be restored before the formation of a significant corium pool in the core and, in any case, before the corium transits to the bottom of the vessel;
- if water is present in the reactor pit, allowing external cooling of the vessel, water injection into the vessel can allow stabilisation of the situation if it is restored before significant ablation of the vessel walls. It should be recalled that as things currently stand, flooding of the reactor pit is the result of operation of the containment spray system (EAS), when available, by run-off of spray water to the reactor pit.

In practice, the injection of borated water to the vessel by make-up drawing directly from the FPCS tank, this latter if possible being resupplied, is preferred in order to keep the core flooded, while delaying the moment of transition to recirculation.

After the CSAs, EDF aims to have the reactor coolant system injection means backed-up by an Ultimate Backup Diesel Generator (DUS). ***An ASN requirement concerns the composition of the hard-core, of which these systems should be a part..***

Flooding of the corium in the reactor pit

Assuming failure of the vessel, the corium pours into the reactor pit. In the CSA reports, EDF stated the strategy currently in place on the reactors in operation, which is to inject water:
- by an input of water subsequent to vessel failure, using reactor cooling system make-up through the breach at the bottom of the vessel, in accordance with severe accident operations. Furthermore, when the reactor pit is initially dry or contains a low water level, the risk of a steam explosion is considered to be low. According to EDF, the conclusions of the MCCI (Molten core concrete interaction) programme run under the aegis of the OECD confirm this ex-vessel reflooding strategy. This international scientific programme dedicated to the ability to cool the corium-concrete mixture, demonstrated on an experimental scale that a corium pool can be stabilised by the injection of water;
- by flooding of the reactor pit prior to vessel failure, linked to operation of the reactor building containment spray system (EAS) if available before entering the severe accident phase. If the reactor pit is flooded up to the level of the vessel bottom head, this significantly reduces the risk of basemat melt-through. Retention of a part of the cooled corium in the vessel and corium contact with the water in the reactor pit reduces the quantity of corium that will contribute to the corium-concrete interaction (CCI).

In the CSA reports, EDF stated that the current mitigation strategy, which aims to inject water before or after vessel melt-through, should be able to slow down or even prevent basemat melt-through. Complementary corium-concrete interaction tests (tests CCI-7) are planned for 2012 to confirm the possible stabilisation of a corium pool by means of flooding from above. However, *ASN considers that transposition to the scale of a reactor is not direct and requires the use of computer codes. It is therefore problematical as things stand to draw complete conclusions on the situation of a reactor.* R&D *and testing need to be continued in this field.*

In the CSA report for the Flamanville EPR reactor, EDF stated that this reactor will have a corium catcher enabling spreading and cooling of the corium. Passive flooding of the spread corium in the catcher and removal of the residual heat by the system thus ensure long-term protection of the basemat. *The detailed design of the CHRS system will be studied by ASN as part of the EPR commissioning process.*

Risk of cliff-edge effects and means of mitigation

In the CSA reports, EDF stated that the cliff-edge effects liable to compromise corium retention in the vessel are, for the reactor fleet:
- long-term loss of electrical power supplies; the countermeasure being to restore vessel make-up by a diversified means (thermal motor-driven pump for example);
- non-restoration of the recirculation function after complete depletion of the borated water reserves. This takes several days. Limiting the injection flow to that strictly needed for residual heat

removal and resupply of the FPCS tank with borated water would enable this period to be extended.

In a long-duration station black-out situation (SBO situation) combined with the loss of water supply to the steam generators (emptying of EFWS tank), none of the present injection means would allow flooding of the corium in the vessel and in the reactor pit. As a result of the CSAs, EDF envisages using a generator-driven pump for the reactor fleet, allowing injection of water from the FPCS tank to the reactor coolant system. EDF specified that this will be incorporated into the means available to the FARN.

For the reactor fleet, in addition to these preventive measures, examination of countermeasures to the dissemination of radioactive products by the "water route", in other words the potential contamination of the groundwater by liquid radioactive releases, is in progress. *This examination, which began before Fukushima as part of the reactor operating life extension beyond 40 years, takes account of the opinion of the Advisory Committee which met in June 2009 on this subject and which was followed by ASN requests.*

As part of the complementary safety assessments subsequent to the Fukushima accident, EDF decided to speed up the studies in response to the ASN requests, in relation to the schedule initially stipulated by ASN following the 2009 Advisory Committee meeting. These studies, which are specific to each site, comprise hydrogeological surveys based on in-situ measurements and feasibility studies concerning the technical measures, such as geotechnical or equivalent containments, designed to delay the transfer of contamination to the groundwater. EDF undertook to provide these studies in 2012 or 2013 depending on the sites. *Given their unfavourable conditions in the event of pollution, ASN considers that the sites of Fessenheim, Bugey and Civaux are priorities.*

ASN required that EDF speed up the submission of the hydrogeological surveys. Furthermore, the possibility of implementing countermeasures to basemat melt-through and soil pollution are among the topics being examined as part of the more general ten-yearly safety reviews framework. In this context, ASN asked EDF to send it a feasibility study on the implementation of technical arrangements to prevent the transfer of radioactive contamination to the groundwater in the event of a severe accident leading to melt-through of the basemat by the corium.

For the particular case of the Fessenheim reactors, the 1.50 m thickness of the basemat is the lowest in the fleet (3 to 4 metres for most reactors in the fleet). In the current situation, EDF considers that the time to melt through the basemat following a severe accident with fuel melt and vessel melt-through could be about one day in the worst case (malfunction of all safeguard systems). In July 2011, for the continued operation of Fessenheim reactor n°1 beyond 30 years, and without prejudice to the conclusions of the CSAs:

ASN asked EDF to reinforce the Fessenheim basemat before 30th June 2013 in order to significantly increase its corium resistance in the event of a severe accident. The dossier was submitted by EDF on 9th December 2011 and will be examined by ASN in 2012.

3.3.6 Supply of electricity and compressed air for operation of the equipment used to preserve containment integrity

The ASN specifications required that EDF also adopt a stance on the electrical systems used by the equipment designed to preserve the integrity of the reactor buildings containment.

In the CSA reports, EDF mentioned that a limited number of items are needed for directly managing preservation of the integrity of the containment in the event of a reactor "severe accident". These are the containment isolation valves and the wide-range containment pressure measurement system which outputs information determining when to open the U5 filter, if necessary.

Following the CSAs, EDF decided to back-up the electrical power supply to all this equipment with an Ultimate Backup Diesel Generator (DUS) to be added to each reactor. Pending the implementation of this modification, an electrical back-up (mobile diesel generator) will be installed by the FARN, except for the containment isolation valves. An ITS (temporary safety instruction) to request manual closure of these valves before entering the SAMG phase will be proposed by EDF. ***This is considered by ASN to be satisfactory.***

3.3.7 Instrumentation required to protect the integrity of the containment

The pressure in the containment is managed by monitoring the wide-range containment pressure measurement. This monitoring system helps determine the moment at which to open the U5 device when the pressure in the reactor building exceeds a threshold.

In the CSA reports on the reactors in the fleet, EDF stated that the primary pressure measurement on all plant series, as well as the wide-range containment pressure measurements at Fessenheim, the CPY and N4 plant series, are backed-up electrically via the LLS turbine generator set. In addition, following the CSAs, EDF undertook to conduct a feasibility study on short-term electrical back-up (less than 24 hours) of the containment pressure for the reactors of the Bugey NPP and the 1300 MWe plant series by the end of 2012.

In the CSA reports on the reactors in the fleet, EDF stated that in situations involving a total loss of electrical power sources, the pressure measurement in the containment is lost. It is then possible to use the containment pressurisation kinetics charts available for the various plant series. In situations involving a total loss of electrical power sources, the unit having lost all its means of injecting water into the core, pressurisation of the containment is slow and opening of the U5 venting device therefore takes place after a few days. This time can be used to restore the unit's electrical power sources or deploy the mobile resources provided by the FARN.

EDF stated that the Ultimate Backup Diesel Generator (DUS) will be able to provide electrical back-up for the instrumentation enabling operation to continue in a severe accident situation. This is satisfactory in principle.

ASN will examine whether the information backed-up by the SBO diesel generator is complete, based on the proposals submitted by EDF for the hard-core.

In the meantime, ASN also considers that the operations shift crews must be able to access the containment pressure and vessel pressure measurements as of the first hours, in all circumstances, without waiting for the FARN. In addition, EDF undertook to guarantee that as of the first hours of an accident, the primary system pressure and containment pressure measurements would be available, including in the event of failure of the LLS turbine generator set, by deploying a small generator pending the installation of the Ultimate Backup Diesel Generator (DUS).

With regard to the robustness of this instrumentation, EDF stated in the CSA reports for the reactors in the fleet that this entails no risk of unavailability in a flooding situation, but that it is not classified for the seismic risk. EDF will study its seismic resistance on the basis of the conclusions regarding the content of the hard-core.

Moreover, the installation of instrumentation dedicated to severe accident management, able to detect reactor vessel melt-through and the presence of hydrogen in the containment is currently planned for the third ten-yearly inspections of the 900 MWe and 1300 MWe reactors and the first ten-yearly inspections of the 1450 MWe reactors. ***ASN considers that these elements would facilitate management of the situation by the licensee and the public authorities.***

ASN has asked for accelerated implementation of this instrumentation, which shall also be redundant.

3.3.8 Ability to manage several accidents in the event of simultaneous core melt / fuel damage in different units on the same site

Feasibility of immediate SAMG actions

Assuming an event leading to simultaneous loss of all electrical power supplies and cooling for the reactor coolant system on all the reactors of a site, *ASN considers that, for each reactor, the feasibility of all the immediate actions provided for in the GIAG must be guaranteed, in particular depressurisation of the reactor coolant system, with the operations and emergency crews present on the site.*

In this respect, following the CSAs, EDF undertook to study the adequacy of the resources, both human and material, for the activities involved in implementing the equipment of the hard-core (including the immediate actions of the Severe Accident Management Guidelines and the additional equipment proposed following the CSAs.

The main steps in this study are as follows:

- identification of the duties to be performed (emergency management, control of the facilities, etc.) on all the plant units;
- identification of the activities to be carried out with their main characteristics, such as duration, conditions of interventions, etc.;
- consideration of the additional material resources to be implemented, taking their utilisation constraints into account as of the design stage;
- final verification of the adequacy of the human resources (numbers and skills) for all the activities to be carried out;
- identification of any additional training needs.

By the end of 2012, EDF shall inform ASN of the progress of the work, particularly with regard to the adequacy of the workforce present on the site.

Habitability of the control room

The situation considered for evaluating the habitability of the control room of the reactor fleet in the event of a severe accident is a core melt situation initiated by total loss of electrical power supplies, with opening of the containment decompression and filtration system (U5) 24 hours after entering the SAMG phase.

In the CSA reports for the reactor fleet, EDF stated that the existing preliminary studies, based on penalising hypotheses (injection of soda to maintain the alkaline nature of the Reactor Building sumps is not taken into account and the DVC ventilation-filtration of the control room is assumed to be unserviceable), mean that permanent operator presence must be avoided in the control rooms in the period following opening of the U5 system (for 24 hours), while maintaining control and monitoring of the facilities by additional means.

Consequently, following the accident that occurred on the Fukushima site in Japan, among the possible measures for mitigating the radiological consequences, EDF envisages installing a system able to guarantee the alkaline nature of the water in the Reactor Building sumps and thus reduce the maximum quantity of organic iodine liable to be released in the event of an accident.

Moreover, EDF plans to reinforce the electrical back-up of control room ventilation and filtration (DVC system) through the Ultimate Backup Diesel Generator (DUS). Pending implementation of this modification, the FARN will deploy resources to provide electrical back-up for this equipment.

To conclude, ASN thus considers that everything must be done so that opening of the U5 system on a reactor does not prevent the management of all the reactors on the site, considering that their condition at that moment may be degraded to varying extents and must thus be managed. In this respect, evacuation of the site, if prolonged, means that this requirement cannot be met. EDF undertook to evaluate the dose rates in the control room, in the BDS and on the site by mid-2012, taking account of the impact of the modifications decided on. ASN has issued a requirement on this subject.

On the Flamanville EPR, DCL ventilation guarantees that the control room is habitable. In the case of an SBO situation, a period of 3 days is available, during which the atmosphere in the control room remains breathable. EDF is studying the provision by the FARN of a mobile electrical power supply source within 3 days. The technical investigation will continue as part of the Flamanville EPR commissioning process.

3.3.9 Conclusions concerning the planned steps to maintain the integrity of the containment in the event of a severe accident

The planned steps to maintain the integrity of the reactor fleet containment rely on the U5 venting-filtration system as a last resort. As an earthquake is not considered in the design and during the periodic safety reviews as a plausible initiator of a severe accident, given all the design measures taken on the safety-classified structures, systems and components, the elements of the U5 system, except the containment penetration and the isolation valves, are not therefore seismic-classified. However, EDF stated that the metal pre-filter and the piping inside the containment are able to withstand an earthquake.

EDF has undertaken to conduct an overall review of U5 system filtration taking account of the following points:

- the robustness of the current system to hazards;
- the filter common to a pair of units on the 900 MWe plant series;
- the impact on the habitability of the control room, the BDS, on site accessibility and the radiological consequences of opening of the U5 system;
- the feasibility of filtration of iodines and noble gases;
- the role of the U5 system, taking account of the other foreseeable measures to limit its utilisation or its role.

ASN considers that the proposed improvements, which meet the CSA specifications, should be implemented. It has issued a requirement on this subject.

With regard to the Flamanville EPR reactor, the design of which already offers improved protection against severe accidents, EDF will identify which among the planned equipment is to be included in the hard-core for the prevention and mitigation of the consequences of a severe accident, including systems or equipment allowing depressurisation of the reactor coolant system, isolation of the containment and control of the pressure in the containment. ASN has issued a requirement on this subject.

By virtue of its design, the Flamanville EPR reactor has no containment venting and filtration system. The CHRS system has the role of removing heat from the containment and controlling its pressure, with the residual power being evacuated to the diversified ultimate heat sink UCWS. To prevent a cliff-edge effect in the event of total and prolonged loss of electrical power, EDF envisages adding a mobile and independent water make-up system in the reactor building, via the CHRS spray nozzles, which would be deployed within 48 hours of the beginning of the accident. This arrangement extends the 5-day period, beyond which the FARN would be responsible for providing a high-power mobile electrical device for resupplying the CHRS/UCWS chain. *ASN has no objection to this additional system, but considers that EDF could go further (see § 3.3.10).*

3.3.10 Measures envisaged to reinforce the maintaining of containment integrity after fuel damage.

In general for the reactor fleet, concerning the equipment designed to limit the consequences of a severe accident and radioactive releases, the current baseline safety requirements make no provision for off-site hazards. ***EDF shall, in response to a requirement issued by ASN concerning the hard-core, specify the hard-core equipment (existing equipment and additional countermeasures) preventing and mitigating the consequences of a severe accident. This equipment shall be robust to hazards beyond the current hazard level considered for the facilities. This in particular applies to the hydrogen recombiners and the U5 systems in use on the reactor fleet.***

In addition, for the reactor fleet, in the light of the cliff-edge effect on the consequences of a reactor core melt, when a containment is already open, EDF undertook, after the CSAs, to study the feasibility of measures to guarantee the time needed to close the equipment hatch (TAM) in the event of total loss of electrical power.

With regard to the EPR, in addition to the steps planned to maintain the integrity of the containment, assuming the possibility that a heat sink might not be restored with certainty in the scenarios envisaged by the CSAs, ***ASN asked EDF to identify the existing or additional systems to be included in the hard-core to ensure management of pressure in the containment in the event of a severe accident and to perform a study of the advantages and drawbacks of the various possible systems.***

With regard to the ability of the EPR's severe accident equipment to withstand hazards, the systems participating directly in heat removal and thus in maintaining the integrity of the containment have a seismic safety classification SC1[52]. In the Flamanville EPR's CSA report, EDF stated that this equipment is robust to seismic levels beyond its design basis. As part of the Flamanville EPR commissioning review, EDF will send ASN a demonstration of the robustness of the hard-core equipment.

3.4 Measures to limit radioactive releases in the event of a severe accident

3.4.1 Radioactive releases after loss of containment integrity

In the CSA specifications, ASN asked EDF to tackle the steps planned to limit radioactive releases from the facilities in the event of a severe accident.

In the CSA reports on the reactor fleet, EDF stated that the U5 venting-filtration device, even though reserved for ultimate safeguard of the containment and concerning which all the countermeasures are designed to prevent it from opening, can – once the gas plume resulting from its opening has passed – help limit the radiological consequences off the site. Thanks to the effective filtration of long-lived products in the aerosols, such as caesium 137 with a radioactive half-life of about 30 years, the long-term radiological consequences of U5 opening are limited. If the U5 system were to be opened, population protection measures during the radiological emergency phase would be deployed around the nuclear site.

[52] The requirements for seismic class 1 are, whenever required, operability during or after an earthquake, functional capacity, integrity and stability.

For the Flamanville EPR, EDF stated in the CSA report that the core melt accident is part of the EPR design-basis and complies with stringent requirements. The radiological objectives associated with a severe accident are that in these situations, only protection measures that are extremely limited in terms of space and time should be necessary: limited sheltering of the population, no need for emergency evacuation beyond the immediate vicinity of the facility, no permanent rehousing, no long-term restrictions on the consumption of foodstuffs (in accordance with the technical directives applicable to the EPR). Equipment and devices specific to the management of a severe accident (for example passive flooding of the corium following its spreading in the specific area provided and the CHRS system to control the containment pressure) were thus defined in the EPR design. In the CSA reports, EDF conducted a deterministic study of a combined failures situation leading to total loss of the SBO diesels. Assuming the unavailability of the soda injection and the shutdown of the ventilation and filtration systems for 24 hours, the rise in effective dose for the population would remain limited, but this situation would lead to an iodine release level requiring the deployment of population protection measures during the radiological emergency phase, such as the distribution of stable iodine tablets. EDF stated that it was examining the possibility of making the IRWST water alkaline, including in situations involving a total loss of electrical power supply.

3.4.2 Accident management after uncovering of the top of the fuel in the pool

For the purposes of the CSAs, ASN asked EDF to "*describe the measures taken to manage the consequences of the loss of the cooling function for the spent fuel pool or for any other fuel store (the following concern the storage of fuel):*

- *before and after the loss of appropriate protection against radiation;*
- *before and after uncovering of the top of the fuel in the pool;*
- *before and after severe damage to the fuel in the store.*"

The approach adopted by EDF in its complementary safety assessments concerning the spent fuel pools was to examine the consequences of a major natural hazard on the systems capable of removing the residual heat from the fuel stored in the pool, by examining the consequences of the loss of heat sink or electrical power supplies (see § 2).

In its CSA reports, EDF did not however study the possible consequences of a loss of the integrity of the pools in the fuel building or reactor building, as well as the systems connected to them. *ASN considers that the natural hazards to be considered as part of the CSAs can induce risks other than the loss of electrical power sources or heat sinks, such as:*

- *the risk of deformation of the storage racks;*
- *the risk of falling loads;*
- *shaking of the civil engineering structures supporting the spent fuel pool;*
- *a breach of a pipe or leaktight barrier connected to the pool;*
- *the loss of integrity of a door or sluice.*

These risks were analysed by IRSN during the review prior to the meeting of the advisory committees in November 2011. The analysis focused on evaluating the existing or foreseeable lines of defence to prevent uncovering of the fuel assemblies and melting of the fuel in the fuel building.

With this in mind and in order to limit the risk of accidental drainage of the spent fuel pool, several improvements to the material and organisational arrangements are currently being implemented or studied for the NPP reactors in service:

- *doubling of the diameter of the siphon-breaker devices on the FPCS system discharge line;*
- *automation of isolation of the cooling system intake line.*

ASN considers that the proposed improvements, which meet the CSA specifications, should be implemented. ASN has issued technical requirements concerning accelerating the implementation of these equipment modifications on all the NPPs in service, as the EPR design already comprises effective measures to deal with these risks.

The Bugey and Fessenheim plants entail a particular risk of spent fuel pool damage in the event of a falling fuel transport container: in these plants, unlike the others, between the handling zones and the fuel building spent fuel pool, there is no seal separating the part of the BK supporting the pool from the heavy loads handling zone, which would prevent any transmission of loads in the event of a falling container.

ASN considers that EDF should present a study of the possible additional measures to prevent or limit the consequences of a falling container accident in the fuel building, incorporating the extreme situations studied in the CSAs. ASN has issued a requirement on this subject.

ASN also considers that the current provisions concerning the transfer tube and safe positioning of an assembly during the course of handling should be the subject of detailed studies by EDF.

With regard to the transfer tube on the NPPs in operation, analysis of the CSA reports showed that for the CP0, CPY and 1300 MWe plant series, the transfer tube rupture margins for seismic stresses going beyond the design-basis earthquake, could be limited. Moreover, the transfer tube is hard to inspect. It is therefore difficult to demonstrate that the risk of tube break is virtually to be ruled out.

ASN therefore considers that EDF must study changes to hardware or to operating conditions to prevent uncovering of an assembly during handling in the event of a transfer tube break. EDF must also study the possibility of modifications such as to limit a fall in the water inventory of the pools in the reactor and fuel buildings. ASN has issued a requirement on this subject.

In the case of the EPR, the design of the reactor and fuel buildings, which rest on a common basemat, thus limiting differential displacements, would make it possible to envisage a second containment barrier around the transfer tube such as to prevent the risk of uncovering of an assembly during handling. This topic is currently being examined as part of the Flamanville 3 detailed design review, concerning situations that are practically eliminated, as listed in the facility's authorisation decree.

As part of the analysis of the CSA reports, EDF stated that for technical reasons which it considered to be prohibitive, it did not envisage installing a system for automatic safe positioning of a fuel assembly when the ambient conditions ruled out access to the premises.

EDF prefers having the fuel assembly secured by operators present in the reactor building or the fuel building, making provision for the material or organisational measures enabling them to do so, while the ambient conditions are still acceptable. The goal is to ensure the that fuel assembly can be made secure within a period of less than two hours.

ASN considers that EDF must continue to carry out studies and look for solutions to counter the difficulties mentioned earlier, look for technical measures to prevent the risk of uncovering of a fuel assembly and ensure that an assembly being handled is safely positioned as rapidly as possible when the ambient conditions still allow access to the premises. ASN has issued a requirement on this subject.

<u>Hydrogen management</u>

Following the Fukushima accident, ASN asked EDF to examine the risks linked to the build-up of hydrogen in the buildings other than the containment, especially the fuel building. ASN in particular asked EDF to identify:

- *the phenomena capable of generating hydrogen (radiolysis, zirconium/steam reactions);*
- *the possible build-up of hydrogen;*
- *the means implemented to prevent hydrogen explosion or detonation.*

As part of the CSAs, EDF stated that the presence of fuel assemblies in the BK pool can lead to the production of hydrogen in normal operation by radiolysis of the water and that an additional analysis has been initiated to assess the possible risk in the absence of ventilation.

EDF also stated that oxidisation of the cladding by steam, would lead to the production of hydrogen in sufficiently large quantities to exceed the flammability threshold, but that bearing in mind the means used to prevent uncovering of the fuel assemblies, the risk of hydrogen production by oxidisation of the zirconium cladding is ruled out.

EDF therefore proposed completing its thermohydraulic studies of the fuel storage pool before the end of 2012, taking account of the different behaviour of the various areas of the spent fuel pool. In accordance with the hydrogen risk studies, particular steps may need to be taken depending on the result of these studies, such as the installation of passive autocatalytic recombiners in the fuel building. These studies cover both the NPP fleet in service and the EPR.

ASN considers these studies to be necessary in order to determine the material and organisational measures that could be taken on the NPPs in operation and on the EPR, such as the installation of passive autocatalytic recombiners in the fuel building. ASN has issued a requirement on this subject.

Protection against radiation

ASN asked EDF to examine the current situation and the existing and complementary management measures, concerning protection against the level of radiation that could be reached.

In the CSA reports, EDF feels that a water height more than 1.5 m above the fuel assemblies is enough to ensure radiation protection compatible with human intervention, but that given the steam generated by the heating of the pool water, this intervention would take place in degraded ambient conditions.

EDF however considers that if the water height were to be less than this value, the thickness of the concrete walls would be sufficient to maintain equivalent dose rates at values compatible with human intervention in the adjacent premises, even if the ambient conditions were no longer to allow access to the BK pool area.

Nonetheless, the preparatory work for water make-up of the spent fuel pool would be carried out in advance, while the ambient conditions are not yet degraded. The start/stop make-up actions would not subsequently require entry into the spent fuel pool area or adjacent room.

For the NPP fleet in operation, outside the fuel building, the radiation from the fuel assemblies induced by skyshine generates dose rates that rise as the water level drops. In the CSA reports, EDF specified that it is studying this phenomenon (which corresponds to the scattering of gamma radiation by the atmosphere) and gives initial dose rate estimates at 20 metres from the fuel building of about 1 mSv/h.

For the EPR, the airplane crash shell covering the fuel building offers a sufficient thickness of concrete (180 cm) to guarantee no dose rates induced by "skyshine" outside the building.

ASN considers that the Fukushima accident highlighted the accident management difficulties that could arise when the water inventory in a spent fuel pool is reduced. It thus appears necessary that EDF be able to manage a situation deteriorating in a spent fuel pool, for as long as possible.

Based on this finding, EDF proposed supplementing the radiological environment studies already performed by developing its analysis of the dose levels liable to be received by the intervention personnel, induced by a reduced water inventory above the fuel assemblies and a two-phase state in the fuel storage pool.

ASN considers this approach to be satisfactory and has issued a technical requirement on this subject.

Mitigation of releases after fuel melt

In the CSAs, EDF does not describe the means for mitigation of releases after fuel melt in the spent fuel pool.

The fuel building containment was designed to take account of a fuel assembly falling and breaking during handling under water in the spent fuel pool. The elements not retained by the water of the spent fuel pool would be captured by the DVK fuel building ventilation system and filtered by filters and iodine traps.

In the case of an accident involving loss of pool cooling, this would lead to boiling of the water in the pool. Dynamic containment would then no longer be effective, as DVK system filtration is ineffective in the presence of the steam given off by spent fuel pool boiling. Furthermore, the fuel building consists of a metal cladding roof and a thin concrete wall (about 30 cm), for the entire fleet in operation and the EPR. The fuel building is not therefore designed to ensure static containment in the event of a pressure rise following a release of steam owing to boiling of the spent fuel pool.

Given the difficulty, if not the impossibility, of implementing effective means to limit the consequences of prolonged uncovering of fuel assemblies, ASN has required that EDF reinforce the prevention measures and robustness of the facility to limit the possibility of such an accident, thus ensuring that this risk remains residual.

Instrumentation necessary for accident management

As part of the CSAs, ASN asked EDF to analyse the adequacy and availability of the required instrumentation for monitoring the parameters of the spent fuel pool in the event of a severe accident.

For the NPPs in operation and the EPR, EDF proposed studying the steps to be taken to reinforce the robustness of the instrumentation in the spent fuel pool (water temperature, water level, dose rate in the hall) to ensure management of the situation and in particular management of make-up.

ASN considers that such modifications are essential in order to guarantee a clear picture of the status of the facility during a severe accident. ASN has issued a technical requirement on this subject.

Accessibility and habitability of the control room

In the event of an accident in the spent fuel pool, ASN asked EDF to evaluate the adequacy of the existing management measures, including the severe accident management guidelines and the possible additional measures. The accessibility and habitability of the control room were among the particular points to be examined by EDF.

In the CSA reports, the EDF analysis concludes that releases into the environment in the event of boiling of the BK spent fuel pool, without deterioration of the fuel assemblies, remain below those involved in a loss of coolant accident (LOCA) of category 4 in the baseline safety requirements. Consequently, the habitability of the control room remains guaranteed for the loss of cooling accident or the loss of water inventory in the BK spent fuel pool.

As mentioned above, an accident leading to deterioration of the fuel assemblies, subsequent to their uncovering in the BK spent fuel pool could lead to significant releases in the fuel building, against which it is hard or even impossible to implement effective means of mitigation.

Following the CSAs, EDF will examine the feasibility for the NPPs in operation and the EPR, of relocating the make-up system controls to areas completely protected from the propagation of steam and of improving the operation of the steam outlet. ***ASN considers this approach to be pertinent.***

3.4.3 Conclusions concerning the steps taken to limit radioactive releases in the event of a severe accident

In the CSA specifications, ASN asked EDF to look at the possible areas for improvement to limit radioactive releases.

Following the CSAs, EDF will examine the modifications necessary to systematically ensure an alkaline pH in the sumps of the reactors in service in the event of core melt, in order to limit iodine releases and further reduce the short-term impact on the site and on the surrounding populations in a severe accident situation.

ASN also asked EDF to perform a detailed study of the possibilities for improving the U5 venting-filtration device, taking account of the robustness to hazards, the efficiency of filtration in the case of simultaneous use on two reactors, the improvement of filtration of fission products, in particular iodines and the radiological consequences of opening, especially in terms of accessibility of the site, the emergency management rooms and the control room.

Following the CSA on the EPR reactor, ASN considers that the design of this EPR reactor already ensures improved protection with regard to severe accidents. Of the planned equipment, EDF shall identify that which is to be a part of the hard-core for the prevention and limitation of the consequences of a severe accident, including systems or equipment used to depressurise the reactor coolant system, isolate the containment and control the pressure in the containment. ASN has issued a requirement on this subject.

ASN also notes EDF's commitment to studying the feasibility of implementing a system able, in a total loss of electrical power situation, to ensure the alkaline nature of the water in the IRWST tank. EDF has undertaken to perform a feasibility study for mid-2012.

3.4.4 Summary: Severe accident management

In order to perform its duties in an emergency situation, the licensee must have an organisation that is robust, in particular to the extreme situations studied in the CSAs. ASN thus asked EDF to incorporate into the hard core (see § 1.1.3), those elements essential for emergency management, in other words the emergency management premises, the material resources required for emergency management, the communication resources and the essential technical and environmental instrumentation. ASN will also be asking EDF to include in this hard core the active dosimetry equipment, the measuring instruments for radiation protection and the personal and collective protection equipment.

The emergency management premises must be designed and dimensioned for hazards beyond the current design safety baseline. They shall be accessible and habitable during long-duration emergencies and designed to accommodate the crews necessary for long-term site management. The control rooms are also essential for emergency management and it is therefore important that their accessibility and their habitability enable all the reactors on the same site to be operated and monitored in the event of releases of hazardous or radioactive substances.

ASN has also required the implementation of an intervention system comprising specialist teams and equipment, capable of taking over from the shift crews working on a damaged site and deploying complementary emergency intervention resources within 24 hours, with operations beginning on the site within 12 hours from the moment they are mobilised.

The Fukushima accident proved that an off-site hazard could affect several facilities on the same site simultaneously. Following the CSAs, ASN considers that EDF's existing emergency organisations do not take sufficient account of this possibility. ASN asked EDF to supplement its emergency organisation so that it is able to manage a "multi-facility" event. For multi-licensee sites, it is also important for the operators to coordinate emergency management and minimise the impact on neighbouring facilities. This point is the subject of a requirement stipulating reinforcement of coordination between the operators of facilities, both nuclear and non-nuclear.

ASN also considers that the means of limiting releases in the event of core melt are not as yet sufficiently robust to the hazards covered by the CSAs. In the same way as for the prevention measures, ASN asked EDF to define a range of means for limiting releases in the event of a severe accident involving hazards of a level higher than those included in the current baseline safety standards. EDF is in particular required to propose improvements to the venting-filtration system in order to improve its robustness and its efficiency and to continue its studies into preventing the pollution of groundwater and surface water in the event of a severe accident with core melt.

With regard to the spent fuel pools, given the fact that it is difficult, or even impossible to implement effective means of limiting the consequences of prolonged uncovering of the fuel assemblies, ASN asked EDF to define and implement reinforced measures to prevent uncovering of these assemblies.

3.5 Summary table: Topic 3 - Severe accident management

Activities	Activities of the Licensee			ASN activities		
	Activity Completed In progress? Envisaged	Calendar Or steps for the activitie envisaged	Result Obtained Yes? No?	Activity Completed In progress? Envisaged	Calendar Or steps for the activities envisaged	Conclusions available Yes ? No?
Topic 3: Severe accident management						
Implementation of a "hard core" of robust material and organisational measures to ensure that in the extreme situations studied by the CSAs, an accident with core melt is prevented or its progress limited, minimising large-scale releases and enabling the licensee to perform its emergency management duties. This "hard core" will in particular include steps to ensure that the emergency organisation and resources are operational in the event of an accident affecting all or part of the facilities on a given site and the licensee will in particular set requirements concerning the emergency management premises, the mobile and communication resources essential for emergency management, the availability of the parameters enabling the state of the facility to be diagnosed, as well as the meteorological and environmental measurements, operational dosimetry means, radiation protection measuring instruments and personal and collective protection equipment.	In progress	Proposed definition of scope and associated requirements in 2012	Yes	In progress	Examination of EDF proposals in 2012	No
Study of a system to ensure the alkaline nature of the water in the Reactor Building sumps and thus reduce the maximum quantity of organic iodine liable to be emitted.	In progress	December 2012	No			
Study of radiological ambience conditions in the control room and on the site if the U5 filter is opened.	In progress	December 2012	No			

Study of a system to ensure the alkaline nature of the water in the Reactor Building sumps and thus reduce the maximum quantity of organic iodine liable to be emitted.	In progress	December 2012	No			
Study concerning the sizing of the teams permanently present in the NPPs for management of severe multi-unit accidents	In progress	June 2012	No			
Sizing of the teams permanently present in the NPPs – implementation	Envisaged	Coordinated with creation of the FARN	No			
Creation of the FARN – 1st team	In progress	31/12/2012	No	Completed	Requirement 2012	
Creation of the FARN – Deployment on a 4-unit site	In progress	31/12/2014	No	Completed	Requirement 2012	
Creation of local emergency centres – specifications	Completed	31/12/2012	Yes			
Creation of local emergency centres – construction	Envisaged	2016	No			
PUI standardisation	In progress	15/11/2012	No			
Multi-unit PUI	In progress	15/11/2012	No			
Fessenheim and Bugey Study of the consequences of a spent fuel transport container fall, incorporating situations beyond current design. Study of possible additional measures to prevent or limit the consequences of this fall.	In progress	31 December 2012 31 December 2013		Completed	Requirement 2012	
Modifications to be made to the facilities to reinforce prevention	In progress			Completed	Requirement 2012	

of the risk of accidental emptying of the fuel building pool, in particular: • measures to prevent complete and rapid siphon emptying of the pool in the event of break of a connected pipe • automation of isolation of the cooling system intake line.		31 March 2014 31 December 2017				
Study of the evolution versus time of the fuel and the water present in the spent fuel pool, in emptying and loss of cooling situations.	In progress	31/12/2012		Completed	Requirement 2012	
BK spent fuel pool: Study of radiological ambience induced by a reduced water inventory above the fuel assemblies and a two-phase state in the fuel storage pool; study of the consequences of pool boiling (change in level, radiological ambience, production of H2 and concentrations).	In progress	Presentation of studies in 2012	No			
Study of changes to equipment or operating conditions conceivable to prevent uncovering of the assemblies during handling, for example as the result of a break in the transfer tube between the reactor and fuel building pools or in the compartment drainage pipes.	In progress	30/12/2012		Completed	Requirement 2012	
Changes to equipment or operating conditions conceivable to prevent rapid loss of water inventory above the stored fuel assemblies, for example as the result of a break in the transfer tube between the reactor and fuel building pools or in the compartment drainage pipes.	In progress	Presentation of studies in 2012.		Completed	Requirement 2012	
Feasibility study concerning the installation or renovation of technical systems to prevent the transfer of radioactive contamination to ground and surface waters in the event of a severe accident which led to reactor vessel melt-through by the corium.	In progress	30/12/2012		Completed	Requirement 2012	

Performance of hydrogeological analyses on each site	In progress	Depending on the sites (2012 or 2013)	No			
EPR: identification of existing or additional systems to be included in the hard core to control the pressure in the containment in the event of a severe accident.	In progress	30/06/2012		Completed	Requirement 2012	
Study of the possible improvements to the U5 venting-filtration system, taking account of the following points: • resistance to hazards, • limitation of hydrogen combustion risks, • efficiency of filtration in the case of simultaneous use on two reactors, • improved filtration of fission products, in particular iodines, • radiological consequences of opening, in particular for accessibility of the site, emergency premises and control room.	In progress	31/12/2013		Completed	Requirement 2012	
Study of the changes to be made to ensure operation and monitoring of all facilities on a site, until a long-term safe state is reached in the event of releases of dangerous substances or opening of the venting-filtration system (U5).	In progress	31/12/2012	No	Completed	Requirement	
Calendar for accelerated performance of changes to improve the reliability of the pressuriser relief valves opening control.	In progress	Presentation of the calendar in June 2012	No			
Analysis of hydrogen risk in the U5 venting-filtration system.	In progress	Presentation of studies in 2012	No			
Calendar of changes designed, as of the first hours of an accident, to guarantee the availability of the reactor coolant	In progress	Completion	No			

system and containment pressure measurements, including in the event of failure of the LLS turbine generator.		calendar in June 2012				
Calendar for changes to improve the detection reliability of corium (vessel melt-through) and hydrogen in the containment.	In progress	Completion calendar in June 2012	No			
Study of the changes to be made to ensure operation and monitoring of all facilities on a site, until a long-term safe state is reached in the event of releases of dangerous substances or opening of the venting-filtration system (U5).	In progress	31/12/2012	No	Completed	Requirement	

4 National Organisations

The Fukushima Daiichi accident has had a significant impact on the organisation of all the French actors involved in the supervision of nuclear safety and radiation protection of nuclear facilities.

It has firstly confirmed the ability of ASN and IRSN to mobilise their resources in a large-scale accident situation and highlighted the points to improve in an emergency situation:

- ASN's emergency situation organisation (information and communication means, in-house analysis capabilities, procedures for calling upon external expertise and institutional connections at national and international level) has been tested and proved its robustness during the accident. The reinforcement of certain resources has nevertheless been found necessary. This is currently being implemented ("Plan of action to integrate experience feedback on ASN's internal organisation during Fukushima").

- The IRSN has mobilised its Emergency Technical Centre (ETC) and, on the basis of the data collected, has set up a continuous appraisal in the diagnosis and prognosis of the accident and releases, the environmental consequences (Japan and France) and the dosimetric consequences (computer modelling, syntheses). The IRSN has also played a very active role in informing the public, particularly on the radiological consequences of the accident. The IRSN has worked in close collaboration with the Japanese authorities, notably by participating in an environmental measurements campaign around Fukushima.

The stress tests conducted on the nuclear facilities following the accident provided the opportunity to study certain organisational aspects. ASN will be issuing a number of requirements in this respect, particularly with regard to the setting up of a "hard core" of material and organisational measures to control the fundamental safety functions in extreme situations and, for the NPPs as from 2012, the progressive setting up of the "FARN" (Nuclear rapid intervention force) proposed by EDF.
With regard to the social, organisational and human factors, ASN has adopted and will be attentive to the following priorities: the renewal of the licensees' personnel and skills, the organisation of subcontracting and research on these subjects.

In order to set forth the actions carried out since the Fukushima Daiichi accident, it is important to first briefly describe the emergency organisations to which these actions have been applied.

4.1 Description of the existing emergency organisation

4.1.1 Principles

The emergency organisation comprises all the organisational methods, techniques and means used to prepare for and respond to the occurrence of an emergency, and then to draw the lessons from it.

In accordance with the regulations, the nuclear power plant licensee EDF has put in place an emergency organisation that is connected to that of the public authorities. Designed to be robust and adaptable to any event, even unpredictable, it defines the measures necessary to protect the site personnel, the population and the environment, and to control an accident and its consequences.

From the operational aspect, the emergency organisation implies implementing coordinated emergency plans involving the licensee and the public authorities:

- **the on-site emergency plan (PUI),** under the responsibility of EDF, designed to control the situation at site level;

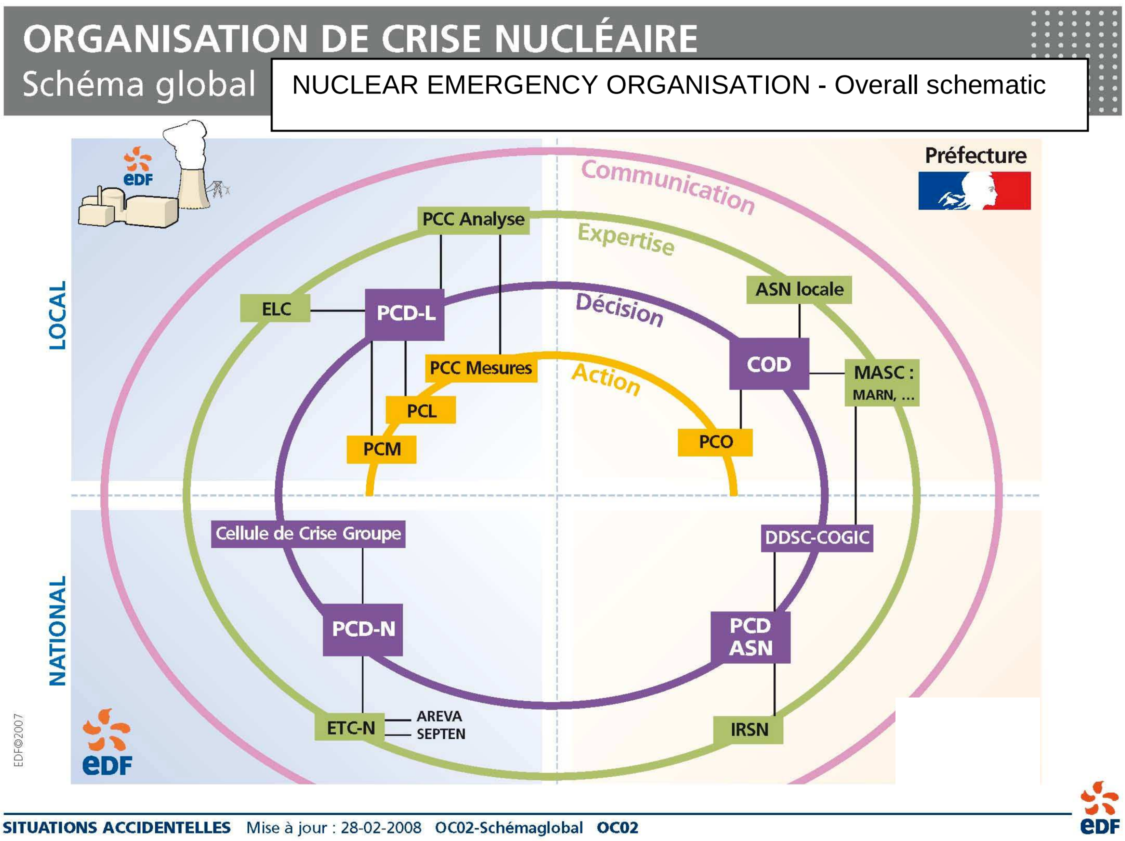
▪ **the off-site emergency plan (PPI)**, under the responsibility of the public authorities, to ensure the protection of the populations.

For the on-site emergency plan (PUI), EDF has, since it started operating its NPP fleet, adopted an organisation comprising a local level (on site) and a complementary national level; with their respective responsibilities and duties clearly defined.

The local level concentrates on the control of the facility to bring it to a satisfactory safe condition, while the national level focuses on how the situation could evolve. The licensee's communication teams at both these levels liaise with the public authority's communication teams to ensure that the neighbouring populations and the public are given clear and reliable information, particularly via the national and local media.

Taking advantage of the NPP fleet standardisation, the organisational structure is identical on all the sites, which represents a significant advantage in terms of both emergency management support resources and experience feedback.

Illustrated schematically, the EDF emergency organisation is linked to the public authorities as follows:



ELC: local emergency team
PCD: strategic management command post (L: local; N: national);
COD: departmental operations centre
PCC: controls command post
PCM: resources command post
SDC: control room
ETC-N: national emergency technical support team
MASC/MARN: nuclear risk management support mission
PCL: local command post

PCO: operational command post (Préfet)[53]
DDSC/COGIC: interministerial emergency management operational centre
SEPTEN: thermal and nuclear studies and projects service

4.1.2 Setting up the emergency organisation

The normal control of a nuclear reactor within an NPP is ensured by a shift team under the authority of an operations supervisor.

As soon as an incident arises, the operating team applies procedures for which it has been specially trained, and immediately calls the safety engineer who makes an external assessment of the appropriateness of the team's actions. The safety engineer is operational less than 40 minutes after being called by the operations supervisor.

If the situation so justifies, on the basis of simple and unambiguous criteria, and if necessary without further delay, the operations supervisor asks the NPP on-call manager to trigger the on-site emergency plan (PUI), which from that moment substitutes for the normal operation organisation. The local PUI teams, which count about 70 people (the number varies according to the size of the site), are operational less than one hour after triggering the alert.

When informed of the situation, the Préfet of the département[54] in which the reactor is located triggers the off-site emergency plan (PPI) to mobilise the environmental monitoring means (measurement plan) and implement - on the recommendations of ASN - population protection measures if necessary.

Alongside this, the national emergency organisations of EDF, ASN and the IRSN are deployed. The national emergency organisation of the EDF's Nuclear Production Division (DPN), which comprises some fifty people between its decision-making and technical levels (see diagram in § 5.1.2.7), is operational less than two hours after the alert is triggered by the national messaging system.
The organisation, based on on-call duty cycles with 5 or 6 teams, allows team changeover and long-term emergency management.

The emergency organisation is particularly attentive to equipment operability during the emergency. By way of example, to guarantee continued operation of the emergency diesel generator sets over time, the minimum guaranteed fuel autonomy of 3.5 days is supplemented by a national contract for resupply within 24 hours from strategic fuel reserves dedicated to EDF.

Whatever the situation, and more particularly to optimise shift changes, the actions and information exchanges of the teams are traced systematically:

- at local level for the operating teams, in the documents applicable in severe accident situations, which are filled out as and when they are applied,
- at local level for the teams involved in the PUI, in the daybook drawn up for each Command Post.
- at national level, in a log book

In addition to this, an information system common to the local and national emergency centres enables the information to be classified and prioritised.

[53] In a *département*, representative of the State appointed by the President
[54] Administrative region headed by a *préfet*

4.1.3 A specific aid: Emergency Team Guidelines

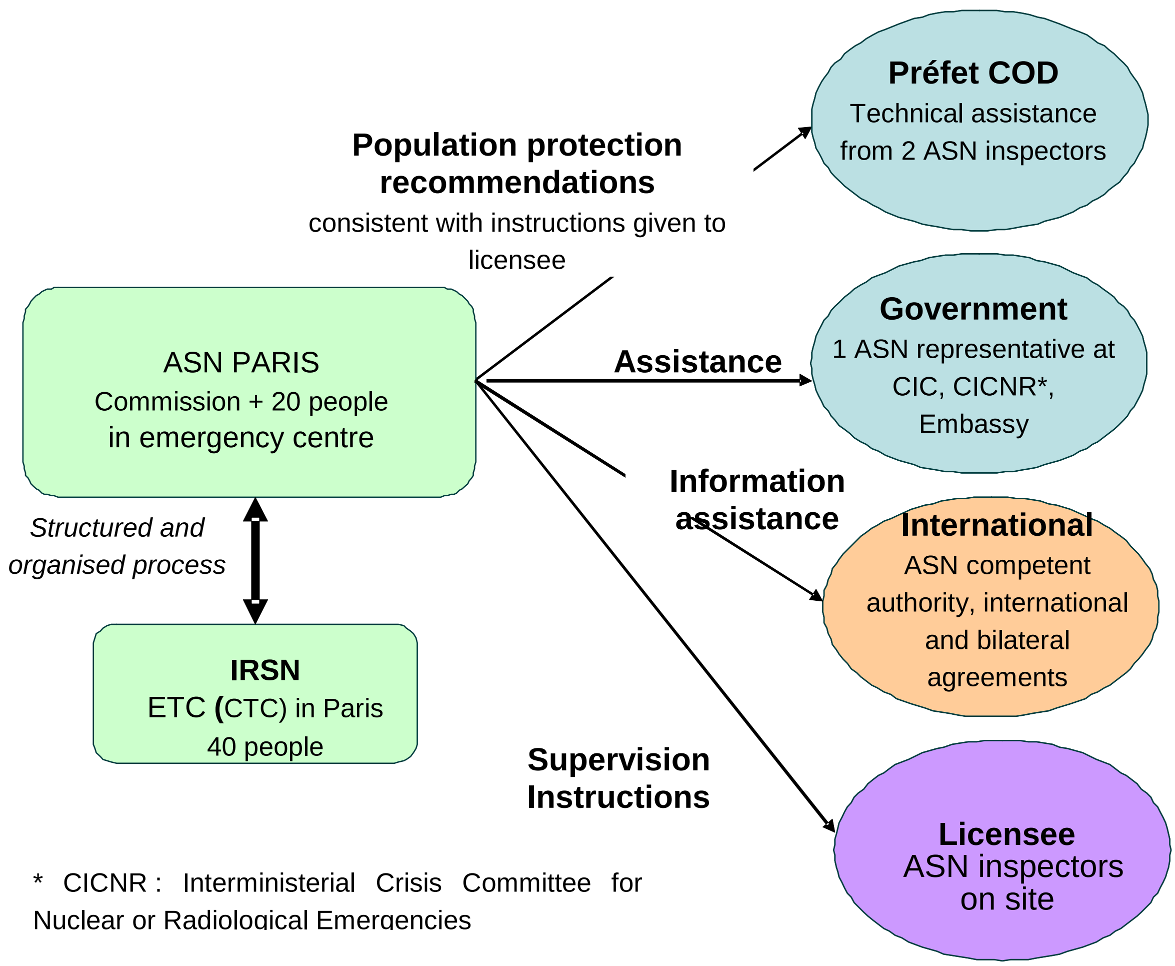
In addition to the incident operating instructions and the Severe Accident Management Guidelines (SAMG), EDF has produced Emergency Team Guidelines (abbreviated GAEC in French). This is a document to help the national and local emergency teams assess and manage NPP incidents and accidents. This guide is intended to help refine the situation diagnosis and facilitate control of the facilities.

The Emergency Team Guidelines comprises 4 sections:

- the *Strategies* section for structuring the analyses and proposing alternative or complementary operating control strategies to the incident instructions. This guide currently integrates 24 subjects, such as long-term LOOP (Loss Of Off-site Power) management, and the long-term management of water stocks.
- the *Containment* section, whose end-purpose is to detect containment deficiencies and take national measures that complement or ensure redundancy of local monitoring measures.
- the *Primary System Ultimate Makeup* section, the aim of which is to identify all the means of injecting water (borated or not) into the Reactor Coolant System (RCP) (ad hoc line connections) in order to limit the risks of core meltdown in a post-accident situation not anticipated in the design.
- the *Measurements* section, the aim of which is to evaluate the level of confidence to give to the instrumentation.

4.1.4 The role of the public authorities

According to the provisions of the Act on Transparency and Security in the Nuclear Field of 13 June 2006 (the "TSN" Act), ASN is an independent administrative authority. With the technical support of the IRSN, ASN assists the government in the event of a radiological emergency situation as shown in the diagram below:



4.2 Action undertaken by the licensee

4.2.1 Standardisation and streamlining of the emergency plans

In view of:

- the actual situations encountered since the setting up of the PUI organisation (which are not limited solely to the PUIs insofar as, due to its effectiveness and the confidence it gives the players, the emergency organisation is sometimes used to manage emergency situations before a triggering safety criterion is attained),
- the numerous local and national drills,
- the new risks that have appeared during plant unit modifications,

at the end of 2008, EDF began the streamlining and standardisation of its on-site emergency plans and thus modernised its emergency baseline standards by creating new on-site emergency plans (such as the "Toxic hazard" PUI), which complement the Support and Mobilisation Plans, whose end-purpose is to ensure the structured deployment of all or part of the emergency teams in anticipation of a foreseeable hazard (such as the arrival of a severe weather event).

Developed under the French legislative framework, this new baseline standard is submitted to ASN for an opinion with a view to entry into application at the end of 2012.

This modernised baseline standard constitutes a robust support for the changes in emergency organisation that will result from the Fukushima Daiichi accident experience feedback.

4.2.2 Implementation of a multi-plant-unit Emergency Plan

As part of the modernisation of its emergency baseline standard, and to integrate the specific management rules developed previously to protect against flooding (experience feedback from the storms of 1999), a new on-site emergency plan called "SACA" from the French acronym for "Climatic and Assimilated Risks Safety ", has been developed.

It has the particularity of integrating multi-plant-unit management into the PUIs and will be implemented at the end of 2012 at the same time as the baseline standard as a whole.

4.2.3 Taking external hazards into account

Application of the procedures by the operators in the control room is not affected by an external hazard (earthquake, flooding), as the control room is robust to the design-basis hazards. In the event of a severe accident combined with flooding or an earthquake, the equipment used in the reactor containment will not be damaged. The operating team has procedures for dealing with this situation and managing its consequences (loss of heat sink in particular).

In the event of total loss of the electrical power supply (station blackout - SBO), the actions to carry out in the facilities will have to be secured, particularly if building lighting is lost. Specific intervention means are currently being acquired by the sites (see § 3.1.2).

Lastly, as indicated in the chapters 1 (External events: earthquake, flooding, extreme climatic conditions), 2 (Design studies: loss of electrical power supplies and cooling systems) and 3 (Severe accident management), the CSAs have firstly enabled the margins with respect to external hazards to be consolidated, and secondly led to reinforcing of robustness with respect to extreme situations, with the defining of a "hard core" of measures and the creation of the FARN, as indicated in the corresponding summary tables (tables 1.1.4 - 1.2.4 - 2.2 and 3.5).

4.2.4 Setting up of the nuclear rapid intervention force (FARN)

As was mentioned earlier (see § 3.1.3), EDF has planned to make improvements in emergency organisation, particularly with the creation of a Nuclear Rapid Intervention Force ("FARN" from its French acronym) and the defining of its material and human resources. The FARN is a national EDF body that is currently being set up and will be integrated in the EDF emergency organisation. It will be capable of rapidly providing material and human aid to a site in difficulty.

EDF thus plans for the FARN to be able to:

- intervene within 24 hours, without interruption and to take over from the operating teams that will have carried out the emergency measures for the site concerned and whose access infrastructures may be partially destroyed;
- work autonomously for several days on a partially destroyed site (non-seismic tertiary buildings, for example), whose environment could be radioactive, and - on some sites - possibly affected by chemical pollution;
- deploy heavy-duty protection or intervention means within a few days;
- ensure a permanent link with company management, site management and teams, and the local authorities in order to manage and coordinate the interventions;
- prepare for continuation of the intervention beyond the first days of autonomy in the event of a long-duration emergency.

4.3 Action undertaken by ASN

A steering committee (baptized COPIL Fukushima) was set up in early April 2011 to coordinate ASN's action relating to the experience feedback from the Fukushima Daiichi accident.

This decision-making authority unites representatives of various departments of ASN, the IRSN, and the ASND (defence nuclear safety authority). The committee is chaired by the ASN Director-General.

The COPIL Fukushima monitors the action undertaken. In 2011 the committee had heavy and ambitious agenda:

- respond to the referral from the Prime Minister and the demand of the European Council to perform stress tests;
- undertake a campaign of targeted inspections of the facilities judged to take priority in 2011;
- perform the Complementary Safety Assessments (CSAs) of the priority facilities;
- issue technical instructions to the licensees;
- reflect upon the impact of Fukushima on the regulatory texts currently being prepared;
- associate the stakeholders with the process as a whole.

The COPIL steering committee meets at least once a month to decide on the strategy to adopt, communication concerning ASN actions, the organisation of the meetings of the advisory committees of experts, the involvement of the stakeholders, etc.

4.3.1 Management of an emergency centre

As soon as ASN was informed of the Fukushima Daiichi NPP accident on 11 March, it deployed its emergency centre and set up a full-time emergency organisation which was able to be tested over one month, far longer than in the usual emergency drills which last just a few hours.

The emergency centre was maintained in activity 24h/24 for one month until the situation became stabilized. ASN subsequently kept in place a team tasked with monitoring situation development and providing regular information updates.

About ten people were present permanently at the emergency centre to man the technical hubs (nuclear safety and radiation protection), the communication hub and the international relations hub.

This operation mobilised about 200 staff members of all levels, from all the departments and several regional divisions.

Altogether this operation mobilised 1,000 man-days in one month.

It was also at the emergency centre that the first daily audio conferences took place with the IRSN - ASN's technical support organisation, and the IAEA (International Atomic Energy Agency), other foreign nuclear safety authorities (USA, Canada), and the French embassy in Tokyo.

Experience feedback

The emergency management of the Fukushima Daiichi accident has shown that progress remains to be made in the organisation of the emergency centre, of the internal logistics and relations with the French external entities (the IRSN, the ministries and the French embassy in Japan), the media, the foreign counterparts and the international organisations.

The ASN's emergency organisation implemented for the Fukushima accident was internally assessed.

The functional assessment of the ASN emergency centre focused in particular on the material and logistic resources, its missions, its internal functioning, its deployment and the ASN's external relations (with the media and public, the IRSN, the other public and institutional players and the international authorities).

The assessment report sets out the strong points and lines for improvement.

This resulted in the development of a plan of action that is to be carried out throughout the year 2012. It concerns the following improvement points in particular:

- development of a single shared tool for organising deployment in a long-duration emergency,
- setting up additional training courses for the potential heads of Strategic Management Command Posts (PCDs),
- defining the documentary baseline standard held at the emergency centre.

It has also been decided to create a working group to address certain aspects of the ASN emergency organisation by the end of 2012.

4.3.2 Communication and informing the public

During the Fukushima Daiichi accident, the press service worked 24 hours a day, 7 days a week from 13 to 21 March 2011, then during daytime hours until 26 March. The communication team was boosted by personnel from other departments (35 people in all).

This was therefore an unprecedented emergency management "exercise" for ASN.

The Fukushima Daiichi accident demonstrated ASN's ability to respond to strong demands from the public over a long period of time. ASN's response was massive and went far beyond the usual scope of communication. The main public information channels were:

- Web site:

A dedicated emergency web site "special Japan " (http:/japon.asn.fr) was created. Deployed as from 15 March 2011, it is still running.

The frequentation of the site between 15 March and 30 April 2011 was on a par with the efforts involved in running it.

Almost 750,000 visits from some 400,000 visitors were recorded.

It provided access to all the videos of the ASN press conferences. Fifty videos on the ASN's interventions (reports, TV interviews, press conferences) were put on line on the Internet.

- Telephone information centre:

Opened for the Fukushima Daiichi accident, it received more than 1,000 calls between 24 March and 1 April 2011.

The outsourced telephone platform for answering straightforward questions was reinforced by a team of ASN specialists to handle technical or complex questions (83 calls concerned on 1 April 2011).

- Press releases:

Thirty eight "situation review" press releases were published by ASN and posted on its web site. .

- Press conferences and briefings:

Seventeen press conferences and briefings were organised from 12 March to 14 April 2011.
A daily press briefing was held between 10h30 and 11h30 from 14 to 29 March 2011.

- Other information initiatives:

An electronic newsletter "Nuclear situation in Japan" was created to track the events. 15 issues were published, reaching 4,300 subscribers.
ASN was also present on the social networks Facebook, Twitter and Dailymotion.

4.3.3 Reinforcing of ASN's human and financial resources

ASN asked the government for personnel reinforcements. It has been granted twenty-two additional appointments (based on personnel provided by the IRSN) for a period of 6 years. The majority of them will be filled during 2012.

Further to the Fukushima events, the ASN's annual budget has been increased by 4 million Euros. Out of this sum of 4 million Euros, ASN will transfer an additional allocation of 200,000 Euros to the local information committees (CLIs), forums for discussion made up of elected officials and representatives of the civil society, and which are attached to the BNIs.

4.3.4 Increase in contacts with the other French institutions

ASN is in permanent contact with numerous institutional players: the government, the Parliament, and in particular the OPECST (Parliamentary Office for the Evaluation of Scientific and Technological Choices) and the HCTISN (French High Committee for Transparency and Information on Nuclear Security).

Discussions between these national stakeholders and the ASN have increased substantially since the Fukushima accident. Thus, the ASN Chairman, the other commissioners and General Management have participated in numerous meetings with the ministers in charge of nuclear safety or their advisors. They have taken the floor at several parliamentary hearings. They have also participated in the meetings of the HCTISN, notably to assess the progress of the CSAs.

The meetings with the other French institutions are continuing in the framework of the work organised by the SGDSN (General Secretariat for Defence and National Security) (see below).

4.4 Action undertaken by the IRSN

4.4.1 Action during the Fukushima Daiichi emergency

4.4.1.1 Emergency Technical Centre (ETC)

Right from the start of the nuclear emergency in Japan, the IRSN deployed its Emergency Technical Centre and devoted substantial human resources (150 experts ensured rotas 24 h/24) to analysing the development of the stricken reactors, quantifying the radioactive releases into the environment and their evolution in the atmosphere and at sea. This work, carried out virtually in real time, enabled the IRSN to respond to the analysis and expert opinion requests made by the French authorities and to provide technical support to the interministerial coordination ensured by the SGDSN (General Secretariat for Defence and National Security).

The emergency organisation remained deployed from mid-day on Friday 11 March until 29 April 2011.

4.4.1.2 Appraisal capacity

On the basis of the data collected, the IRSN has set up a continuous appraisal in the diagnosis and prediction of the accident and the releases, the environmental consequences (Japan and France) and the dosimetric consequences (computer modelling, syntheses).

Modelling of the dispersion of radioactive releases into the atmosphere on the global scale: Working in cooperation avec Météo France, the IRSN simulated atmospheric dispersion of radioactive releases over a very long distance. Among other things, this work correctly anticipated the way the contaminated air masses would pass over France, and the very low levels of contamination expected, levels later confirmed by the laboratory measurements. The information provided by the network of Téléray sensors distributed across metropolitan France and its overseas territories was available on the Internet in real time.

4.4.1.3 Informing the public

The IRSN helped inform the public via the web site and the media, by proposing clear and informative explanations on the unfolding of the events.

The communication unit answered numerous requests from journalists and organised press briefings at the IRSN head office. More than 2 million people visited the IRSN web site between 20 and 26 March 2011, viewing nearly 5 million pages, essentially devoted to the Fukushima nuclear accident and its radiological consequences.

A "medical" unit was also set up to answer questions from doctors and individuals with colleagues and relatives in Japan.

On-line information reports: The IRSN collected, analysed and regularly posted data relating to the following issues:

- situation of the Fukushima Daiichi NPP in Japan;
- reinforced monitoring of radioactivity in France: as of mid-March, the IRSN reinforced radioactivity monitoring in metropolitan France and the overseas territories to assess the radioactivity resulting from the Fukushima accident. The results of several hundred analysis of air, plants and milk were communicated regularly;
- the radioactive contamination of the terrestrial environment following the Fukushima Daiichi accident (analysis briefs and reports on the radiological situation of the contaminated regions in Japan on the basis of the information published by the Japanese authorities);
- the impact of the radioactive releases on the marine environment.

Visits to the ETC: At the end of March 2011 a team from the Japanese television channel NHK came to shoot a documentary for a 70 minute programme on research into severe accidents and French expertise in this area.

4.4.1.4 IRSN support to the French embassy in Tokyo and French citizens in Japan

The IRSN seconded a technical advisor - an expert in radiation protection - to the French ambassador in Tokyo within 2 days following the accident, for more than 5 weeks.

The IRSN technical advisor's missions included:

- assisting the embassy in its action: daily briefings, communication. The IRSN has regularly published an information bulletin for the French residents in Japan. It summarises the principal information relative to the Fukushima Daiichi nuclear accident (review of the situation of nuclear facilities in Japan, record of radioactivity of the air in Tokyo, review of radioactive deposits and the contamination of terrestrial foodstuffs, and the contamination of seawater and marine species in Japan) and its consequences, and gives the IRSN's recommendations.
- radiation protection support to the disaster and emergency service team sent to Japan,
- advice to French citizens, private individuals and companies,
- installation of one measuring station (embassy) and taking measurements.

The IRSN performed radiological checks on 144 French citizens returning from Japan after the Fukushima Daiichi accident.

4.4.2 Actions carried out, in progress or scheduled since the Fukushima Daiichi accident

4.4.2.1 Organisational set up for the stress tests

The IRSN put a lot of effort into the stress tests, assisting ASN in their analysis.

4.4.2.2 Participation of the IRSN in an environmental measurement campaign around Fukushima

A first campaign was carried out in cooperation with JAEA (Japan Atomic Energy Agency) under the auspices of the MEXT (Japanese ministry of education, culture, sports, science and technology) (7 IRSN experts sent to Japan for 10 days), and another campaign is to follow.

4.4.2.3 Epidemiological studies

The IRSN has projects to participate in:

- the epidemiological studies to monitor the health of the populations, with the Medical University of Fukushima,
- the international committee of experts in charge of advising the Medical University of Fukushima and the group of 8 Japanese experts working for the Japanese government cabinet office.

4.4.2.4 Other collaborations with the Japanese organisations as from 2012

Having very little forward visibility until April 2012 (date planned for the reorganisation of nuclear safety in Japan) and being very busy with the national "post-Fukushima" activities, a number of Japanese organisations (such as the JAEA - Japan Atomic Energy Agency, JNES - Japan Nuclear Energy Safety Organisation, and NIRS - National Institute of Radiological Sciences) have expressed the desire to have further collaborations with the IRSN (in areas such as "emergency management", "marine containment", the "human factor", etc.) but not before April 2012.

4.5 Action undertaken at government level

Following the Fukushima Daiichi accident, one of the Prime Minister's services was tasked with reflecting on the security aspects of the preparation of high-level decisions and tracking their implementation. It is the General Secretariat for Defence and National Security (SGDSN) that is tasked, among other things, with:

- leading and coordinating the interministerial work relative to the national defence and security policy and the public policies that contribute to it;
- tracking the emergencies that affect the security environment;
- developing the interministerial schedule of national defence and security and ensuring that it is implemented.

Eight working parties have been set up under SGDSN coordination, bringing together the public authorities, the licensees and the technical support organisations.

The aim is to produce, by summer 2012, a government plan encompassing all aspects relating to a severe nuclear accident occurring in France, or abroad if it would have a major impact on France.

An intermediate report was sent top the Prime Minister at the end of 2011.

This plan should be tested during a large scale SEC-NUC (nuclear security) exercise in autumn 2012.

4.6 ASN's conclusions on the results of the licensees' activities

The nuclear rapid intervention force (FARN)

As was mentioned earlier (see § 4.1.4), EDF has planned to make improvements in the emergency organisation, particularly with the creation of a nuclear rapid intervention force ("FARN" from its French acronym) capable of rapidly providing material and human aid to a site in difficulty.

ASN considers that EDF's proposal for a "nuclear rapid intervention force" (FARN) contributes to the robustness of the organisation:

- it time, by relieving the emergency teams on the accident-stricken site,
- in the event of an accident affecting several facilities simultaneously.

ASN thus required EDF to progressively implement, as from 2012, a national intervention system comprising specialist teams and equipment, capable of taking over from the shift teams working on an accident-stricken site and deploying complementary emergency intervention resources in less than 24 hours, with operations beginning on the site within 12 hours from the moment they are mobilised. The system shall be projectable to any site by the end of 2012, and have the capacity to intervene on all the reactors of a site simultaneously by the end of 2014.

EDF will detail the organisation and sizing of these teams, and notably:

- the activation criteria;
- the tasks incumbent upon the teams;
- the material and human resources at their disposal and the organisation implemented to ensure the maintenance of the material resources and their permanent operability and availability;
- and lastly the training of the teams and the process for maintaining skills currency.

4.7 Summary table: Topic 4 – National organisations

Activities	Activities by the Licensee*			Activities by the Regulator*		
	Activity Completed In progress Envisaged	**Calendar** or steps for the activities envisaged	**Result obtained** Yes No	**Activity** Completed In progress Envisaged	**Calendar** or steps for the activities envisaged	**Conclusions available** Yes No
Topic 4: National Organisations						
Modernisation of the licensee's on-site emergency plan (PUI): integration of multi-plant-unit emergency management, the chemical risk, anticipation of predictable hazards (e.g. storm)	In progress	End 2012	No			
Setting up of the Nuclear Rapid Intervention Force (FARN)	In progress		No			
Increase in ASN personnel numbers				In progress	New personnel in first months of 2012	
Increase in ASN budget				Completed		
Emergency situation organisation: Implementation of the Plan of action to integrate experience feedback on ASN's internal organisation during Fukushima.				In progress		
Complementary safety assessment (CSA) of the licensees' organisation – stress tests				Completed		Report published on 3 January 2012
ASN requirements with organisational implications				In progress	From April 2012 to end 2012 - beginning 2013	
Participation of the IRSN in environmental measurement campaigns around Fukushima				1st campaign completed	2nd campaign planned	

IRSN participation in the epidemiological studies to monitor the health of the populations, with the Medical University of Fukushima,				Envisaged		
Issuing of the government plan drawn up by the SGDSN aiming to encompass all aspects relating to a severe nuclear accident				In progress	Summer 2012	

5 Off-site organisation in emergency and post-accident situations

5.1 Description of the existing situation

5.1.1 Reminders about the national emergency organisation

The Fukushima Daiichi nuclear power plant (NPP) disaster confirms that in spite of the precautions taken in the design, construction and operation of nuclear facilities, the possibility of an accident can never be ruled out. To cope with such an accident, however unlikely, it is necessary to provide for and regularly test specific material and organisational measures to manage emergency situations as effectively as possible.

The Ministries concerned on account of their remit, and ASN, gear themselves to advise the Préfet[55] - who is responsible for managing the situation at local level - on the protective measures to take. They provide the information and advice necessary for the Préfet to assess the state of the facility, the seriousness of the incident or accident, its possible developments, and the measures required to protect the populations and the environment.

The main state entities involved are:

- General Secretariat for Defence and National Security (SGDSN): The SGDSN is responsible for ensuring the interministerial consistency of the planned measures in the event of an accident, and for the planning and assessment of drills. It ensures the secretaryship of the CICNR (French Interministerial Committee for Nuclear or Radiological Emergencies). Meetings of the CICNR are convened by the Prime Minister. Its role is to coordinate the governmental action in radiological or nuclear emergency situations;

- Ministry of the Interior: The DGSCGC (General Directorate for Civil Protection and Emergency Preparedness) has the COGIC (French Government Emergency Management Operations Centre) and the MARN (Nuclear Risk Management Aid Committee) at its disposal. It provides the Préfet with material and human resources to protect persons and property;

- Ministry in charge of Health: it ensures the protection of individuals against the effects of ionising radiation;

- Ministry in charge of Ecology: the MSNR (Nuclear Safety and Radiation Protection Mission) participates in the State's nuclear safety and radiation protection missions in liaison with the other competent departments, particularly the disaster and Civil security services;

- Ministry of Defence: The ASND (Defence Nuclear Safety Authority) is the competent authority for inspecting the safety of secret basic nuclear installations (SBNIs), of military nuclear systems (SNM) and defence-related transport operations. ASN and the ASND signed an agreement on 26 October 2009 to coordinate their efforts in the event of an accident affecting an activity controlled by the ASND in order to facilitate the transition from the emergency phase managed by ASND to the post-accident phase which is the responsibility of ASN;

- Ministry of of European and Foreign Affairs: the MAEE is the "National warning point" under the Early Notification and Assistance Conventions and the decision of the European Council in 1987, responsible for disseminating the information received immediately.

[55] In a *département*, representative of the State appointed by the President

Moreover it is responsible for responding to requests for assistance received from third countries, if they are subject to a ministerial statement.
It is also responsible for the management of French nationals abroad (holding plans and supply of safety equipment, issuing via the embassy of relevant information and the measures advocated by the French authorities, planning for a possible evacuation ...)
Finally it is responsible for communications of a political nature with the IAEA, in conjunction with the Governor for France to the IAEA and through the French permanent representation.

- ASN is involved in the management of radiological emergency situations. It checks the measures taken by the licensee, assists the government in all questions for which it is competent, and informs the public on the state of safety of the facility causing the emergency situation. ASN is aided by the IRSN, its technical support organisation. The ASN's duties in the event of an emergency are detailed in section 5.1.3.2.

5.1.2 Licensee's current emergency organisation

5.1.2.1 EDF's on-site emergency organisation

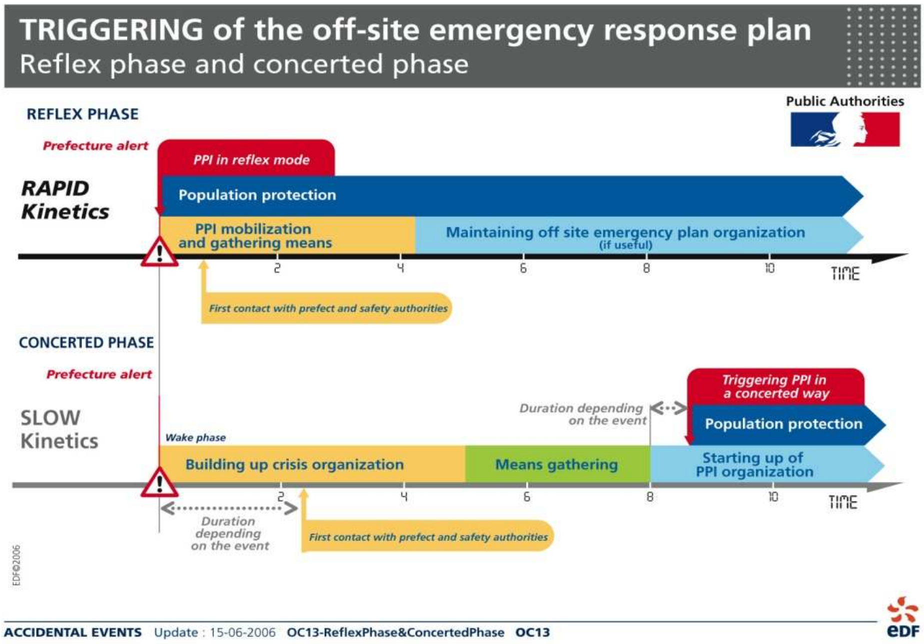
The emergency organisation, of EDF is described in section 3.1. The local emergency organisation of EDF comprises a decision-making centre, three operational response centres and a think tank. It is part of a national organisation. In its CSA reports, EDF describes the site emergency response organisation for incident, accident or severe accident situations. This organisation is described in the site On-Site Emergency Plan (PUI), which is required by the regulations and devised to cover situations presenting a significant risk for the safety of the facilities, and which can lead to the release of radioactive, chemical or toxic substances into the environment. The Local Strategic Management Command Post (PCD-L) is a key element and the hub of the organisation. It is run by the NPP Director (or his representative) who has sole responsibility for the decisions to be taken to ensure the safety of the facilities, protection of the personnel and safeguard of the equipment. On-site, it coordinates the activities of the other PCs and tells them what additional steps are to be taken. Off-site, it liaises officially with the local public authorities, especially the Préfet and the national management command posts of EDF, ASN and IRSN.

5.1.2.2 Reflex phase

In the case of events with fast kinetics, the radiological consequences of the release or threatened release can exceed the intervention level thresholds within six hours following the start of the incident/accident and necessitate population protection measures.

To this end, the licensee, by delegation from the Préfet's office, activates an off-site emergency plan (PPI) in reflex mode. The populations in a radius of 2 km are thus warned by alert sirens installed on the NPP site and a population telephone alerting system (SAPPRE, see below). The populations must take shelter and stay tuned in for further instructions, and not go outside during the hours of the emergency.
These events are listed in the on-site emergency plan instructions to allow effective activation of the alert.

If there is no need to take immediate measures, the public authorities trigger the off-site emergency plan in concerted mode in order to have means of appraisal before taking any decisions on population protection measures.



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5.1.2.3 The population alert system SAPPRE

An automatic voice messaging system has been put in place to give the PUI/PPI alerts.
On the basis of the directory of the population censused in a radius of 2 km around the nuclear power plant, plus those people who "need to be informed" designated by the Préfet (such as the prefecture's emergency teams, heads of schools, heads of companies within the perimeter, etc), this system calls each listed number and delivers the following start of alert message:

"This is an alert, this is an alert. (Préfet) is informing you of an incident at the (NPP) and urges you to take shelter in the nearest house and stay tuned in to the radio and television for further information. This is an alert, this is an alert. In order to know how many households have been successfully contacted, we ask you to follow the acknowledgement procedures as requested by the operator."

The acknowledgement procedure serves to keep track of the population that has been informed.
End-of-alert messages inform the populations when the alert is over. Test messages are also used during drills.

This system is hosted outside the geographic zone of the NPP and is therefore protected from the hazards that could otherwise affect it.

It should be noted that the effectiveness of the system depends on the robustness of the local telecommunication network.

5.1.2.4 Off-site technical support

The off-site technical support depends on the situation of the site and the events that have occurred. It can be ensured by the following:

- the national emergency organisation which has technical support from within and outside EDF.
- inter-site assistance: human resources (operators, maintenance personnel, etc.) can be called in from other NPPs to reinforce or replace the teams on the site impacted by the accident. Likewise, other NPPs can be asked to provide material resources to reinforce the site where an accident situation makes them necessary. With its fleet of 58 reactors in service, EDF thus has the possibility of mobilising human and material resources on a large scale.

- EDF's Corporate Technical Support Department (UTO), which has spare parts and even complete equipment items.
- Thermal Maintenance Agency - Centre (AMT-C) for the logistical aspects of equipment transportation and routing.
- the GIE Intra (economic interest group created jointly by CEA, AREVA and EDF) which has means for intervening in contaminated areas (robots) and excavation equipment.
- ERDF's Electricity Network Rapid Intervention Force (FIRE) which has demonstrated its efficiency in restoring power supplies during extreme climatic events.

The emergency organisation does not include specific arrangements for coping with extensive destruction of the infrastructures around the facility, and if roads and civil engineering structures suffer major damage, the public authorities will be called upon and will deploy the "ORSEC" (Organisation of the Civil Security Services Response) plan, in addition to the on-site emergency plans (PPI) specific to the emergency situation.

See § 3.1.3 for the identification of factors that can hinder accident management and the resulting constraints.

5.1.2.5 Principles of management and protection of persons on the site

With regard to the radiological risk, the means implemented to monitor radiological conditions on the site in normal operation remain operational and are adapted to the conditions that may be encountered in the event of a severe accident. Stocks of stable iodine tablets are held for distribution in emergency situations.

Whatever the situation, the operations for placing the facilities in a safer condition comply with the radiation protection rules (limitation of exposure time, use of radiation shielding, etc.).

It is moreover possible that interventions may have to be carried out in a radiologically hostile environment in the regulatory framework of exceptional exposures (particularly emergency exposure to save human lives, or exposure under special authorisation in the post-accident phase).

In other situations instructions are provided for managing the risks relating to the industrial environment (toxic or chemical) and the risks associated with extreme weather conditions.

The management of site personnel not involved in the emergency measures complies with the principles of identifying and assembling for protection or evacuation. The radiological status of the assembly areas is checked and the personnel are subject to radiological monitoring.

The risks associated with the communication routes and fluid transport pipes situated in the vicinity of the site are limited and the objectives of fundamental safety rule (RFS) I.2.d relative to the consideration of risks associated with the industrial environment and communication routes are met.

5.1.2.6 Maintaining skills currency / Training / True emergency situations

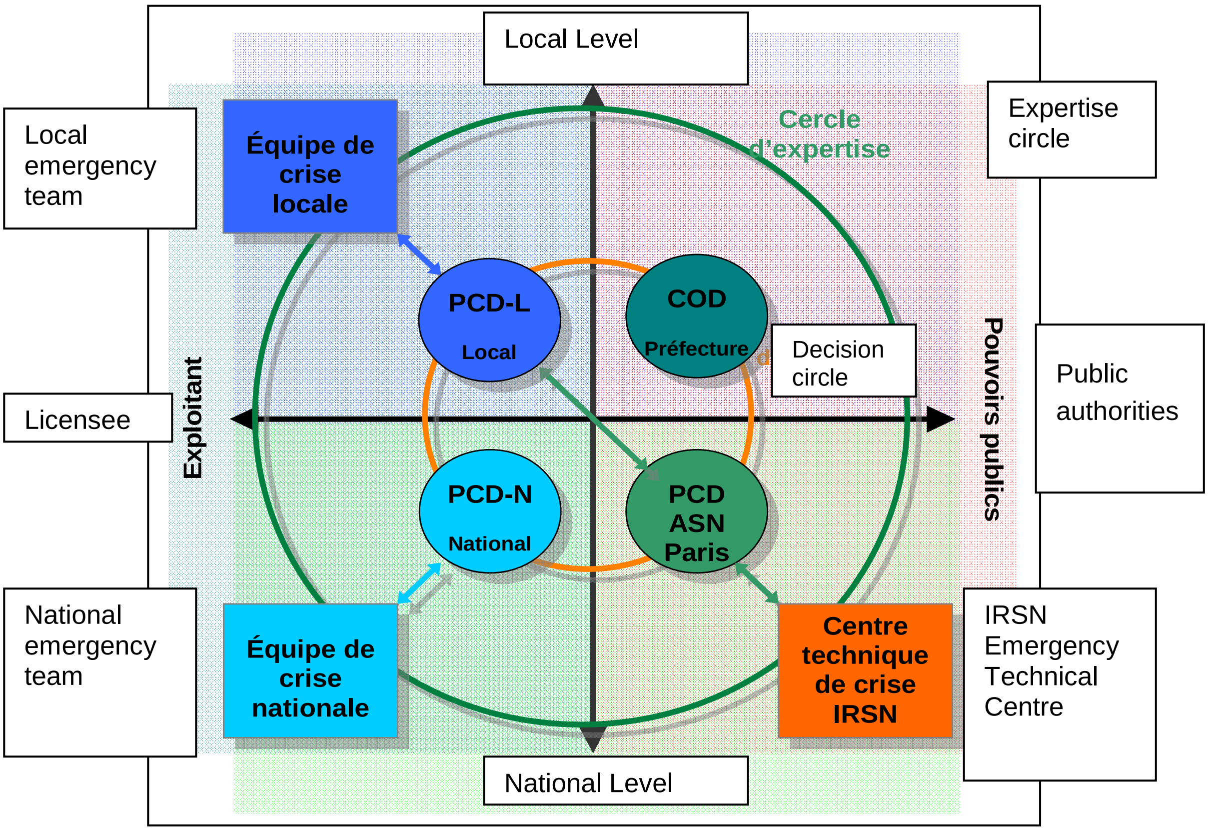
Maintaining the intervention and deployment capacities of the personnel and organisations is ensured by training the emergency team members (severe accidents and emergency-management aids in particular) and by performing periodic drills. To this end, drills are performed regularly, both to train the emergency teams and to test the means and organisational measures in order to identify any malfunctions. The national nuclear emergency drills enable all types of accident situation to be tested, including severe accidents and climatic events.

About ten drills a year are carried out on each site, and at national level by participating in site drills. Each year four or five national drills are organised in relation with the public authorities, and sometimes with the population (confinement, evacuation, etc.).

Experience feedback from all these drills and from actual emergency situations is used to improve the emergency organisation at local and national level, and the necessary coordination between the public authorities and the licensee.

5.1.2.7 Means of communication

The following diagram shows the relations between the public authorities, the government and ASN, the licensees and the technical experts in a radiological emergency situation.



PCD: strategic management command post (L: local; N: national);
COD: departmental operations centre

The means of communication allow internal communication between the emergency teams and the assembly areas and external communication with the external players at local and national level.

The national emergency organisation uses a telecommunications system that enables:

- the players internal and external to EDF to be alerted at the earliest possible stage in order to deploy the local and national emergency teams of both EDF and the public authorities.
- alerting of the populations if a reflex phase PPI-triggering criterion is attained.
- the exchange of data (by voice, fax or electronic interchange) between the various emergency management centres, both on and off the site.
- the public and the media to be informed.

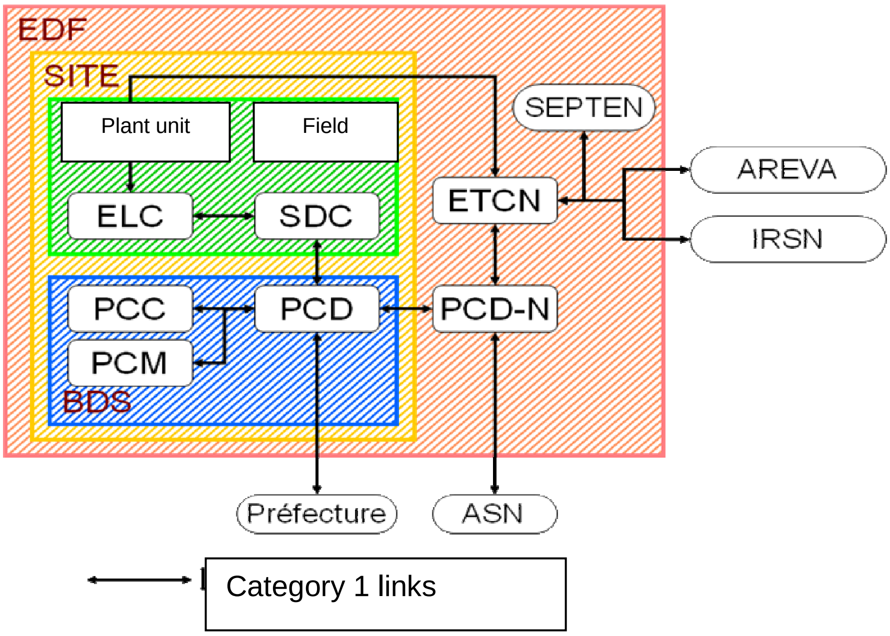
This system meets the functional needs of the national emergency organisation.

The links necessary for the operation of this system are defined and classified in two categories according to their importance:

- the links ensured by two reliable and redundant means with a guaranteed restoration time of 8 hours for loss of a system and 4 hours for loss of the link (category 1 links).
- the links ensured by a reliable means with a guaranteed restoration time of 40 hours (category 2 links).

This guarantees a high level of availability (for example the two links contributing to the site's category 1 link with the exterior are under the permanent supervision of the telecom operators of the France Telecom public network and the dedicated secured network respectively).

The following diagram summarises the category 1 telecom links:



ELC: local emergency team
SDC: control room
ETC-N: national emergency technical support team
SEPTEN: thermal and nuclear studies and projects service
PCC: controls command post
PCD: strategic management command post (L: local; N: national);
PCM: resources command post
BDS: safety bunker

Experience feedback indicates an effective availability of the internal and external links in compliance with the requirement, as observed during the drills, actual emergencies and periodic tests.

5.1.2.8 Post-accident management

Post-accident management is planned for within the EDF emergency organisation. It is coordinated at national level on the basis of a guide issued in 2001 that lists a number of situations that could lead EDF to be faced with a post-accident situation (including situations not initiated by EDF), and the major measures to be undertaken in this context.

5.1.2.9 Role in the iodine tablet distribution campaign

The last iodine tablet pre-distribution campaign was in 2009. EDF plays an active role alongside the public authorities in the iodine table distribution campaign around the NPPs, notably by working directly with the pharmacists and networks that supply them.

The iodine table pre-distribution campaigns are ensured within a perimeter of 10 km around the NPPs. The campaigns, whose frequency is adapted to the tablet expiry dates, provide an opportunity for specific communication measures targeting the local populations.

5.1.3 ASN organisation in the event of a radiological emergency situation

Several players are authorised to take decisions in emergency situations:

On the site, as a reminder, the licensee of the accident-stricken nuclear facility deploys an organisation and means for controlling the accident, assessing and mitigating its consequences, protecting the workers and alerting and regularly informing the public authorities. These measures are defined in the licensee's on-site emergency plan (PUI);

Off the site:

- ASN has authority over and monitors the actions of the licensee. In an emergency situation, aided by the IRSN's assessments, it can at any time instruct the licensee to perform assessments and take the necessary measures ;
- the Préfet of the département[56] in which the facility is situated takes the necessary decisions to protect the population, the environment and the property threatened by the accident. The Préfet acts in the framework of the PPI or the ORSEC plans. As such, the Préfet is responsible for coordinating the public and private, human and material resources engaged in the PPI. He or she ensures that the populations and mayors are kept informed. ASN, through its regional divisions, assists the Préfet in drawing up the plans and managing the situation.
- the mayor, as a trusted and credible figure in his/her parish, plays an important role in the forward-planning and accompanying of the protection measures. To this end, the mayor of a parish included in the scope of application of an off-site emergency plan must draw up and implement a local safeguard plan to provide for, organise and structure the measures to accompany the Préfet's decisions. The mayor also plays a role in passing on information and heightening population awareness during the iodine tablet distribution campaigns.

5.1.3.1 Off-site emergency plan (PPI)

The emergency plans relative to accidents occurring at a basic nuclear installation (BNI) define the measures necessary to protect the site personnel, the population and the environment, and to control the accident.

Reminder: the on-site emergency plan (PUI) established by the licensee serves to bring the facility to a safe state and to mitigate the consequences of the accident. It describes the organisation and the means to be deployed on the site. It also includes the provisions for rapidly informing the public authorities.

56 Administrative region headed by a *préfet*

The off-site emergency plan (PPI) is established by the Préfet in application of decree No. 2005-1158 of 13 September 2005, "to protect the populations, property and the environment, and to cope with the specific risks associated with the existence of structures and facilities whose coverage area is localised and fixed. They implement the orientations of the policy of emergency preparedness and civil protection in terms of mobilisation of resources, information, alert, drills and training". The PPI specifies the first population protection measures to be implemented, the duties of the various services concerned, the alert broadcasting schemes and the human and material resource likely to be engaged to protect the populations or assist the licensee.

The PPI comes into the framework of the ORSEC plan (Organisation of the Response of the Disaster and Emergency Services) that specifies the protection measures implemented in large-scale emergencies. Consequently, beyond the perimeter established by the PPI, the modular and progressive departmental or zonal ORSEC plan applies in full.

More broadly, the interministerial directive of 7 April 2005 on the measures taken by the public authorities in an event leading to a radiological emergency sets the frame for the organisation of the public authorities and the measures they must take if an event could result in a radiological emergency leading to triggering of the ORSEC or PPI-ORSEC plan, or one of the "PIRATE" category plans.

The emergency plans such as the PPIs identify the population protection measures that mitigate the consequences of an accident. The Préfet decides on the implementation of these actions on the basis of intervention levels, depending on the predicted radiation dose that would be received by a person situated in the open air when the accident occurs.

The intervention levels are defined on the basis of the most recent international recommendations, and since 2003 they have been subject to regulatory requirements. The intervention levels are thus defined by ASN decision No. 2009-DC-0153 of 18 August 2009, which modified the intervention level with regard to the administration of stable iodine. The intervention levels associated with the implementation of population protection measures in a radiological emergency situation, mentioned in article R. 1333-80 of the public health code, are therefore as follows:

- an effective dose of 10 mSv for sheltering;
- an effective dose of 50 mSv for evacuation;
- an equivalent dose to the thyroid of 50 mSv for the administration of stable iodine.

The PPI perimeter must protect the population in the first hours following the accident, without excluding the implementation of actions beyond it. As the accident situation develops, and depending on the weather conditions on the day of the accident, the disaster and emergency services may implement population protection actions beyond the PPI perimeter, as part of the ORSEC planning.

To give an example, the emergency plans around a pressurised water reactor are designed to allow the sheltering of the populations and the administering of stable iodine tablets within a radius of 10 kilometres, and population evacuation in a radius of 5 kilometres.
As of 2012, supplementing of the PPIs is envisaged to take into account the new post-accident management doctrine (see § 5.1.4).

5.1.3.2 ASN and IRSN duties in the event of a radiological emergency situation (RES)

In an emergency situation, ASN, supported by the IRSN, has the following duties:

1) check the measures taken by the licensee;
2) advise the government;
3) help disseminate the information;
4) act as competent authority in the framework of the international conventions on rapid notification and assistance.

Checking the measures taken by the licensee

As in the normal situation, ASN drills its roles as the authority overseeing the licensee of an accident-stricken facility. In this particular context, ASN checks that the licensee is fully exercising its responsibilities to control the accident, mitigate its consequences and inform the public authorities rapidly and regularly. On the basis of IRSN's assessments, ASN can at any time instruct the licensee to perform assessments and take the necessary measures, without substituting for the licensee in the technical operations carried out to cope with the accident.

Advice to the government

The Préfet's decision on the population protection measures to take depends on the effective or foreseeable consequences of the accident around the site. It is up to ASN to make recommendations to the government or the Préfet in this respect, integrating the IRSN's analysis. This analysis focuses on both the diagnosis of the situation (understanding the situation of the accident-stricken facility) and the prognosis (evaluation of the possible short-term developments, and notably radioactive releases). ASN's advice relates in particular to the public health protection measures to implement.

Dissemination of information

ASN is involved in the dissemination of information in several ways:

- informing the media and the public: ASN contributes to the informing of the media and the public in different ways (press releases, press conferences); it is important for this to done in close cooperation with the other entities that are required to communicate (Préfet, local and national licensee, etc.);
- institutional information: ASN keeps the government and the SGDSN informed, the latter being responsible for informing the President of the Republic and the Prime Minister;
- informing the foreign safety organisations.

The function of competent Authority as defined in the international conventions

The TSN Act provides for ASN to fulfil the role of competent Authority on account of the international conventions on rapid notification and assistance. As such, it collects and summarises the information in order to make or receive the notifications and transmit the information required by these conventions to the international organisations (IAEA and European Union) and to the countries concerned by potential consequences on their territory.

5.1.3.3 Emergency drills

In order to be fully operational, the emergency resources and organisation must be tested regularly; this is the purpose of the nuclear and radiological emergency drills. These drills, governed by an annual circular, involve the licensee, the ministries, the prefectures, ASN and the IRSN. They serve to test the emergency plans, the organisation and the procedures, and contribute to the training of the participating personnel. The main objectives are defined at the start of the exercise. They aim primarily at correctly assessing the situation, bringing the accident-stricken facility to a safe condition, taking appropriate measures to protect the populations, and communicating effectively with the media and populations concerned. They also serve to test the national and international authority alerting system.

Performing a national nuclear and radiological emergency exercise every 3 to 5 years on each site, depending on the complexity of the nuclear sites, would seem a fair compromise between the training of the personnel and the time required to make the organisational structures evolve.

The number and scale of national drills in France is high compared with foreign practices, as was underlined by the international audit conducted in 2006 by the IAEA's Integrated Regulatory Review Service (IRRS) mission, and the follow-up mission in 2009. This exercise programme enables ASN personnel and the national players to build up considerable knowledge and experience in the management of emergency situations. The drills also provide the opportunity to train the field participants, some 300 people per exercise.

The experience feedback from Fukushima Daiichi has been taken into account in the circular of 20 December 2011, and thus led to the scheduling of drills simulating accidents affecting several facilities simultaneously on a given site in 2012.

<u>The other emergency drills:</u>

ASN also works in the preparation and performance of other emergency drills that have a nuclear safety component and are organised by other players such as:

- its counterparts for nuclear security (HFDS - Defence and Security High Official) or for the defence-related facilities (ASND);
- the international authorities (IAEA, European Commission, Nuclear Energy Agency - NEA);
- ministries (Health, Interior, etc.).

The ASN personnel draws from the experience acquired during these many drills in order to respond more effectively in true emergency situations.

Evaluation debriefings are organised immediately after each exercise in each emergency command post. ASN, along with the other players in the emergency drills, endeavours to identify the good practices and the lines for improvement evidenced during these drills. Similar experience feedback debriefing meetings are organised to capitalise on lessons learned from true situations.

ASN moreover brings together all the players twice a year to determine the results of the good practices and lines of improvement identified at the debriefings organised following the drills.

The drills have, for example, enabled the following to be improved:

- the procedures and doctrines: preventive distribution of iodine tablets in a radius of 10 km around the NPPS, sheltering in the reflex phase in rapidly developing accidents;
- the decision channels: since 2007, the systematic use of audio-conferences ensures the consistency of the worker and population protection measures decided by the licensee and the public authorities;
- the population alerting system: the deployment around the NPPs of the telephone alerting system "SAPPRE" by EDF supplements the existing system of sirens;
- the environmental radioactivity measurement estimates: the interministerial directive of 29 November 2005 mentioned earlier provides for the creation of local measurement programmes adapted to the facilities, and the circular of 12 October 2010 of the Minister in charge of the Interior provides for the development of a measurements master programme to be appended to the PPI.

Lastly, true accidents have demonstrated the importance of communication in emergency situations, particularly to inform the public sufficiently early and avoid the propagation of rumours that could lead to movements of panic in the population. The accident of 12 September 2011 in the furnace of the Centraco facility on the Marcoule site provided a sharp reminder of the need to inform the neighbouring population, even if the PPI has not been initiated.

5.1.3.4 Radioactivity measurements (measurements master programme (PDM), return of measurements, etc.)

For several years now France has focused particular attention on radioactivity measurements. An interministerial directive on the subject was drawn up in 2005, specifying the people responsible for, and the organisation of, radioactivity measurements.

More recently, in late 2010, the Minister of the Interior asked the prefectures concerned by nuclear sites with a PPI to draw up a measurement master programme (PDM from its French acronym) that is to be integrated in the sites' ORSEC/PPI plans. This work is currently in progress in many French prefectures.

This PDM must enable the people responsible for measurements, within a "measurements" unit situated in the field and attached to an operational command post (CPO), to rapidly define the measurement conditions (the purpose of the measurements, when to take them, with what means, by whom, where, etc.) according to the phase of the accident.

In the light of experience feedback from the nuclear emergency drills, priorities have been defined for the PDMs:

- favour the use of remotely-monitored measurement stations (fixed location or to be deployed) which deliver measurement results continuously and in real time without exposing the personnel. The Fukushima Daiichi accident has confirmed the value of the results from these stations for monitoring releases and understanding the environmental situation;
- having regular contact between the licensee's measurement teams, who are the first deployed in the field, and the public authorities' teams located in the measurement cell; it is a question of establishing exchanges for sharing measurement results, and verifying the complementarity of the actions taken and the consistency of the measurement results;
- the need to transmit reliable measurement results rapidly; although the times required to take the measurements may be incompressible, and their interpretation may require expert appraisal, their transmission must be improved, notably by the use of computerised cartographic tools shared by the players.

Regarding this latter subject, the nuclear licensees have developed local cartographic tools, while the IRSN has developed a national tool (CRITER); these tools were tested during the national drills of 2011.

More particularly, CRITER has enabled the measurement results on a national scale to be shared between the measurement experts, which is a big step forward. This type of tool must also enable decision-makers and the public to be informed as rapidly as possible.

The CRITER tool was moreover used during the Fukushima Daiichi accident to provide the French public with the results of radioactivity measurements on the French territory during the period when contaminated air masses passed over the country. Given the very large number of times the tools was consulted, its sizing will be reviewed.

The Fukushima Daiichi accident also brought home the importance of such measurements. Although in emergency and post-accident situations a number of decisions must be taken on the basis of simulations, the measurements served either to confirm the calculations or to identify the more severely affected zones that the calculations did not detect.

The post-accident management work conducted in France in 2011, based on post-accident zonings that would have to be established, enabled the objectives of the radioactivity measurements in the different zones to be specified, distinguishing those measurements relating to the expert appraisal - intended to underpin the assessments of the consequences - from the control measurements, whose objective is to guide action decisions or verify the conformity of a situation or product with predefined criteria (sale of agricultural produce, for example).

5.1.4 Post-accident phase

5.1.4.1 National post-accident programme and guide for exiting the emergency phase

Generally speaking, the post-accident phase is considered to follow on from the emergency phase, once radioactive releases have stopped and the facility has been returned to safe condition. This phase comprises a transition period (from a few weeks to a few months after the accident) and a long-term period (several years after the accident).

In June 2005, ASN set up a Steering Committee to manage the post-accident phase following a nuclear accident or radiological emergency situation (CODIRPA), tasked with developing the corresponding doctrine.

To conduct its work, the CODIRPA set up theme-based working groups with designated coordinators. Since 2005, 13 working groups have been created, involving some 180 experts from different horizons (local information committees, associates, elected officials, health agencies, expert appraisal organisations, authorities, etc..). These working groups have published reports[57], whose results are given in a doctrine document that should be published in the first half of 2012.

The doctrine proposed by the CODIRPA was established considering the case of nuclear accidents leading to short-duration radioactive releases (less than 24 hours), that could occur on the French nuclear facilities concerned by an off-site emergency plan (PPI). It describes the first measures that should be accomplished or initiated immediately on exiting the emergency phase to ensure the protection and taking the populations into care, and the principal strategic lines for the medium and long-term management of the contaminated areas.

From an operational viewpoint, in 2012 the CODIRPA doctrine should be adapted locally, site by site, as part of the updating of the ORSEC/PPI plans, at least as regards the planning of the first actions to undertake on exiting the emergency phase.

Three fundamental objectives have been defined for the post-accident management of a nuclear accident:

1. **Protect the populations against the dangers of ionising radiation;**
2. **Provide support to the population that suffers the consequences of the accident;**
3. **Prepare the social and economic recovery of the affected areas.**

When defining the actions to undertake, four principles - two of them referenced in the international standards - were considered in the preparation of post-accident management and effectively implementing the actions in a true situation: the principles of anticipation, optimisation, justification and transparency.

Working from the three fundamental objectives, and using the four management principles, the post-nuclear accident doctrine is set forth for the transition and long-term periods, with application immediately on exiting the emergency phase. Several key points can thus be summarised in this management strategy:

[57] http://www.asn.fr/index.php/Bas-de-page/Sujet-Connexes/Gestion-post-accidentelle/Comite-directeur-gestion-de-phase-post-accidentelle

- the immediate zoning of the contaminated territories, which can evolve during the transition phase, is a major decision and constitutes the structuring framework for managing the population protection and health monitoring measures, and preparing for the economic recovery of the contaminated territories;
- the population impacted by the accident must receive medical and psychological care, radiological monitoring, financial support, and be indemnified for the losses sustained;
- the radiological characterisation and monitoring of the environment, foodstuffs and water, remains a priority and constant concern throughout the post-accident phase;
- the recovery of economic activity and revitalising of the impacted areas lead to a new governance based on the vigilance and active participation of the persons concerned;
- the large influx of contaminated waste of increasing diversity makes it necessary to replace the temporary management measures adopted on exiting the emergency phase by long-term management solutions.

5.1.4.2 Post-accident zoning

The post-accident zoning is proposed at national level, through consultation between the IRSN and ASN. It is directly dependent on the scale of the radioactive releases that cause environmental deposits of variable persistency. The proposed zoning is then implemented by the Préfet , who is the emergency operations director, and made known to the local services for its administrative and operational application.

The Population Protection Zone (ZPP) corresponds to the perimeter within which measures to reduce the exposure of the people residing there is justified. This zone is defined with the aim of ensuring the radiological protection of the population living in the most contaminated areas. The ZPP is thus delimited on the basis of the most penalising result out of the following two exposure indicators:

- the estimated effective dose received during the first month following the end of releases, all exposure pathways combined, including the ingestion of contaminated local foodstuffs; the guideline value adopted is about 10 mSv in the 1st month;
- the estimated equivalent dose to the thyroid received in the first month following the end of releases; the guideline value proposed is about 50 mSv in the 1st month.

The ZPP is in principle an area were people are free to move, with the exception of forests or other places where radioactive substances can become concentrated, identified after characterisation of the contamination, for which access restrictions could be imposed. In the accident scenarios in question, over the long term, the main source of potential population exposure is the ingestion of contaminated locally-produced foodstuffs. Consequently, it is prohibited to consume and to put on the market foodstuffs produced in the ZPP, whatever their level of contamination. Such foodstuffs would therefore be considered like waste, at least during the first weeks of the post-accident phase.

It is possible - in spite of prohibiting the consumption of locally-produced foodstuffs - that population exposure in some parts of the ZPP might still be considered too high due to radioactive deposits in the living environments. In this case it would be necessary to clear a portion of the residents from the ZPP by creating a population clearing zone (PE), from which the inhabitants will be cleared. If it should be necessary to create a population clearing zone within the ZPP, it would be delimited according to the results of a predictive evaluation of the estimated effective dose over the first month following the end of the releases, without considering the ingestion of contaminated locally-produced foodstuffs, and comparing them with a guideline value of about 10 mSv over the 1st month.

The Tightened Surveillance Zone (ZST) extends beyond the Population Protection Zone (ZPP). It is characterised by lower environmental contamination that does not justify implementing local population protection actions, other than a few recommendations designed to warn against higher-risk living habits. The contamination is nevertheless significant and can affect agricultural foodstuffs and produce, justifying the implementation of tightened surveillance measures. The contamination of certain agricultural products and foodstuffs can exceed - even if only temporarily - the Maximum Permissible Levels (MPL) introduced by a European regulation concerning the marketing of products intended for human or livestock consumption. In this zone, any form of marketing and consumption of local agricultural produce is systematically prohibited pending the setting up of clearing inspection systems adapted to each agricultural production process, aiming at authorising the sale of those products that comply with the MPLs.

Unlike the ZPP, whose chief aim is population protection, the ZST also fosters the preservation of economic activity by ensuring that only products whose radiological quality complies with the MPLs can enter the distribution circuits. In this sense, the MPLs are not to be considered like health indicators.

5.2 Action undertaken by the licensee

5.2.1 On-site emergency equipment

A number of equipment resources are necessary for the intervention of the shift teams in the first 24 hours, such as water injection, compressed air production and electricity production equipment.

These resources supplement the planned emergency organisation means, as appropriate for the dimensioning of the plant units. They are designed to be directly usable on the facility and be consistent with the physical capabilities and availability of the personnel on shift, and are standardised so that the Nuclear Rapid Intervention Force (FARN) can use and/or supplement them, or even replace them with its own equipment.

5.2.2 Means of communication

The means of communication used when deploying the organisation can be deficient (either following immediate damage resulting from an initiating event, insofar ad they are supported on-site and off-site by a wired connection technology, or by exhaustion of the batteries that power them).

To enhance the reliability of these various means of communication, EDF plans reinforcing the strategic links with communication resources that have greater autonomy and are resistant to earthquakes and flooding (i.e. totally independent of hard-wired communication means**).** These links will be classified in "reinforced" category 1.

To achieve this, the control rooms (local command post - PCL) and the security building (accommodating various command posts) will be equipped with satellite telephones, locally coupled to wireless telephony systems, and ultimately with enhanced autonomy.

These means will thus allow:

- the operations shift supervisor to give the alert, whatever the situation of the hard-wired telecommunication system,
- the local and national players involved in emergency management to establish or continue their information exchanges, by having voice communication, fax and/or technical data interchange,
- the local players in the field to remain in contact with the emergency command posts,
- the FARN, should it have to intervene, to communicate with the players on the site.

5.2.3 Storage of the on-site emergency equipment

Until it is possible to store the emergency equipment within the local emergency management centres (CCLs), EDF is going to organise emergency equipment storage in hazard-resistant places, described in the site safety report.

5.2.4 Functional continuity of the emergency equipment

In addition to the emergency equipment described above, EDF is going to acquire substitute or complementary equipment that will be used when the FARN is deployed.

Furthermore, in the framework of GIE INTRA (an economic interest grouping created after the Chernobyl accident by the three leading French nuclear licensees - EDF, AREVA and CEA), EDF has access to additional equipment such as robots that can be used in radiologically difficult conditions. The French licensees envisage extending the range of the GIE INTRA's equipment belonging to a category called M2IN, the French acronym for "shared nuclear intervention means". The list of M2IN equipment is currently being established.

5.2.5 Risks associated with the off-site environment

EDF will produce by mid-2012 a plan of action to study and deal with the risks associated with the industrial environment on and off the site in the event of extreme situations, and to verify the robustness of the complementary safety measures and emergency management means with respect to hazards associated with the industrial environment.

5.2.6 Updating of the Post-Accident (PA) Guide as part of the reflections conducted by the public authorities

EDF is fully in line with the work conducted by the public authorities under ASN coordination in the framework of the CODIRPA.

5.3 Action undertaken by ASN

5.3.1 Organisation in response to the Fukushima Daiichi accident

5.3.1.1 National emergency organisation

The organisational measures implemented by the public authorities in the event of an incident or accident are determined by a series of acts relating to nuclear safety, radiation protection, public order, civil protection and the emergency plans, particularly the "TSN" Act of 13 June 2006 on transparency and security in the nuclear field, and the interministerial directive of 7 April 2005. The first lessons drawn from the government's action in response to the Fukushima Daiichi accident confirm the appropriateness of the general emergency organisation.

As of 12 March 2011, daily interministerial meetings were organised by the French Presidency and the Prime Minister's staff to follow the development of the nuclear situation and determine how France could assist Japan. The interministerial crisis committee (CIC) chaired by the Prime Minister was activated on 17 March 2011. The CIC brought together representatives of the ministries, the ASN, experts (IRSN, CEA) and the licensees (EDF, AREVA).

ASN worked in close collaboration with the SGDSN, responsible for informing the President of the Republic and the Prime Minister. Theme-oriented working groups were also set up to determine the supervisory measures to be implemented. The decisions relating to the measures to ensure the protection of French citizens in Japan, the verification of food products, the verification of the non-contamination of aircraft or ship passengers, depend on the actual or foreseeable off-site consequences of the accident. These decisions were taken on the basis of ASN recommendations that were underpinned by the IRSN's analysis.

5.3.1.2 ASN's H24 organisation

As from 11 March, and for a period of one month, ASN deployed its emergency centre as though the event that had occurred in France. It adapted its organisation to the exceptional context of this accident - exceptional in its distance, its scale, the concatenation of events and the strong social demand that came with it.

The essential mission of ASN was to regularly inform the government, the media and the French population, and to advise the government on the population protection measures to take (protection of French citizens in Japan, screening imported goods for contamination, etc.).

ASN was rapidly alerted of the accident, as competent authority under the international conventions on notification and assistance of 26 September 1986, and on account of the Euratom decision of 14 December 1987. It then regularly monitored the situation in Japan on the basis of information provided firstly by the IAEA's tool USIE, and secondly by daily audio conferences with the French embassy in Japan and the American, Canadian and British nuclear safety authorities. ASN also used the European Commission's network, in liaison with the NEA, to communicate with other countries and have an overall view of the decisions they were taking.

In terms of international assistance, ASN was approached by Japan (requests for information on certain specific tools that could be provided and bilateral requests for technical resources) and by the IAEA (requests for additional experts to man the IAEA emergency centre and requests for satellite maps).

Nearly 200 ASN employees volunteered their services and were mobilised to fulfil functions at the emergency centre. Their monitoring and analyses helped understand and predict the development of the condition of the Fukushima Daiichi NPP reactors. This technical information was then reviewed and verified before being issued to the administrations, the media and the public.

ASN held 17 press conferences and issued 38 press releases, thereby providing regular information on the development of the accident and the nature of the risks involved.

ASN is continuing the feedback of experience on the organisation it deployed to respond to the numerous demands arising in the management of this accident. What emerges in particular is that the management of a large-scale nuclear emergency demands particularly intensive human investment. Furthermore, an in-depth reflection on the further development and modernisation of ASN's emergency centre is underway.

5.3.1.3 The IRSN's organisation

The emergency mobilisation of the IRSN generally consists in activating a specific organisation called the "emergency management organisation" that leads to rapid mobilisation of the appropriate resources, then managing them according to the needs and development of the situation. This emergency management organisation was deployed at noon on Friday 11 March.. It was demobilised on 29 April. It mobilised more than 150 people and consisted in ensuring:

- technical characterisations and risk assessments for the government and public authorities in France and the teams in the field in Japan (secondment of the disaster and emergency services and an IRSN technical advisor to the French embassy in Tokyo), and for the French medical structures involved both in France and locally;
- environmental monitoring initiatives to mobilise the atmospheric radioactivity monitoring networks and the measurement laboratories on the French territory;
- institutional contacts with the aim of rapidly informing the public authorities concerned, notably the ISRN's ministerial supervisors, the interministerial crisis committee (CIC), and the French ambassador in Japan. Discussions were held with foreign bodies, such as the US-NRC, the GRS in Germany, the HPA in the United Kingdom, and the STUK in Finland;
- assistance and advisory services to the local decision maker (French embassy in Japan), by sending a technical expert to Japan;
- the informing of the public and media, by issuing information (press releases, web site, press briefings) on the results of the IRSN's assessments and measurements, and direct contact with French citizens in Japan through public meetings.

5.3.1.4 Advice to the government and decisions

The interministerial crisis committee (CIC), grouping representatives of the ministries, ASN, the experts and the licensees, enabled the governmental work to be organised with rapid decision making and short validation times. Assisted by the IRSN, its technical support structure, ASN advised the government in several areas, including:

- the "recommendations for travellers" sheet available on the Ministry of Foreign Affairs' web site, which was updated regularly, consistently with the development of knowledge on the health situation in Japan. Having an IRSN expert present in the French embassy also enabled information to be relayed;
- for about one month, Roissy-Charles de Gaulle airport set up a screening system for people returning from Japan. Given the very low level of risk, this screening system was optional and based on volunteership;
- the screening of imports ensured there were no health risks for the population and reinforced the feeling of safety in companies trading with Japan. The lack of a common European stance on the screening measures to implement on departure from Japan or arrival in Europe complicated the coordinating of the measures to take. The screening of foodstuffs did not pose any particular problems. Air freight screening conditions were adapted according to the evaluation of the situation in Japan. Screening was performed systematically at the start of the emergency, but by sampling. Maritime freight from Japan was screened randomly as from 20 March 2011.

5.3.2 Avenues for improvement

Further to the Fukushima Daiichi accident, the French government initiated a reflection on ways of improving nuclear accident management with the ministries, the technical support organisations and the licensees. These study areas are presented below.

5.3.2.1 Population protection

A considerable amount of work coordinated by the Prime Minister's services was carried out to list and describe the existing measures (ORSEC plans, sheltering, iodine tablet administration, etc.).

The planned projects (population alert and information system, evacuation doctrine, etc.), aiming at supplementing the existing arrangements were presented to the various ministries and services involved in emergency planning.

5.3.2.2 Means of appraisal available to the public authorities

The Fukushima Daiichi accident and the confirmed needs of the public authorities to have information in order to manage the situation of French citizens and companies established in Japan show that the appraisal means at their disposal must be capable of addressing any radiological emergency situation in the world. It is thus necessary not only to extend the appraisal capacity to any type of nuclear facility, but also to be capable of assessing the consequences of an accident in real time and in any part of the world. A portion of these appraisal means must moreover be projectable in order be as close as possible to the potentially impacted French sources of strategic interest, and thus provide the technical advice necessary for local management of the event.

The global dimension of the response to the Fukushima Daiichi accident also shows that the means of appraisal must provide information in at least two languages: French and English. In certain cases, other languages could also be used (Spanish, Chinese, Japanese, etc.).

The multiple-source appraisals performed by numerous technical entities at international level also require a degree of coordination of their key elements. Technical support centre networks would probably be one means of achieving this coordination.

5.3.2.3 Post-accident phase

Since 2005 ASN has been working to establish a national doctrine, involving numerous stakeholders from diverse horizons. The results of this reflection will be reviewed to take into account the experience feedback from the Fukushima Daiichi accident. The interest of this work, both nationally and internationally, has been confirmed.

It has thus been decided to extend the work undertaken for the CODIRPA by supplementing the study of an accident leading to short-term releases with a scenario resulting in long-term releases. The accident in Japan effectively obliges the consideration of possible spatio-temporal superpositioning of population protection measures in an emergency situation (sheltering, evacuation, etc.) and in a post-accident situation. Coordination of the response organisation under these circumstances is a real subject of concern for the authorities, especially since interventions may still be required on the facilities to return them to a safe state.

Furthermore, beyond the foresight necessary to engage the first population protection and taking into care measures (ORSEC/PPI), a second subject of interest for the national authorities is post-accident management preparation, when the players concerned are not actually "in the situation". The need to act fast and in a coordinated manner is probably an argument in favour of looking ahead at the preparation stage, of a national post-accident programme for example. Programme financing and the allocation of responsibilities between the national and territorial level (regions, départements, and parishes) is a subjacent question, illustrated particularly well in Japan with coordination difficulties between the actions controlled by the national authority and those entrusted to the prefecture (Fukushima Daiichi) or the parishes.

Lastly, according to the information available, in particular from the NGOs engaged in Japan, the Japanese population's confidence in the authorities - a prerequisite for the recovery of the contaminated areas - seems considerably undermined. This third subject of interest confirms the relevance of the initiative for "co-construction" of the doctrine, undertaken by the CODIRPA. This initiative, which associates the stakeholders (elected officials, associations, social and economic players) must be continued, or even expanded, in the future work to transfer the national doctrine to the elected officials and the actors of the economic sectors that could be impacted by a nuclear accident in France.

The CODIRPA's new missions will primarily consist in:

- regularly integrating the experience feedback from Fukushima Daiichi on all the post-accident management aspects;

- going more deeply into certain topics, on the basis of reports from working groups for previous post-accident situations;
- updating the doctrine, associating the administrations and stakeholders concerned;
- integrating and anticipating a reflection on the possible reactions of large industrial and economic groups (e.g.: agri-food industry sector) or international authorities (WHO, IAEA, etc.) ;
- establishing collaborative ties with the neighbouring countries;
- disseminating and transferring the doctrine to all the players, especially those on the ground (economic players, elected officials, etc.).

5.4 Summary table: Topic 5 - Off-site organisation in emergency and post-accident situations

Activities	Activities by the Licensee*			Activities by the Regulator*		
	Activity Completed In progress Envisaged	Schedule or steps for the activities envisaged	Result Obtained Yes No	Activity Completed In progress Envisaged	Schedule or steps for the activities envisaged	Conclusions available Yes No
Topic 5: Off-site organisation in emergency and post-accident situations						
Implementation of autonomous communication means allowing direct contact between the site and the national emergency organisation	In progress	30/06/2012	Yes			
Means of communication – industrial solution for satellite transmission of voice and data communications on the site and with the national emergency organisation	In progress	31/12/2015	Yes			
Setting up of local emergency equipment allowing the management of a multi-plant-unit accident situations	In progress	30/12/2012	No			
Interim storage of the local emergency equipment in earthquake- and flood-resistant places	In progress	30/06/2013	No			
Setting up of local emergency equipment allowing the management of a situation of the same type as the Fukushima Daiichi accident: integration of the hard core measures and multi-plant-unit situation	In progress	31/12/2014	No			
Definition of a list of emergency equipment necessary for medium-term management – first expression of needs	In progress	30/06/2012	No			
Complement to current studies by integrating the risk created by activities situated near the facilities, in the extreme situations studied in the complementary safety assessments	In progress	Specific schedule for each NPP	No			
Interministerial reflection on the national emergency organisation				In progress	06/2012	No
Drafting by the Préfets of the measurements master plan (PDM) in the PPIs				In progress		No

Development and testing of the radioactivity measurements return tool CRITER				Completed	2011	Yes
Publication of a national doctrine document on exit from the emergency phase.				In progress	1st half of 2012	Yes
Starting of regional application of this doctrine in the ORSEC/PPI plans				Envisaged	2nd half of 2012	No
Starting of transfer of the doctrine to the economic players				Envisaged		No
Monitoring of the post-accident measures conducted in Japan				In progress	Several years	No
Consideration of "long release" nuclear accidents"				In progress		No

6 International cooperation

Although nuclear safety is a national responsibility, the Fukushima accident has revealed the international dimension of any accident affecting a nuclear facility. Consequently, international cooperation is at the core of the actions undertaken during the post-Fukushima period.

6.1 Action undertaken by the licensee

EDF has taken part in various seminars and symposia organised in different countries and presented the progress of its action plans.

The most important were:

- the ISONS 2011 (International Symposium on Nuclear Safety) organised at the end of October 2011 in TOKYO by JAES (Japan Atomic Energy Society), where INPO, REA (Rosenergoatom) and EDF presented the progress of their respective Post-FUKUSHIMA projects
- the Post-FUKUSHIMA Feedback Seminar organised by WANO ATLANTA in mid-November 2011, where the world's principal licensees presented the progress of their projects and communicated on the first decisions taken.

It is also to be noted that EDF maintains closer relations with licensees that belong to the EDF Group or with whom a cooperation agreement has been signed. Two meetings were thus scheduled in mid-September and late November 2011 with the South-African licensee ESKOM. Work and discussion meetings are held regularly with EDF Energy.

EDF attended a visit to the Swiss site of REITNAU on which mobile emergency equipment is stored in readiness for an accident on a Swiss site. This visit was organised by WANO PC.

Many discussions also took place with representatives of KEPCO (Kansai Electric Power Company) on the subject of "content of the stress tests and justifications of the measures taken". This Japanese licensee is the first to have presented a stress tests report to its government (OHI reactor 3).

Other licensees have called upon EDF or had discussions with it from time to time: ENEL, CNAT, ELECTRABEL, KEPCO (South Korea), TEPCO.

Specific discussions on the subject of the post-Fukushima actions have also been organised with the Russian licensee REA (Rosenenergoatom), under the cooperation agreement between EDF and REA.

In 2011, three SOERs (Significant Operating Event Report) concerning FUKUSHIMA were issued by WANO:

- SOER 2011-2 (Fuel damage further to earthquake and tsunami) and SOER 2011-3 (Loss of cooling of the spent fuel pool) were issued in March and August 2011 respectively. EDF implemented a major verification and action program to meet the recommendations. The deviations detected have either been, or are in the process of being, resolved. These deviations also resulted in experience feedback.
- SOER 2011-4 (Actions in the short term to cope with a prolonged loss of electrical power sources) is currently being analysed. The action to take will be scheduled so as to meet the deadlines indicated in this SOER.

EDF has also integrated the recommendations of SOER 2011-1 (Large power transformer reliability); this SOER was issued by WANO in January 2011.

6.2 Action undertaken by ASN

6.2.1 International action at European level

6.2.1.1 WENRA

In 2011, WENRA (Western European Nuclear Regulators' Association), an informal club created in 1999 on the initiative of the ASN chairman, continued its work on the harmonisation of safety rules for reactors and waste management facilities. Right from the meeting of 22 and 23 March 2011, all the WENRA members, including the ASN chairman, considered that the association should be a source of proposals in Europe.

On the invitation of the European Council as of 24 and 25 March 2011, and as part of the post-Fukushima initiatives, the WENRA reactors working group played a key role in preparing the specifications for the stress tests of the European nuclear reactors, aiming at assessing the safety margins of the nuclear power reactors in Europe in the light of the Fukushima events. Following the process defined by the European Council, WENRA placed the draft specifications at the disposal of the European Nuclear Safety REgulators' Group (ENSREG) for discussion and adoption at the beginning of May.

If WENRA had not been functioning for years, and if the confidence the association has created between European nuclear safety authorities had not existed, such a document governing the conducting of complementary safety assessments (stress tests) in 17 countries on a single methodological basis, could not have been drafted in such a short time.

6.2.1.2 ENSREG

The European Nuclear Safety Regulators' Group (ENSREG), on the invitation of the European Council as of 24 and 25 March 2011 and in agreement with WENRA, validated the European stress test specifications on 25 May 2011. Under this agreement, 17 countries, namely the 14 countries of the European Union with nuclear reactors in service, along with Lithuania, Switzerland and Ukraine, undertook to examine these reactors in the light of the Fukushima Daiichi events, using the same analysis grid. On 11 October 2011, ENSREG also validated the principle of the second phase of the European stress tests, that is to say the peer review, which extended from February to April 2012. The ENSREG members created a "Council" of key figures qualified to supervise this exercise, and appointed Philippe Jamet, ASN Commissioner, to chair it.

ASN, accompanied by the IRSN, presented the French national report in Luxembourg between 8 and 10 February 2012. The peer review was held in France from 19 to 23 March. During that week, the team of auditors met representatives of ASN, IRSN and EDF and visited the Tricastin NPP.

6.2.1.3 HERCA

HERCA (Heads of European Radiological Protection Competent Authorities), an association formed by 46 radiation protection competent authorities from 28 European countries, has set itself the goal of developing a joint approach to radiation protection, harmonising the regulations and practices, and thereby contributing to a high level of radiation protection in Europe. ASN ensures the secretaryship of the association.

The Fukushima accident has had a large impact on the work of HERCA, as it has for other organisations, and ASN is strongly involved in the actions undertaken in this context:

- **Reflections on the role of HERCA in emergency situation preparedness and management further to the Fukushima Daiichi accident**. At the 7th meeting of the association on 30 June 2011, a theme-oriented session was devoted to reflecting on the role of HERCA in preparing for and managing emergency situations, in the light of the Fukushima Daiichi accident. To provide input for these reflections, a number of nuclear regulators - including ASN - presented the national response to radiological emergency situations. ASN also presented some suggestions to improve harmonisation, particularly concerning the need to clarify the overlap between the emergency phase and the post-accident phase, and the need to analyse the consequences of long-term radiological releases on the protection measures : evacuation, sheltering, iodine prophylaxis

- **New mandate and action plan for the emergency situations working group.** Following the Fukushima accident, a new mandate and plan of action were approved at the 7th and 8th meetings of HERCA in June and December 2011 respectively.

The new mandate integrates research into practical and operational means of ensuring uniform nuclear accident management. This mandate also includes the identification of the measures to take in priority to ensure greater harmonisation of the actions and decisions taken in Europe in the event of an accident (like Fukushima) occurring in a non-European country. With regard to the new plan of action of the "emergency situations" group, it now targets two types of accident: accidents occurring in a European country and accidents occurring in countries far from Europe. In the latter case the objective is to identify the most urgent needs in order to improve the harmonisation of the reactions of the European countries and propose practical ways of achieving these objectives. This work should be finished by the end of 2012. Alongside this, HERCA will endeavour to propose operational recommendations that would uniformly protect the population around the site of a severe accident, whatever the country concerned.
ASN played a considerable role in the development of the proposed new mandate and the plan of action. It has committed itself to a considerable extent in the activities of the new group.

6.2.2 International actions on the multi-lateral plane (outside Europe)

6.2.2.1 IAEA

In the days following the Fukushima-Daiichi accident, the International Atomic Energy Agency played a vital role in the coordination of information exchanges and actions between member countries. ASN supported the various initiatives insofar as possible in this difficult context.

Thus the IAEA-coordinated delegation that went to Japan - and the Fukushima Daiichi site in particular- from 22 May to 1 June 2011, included an ASN Commissioner. This visit resulted in the first detailed report of non-Japanese origin, whose conclusions served as the basis for the work undertaken in the subsequent weeks.
One of the most important initiatives that followed remains the organisation of a ministerial-level conference by the IAEA from 20 to 24 June 2011. The first day of this conference was attended by numerous ministers from the IAEA member countries, and the following four days by the directors of the nuclear safety regulators of the member countries. Organised in four sessions, one of them chaired by the ASN chairman, this conference served to develop the bases of the IAEA action plan, which was approved by the meeting of the Governors' Council in September 2011.

The recommendations given in this plan include the reinforcing of the IAEA's main activities to maintain a high level of nuclear safety in the world (establishing safety standards, the use of peer-review structures such as the IRRS's and OSARTs, revising of the international Conventions relating to nuclear safety, accident notification and assistance to countries suffering an accident, etc.), activities to which ASN has contributed extensively for many years.

Furthermore, ASN takes part in the IAEA's work to improve notification and information exchanges in radiological emergency situations. It is involved in defining the strategy for international assistance needs and resources, and in the creation of RANET (Response Assistance Network). Further to the Fukushima accident, ASN was asked to take part in an international think tank to consider the appropriateness of amending the conventions relative to notification and assistance.

6.2.2.2 G8/NSSG

The Fukushima accident has repositioned nuclear safety at the core of national and international priorities. France played an important role in engaging discussions and deciding concrete actions at the highest levels of State responsibility, particularly in 2011 when France chaired the G8-G20.

After 11 March, it actively worked for the Heads of State and Government of the G8 countries to adopt a proactive statement on the questions of nuclear safety at the Deauville summit (26-27 May).

On 7 June 2011, a ministerial meeting on nuclear safety was jointly organised in Paris by France and the Nuclear Energy Agency (NEA) for the ministers responsible for nuclear safety in the G8-G20 countries. The conclusions of this interministerial meeting of 7 June 2011, which was focused on risk prevention and emergency management improvement, were widely disseminated.

Furthermore, the Nuclear Safety and Security Group (NSSG) also meets in the framework of the G8. ASN advises the French delegation in the area of nuclear safety. The first meeting of this group under French chairmanship was held on 23-24 March 2011, in a particular environment, given that the situation on the stricken NPP site in Japan was not stabilised. A further two meetings were held, again in Paris, on 2-3 May and 17-18 October. The first two meetings resulted in a report appended to the Deauville Declaration.

6.2.2.3 Nuclear Energy Agency (NEA)

Forum of 8 June 2011 on the Fukushima accident

This forum provided an opportunity to bring together various players from the nuclear safety scene, and in particular the nuclear regulators, Technical Safety Organisations (TSO) and a number of manufacturers. ASN was represented by its chairman and its director-general. On the basis of the conclusions of the previous day's ministerial meeting, this forum defined messages - common to the regulators of the NEA member and associate countries - that constituted a good preparation for the planned future discussions, in particular the ministerial conference of the IAEA scheduled for 20 June 2011.

Senior-level Task Group on Impacts of the Fukushima Accident

Further to the Fukushima Daiichi accident, the NEA set up a cross-organisation task group (*Senior-level Task Group on Impacts of the Fukushima Accident*) to identify the subjects that could be addressed by the NEA's various committees and working groups.

This task group is made up of the regulators and a number of technical support bodies (notably the IRSN, whose director general also chairs the NEA's Committee on the Safety of Nuclear Installations (CSNI), and GRS, the German technical support body). ASN is a member of this task group and has taken part in the three group's meetings since its creation in May 2011.

The task group's initial meetings enabled to share the first elements of the accident experience feedback provided by Japan and countries represented within the task group. The task group also includes a person from the IAEA to coordinate the actions initiated by the two organisations, coordination being considered a priority by all the participants to avoid any duplication in the substantial efforts demanded of the countries by the international organisations.

In a second phase this group proposed measures that could be carried out in the short and medium term by the NEA's existing structures and working groups, particularly with regard to inspection, the analysis of precursory events, human and organisational factors, communication, etc.

France, represented by the IRSN and ASN, will continue to take part in the meetings of this task group and support the work it initiates.

ASN also works with the NEA and participates in the Working Party on Nuclear Emergency Matters (WPNEM). Further to the Fukushima accident, ASN has been participating in and coordinating an expert group on aspects relating to the radiological protection of populations.

Coordinated support missions in Japan

In early June 2011, the NEA asked certain NEA member countries to take part in missions to assist the Japanese authorities. ASN thus participated in three missions coordinated by the NEA and the Japanese authorities:

On 16 and 17 October 2011, two ASN representatives, including the deputy director-general Jean-Luc Lachaume, took part in an international conference in Fukushima on the decontamination of polluted soils and the restoration of affected zones. The results of the reflection on post-accident management (CODIRPA programme) that ASN initiated 5 years ago were presented at this conference.

Another mission ran from 16 to 18 November in Tokyo. At the request of the Japanese government, a seminar was held under the auspices of the NEA to exchange information on the procedure adopted in the NEA member countries for the nuclear power plant stress tests. Jean-Luc Lachaume presented the French and European approaches to the stress tests.

On 16 and 17 January 2012, in the framework of the setting up of a new nuclear safety regulator in Japan, the NEA coordinated a meeting on the status, the duties and the key values of an independent nuclear safety regulator. The French example, based on the Act on transparency and security in the nuclear field, was proposed by Jean –Luc Lachaume.

6.2.3 Bilateral actions further to the Fukushima Daiichi accident

Thanks to the longstanding bilateral relations between ASN and its counterparts, information exchanges during the Japanese emergency were established rapidly and effectively.

In the first days following the accident in Japan, daily audioconferences were set up between the foreign nuclear regulators (United States, Canada, United Kingdom and France). These telephone discussions enabled the regulators to be mutually informed of the situation in Fukushima and the recommendations that each country was giving to their respective citizens present in Japan. There is an ongoing reflection on how these discussions can promote wider cooperation between the Regulators on the experience feedback from the accident in Japan.

ASN, the IRSN and the Ministries concerned also took part in daily audioconferences with the nuclear service of the French Embassy in Japan.

Bilateral actions with Japan

In the weeks and months following the Fukushima Daiichi accident, more than 30 Japanese delegations were received - at their request - by ASN. These delegations essentially comprised representatives of the Japanese nuclear regulator NISA (Nuclear and Industrial Safety Agency), the Agency of Natural Resources and Energy (ANRE), government representatives, members of parliament and local elected officials.

The subjects most frequently broached at these meetings were directly linked to the ongoing events:

- the independence of ASN, its missions and responsibilities (TSN Act) in the framework of the reorganisation of nuclear safety regulation in Japan,
- the complementary safety assessments (CSA's) and stress tests undertaken in France and Europe,
- worker occupational exposure to radiation,
- post-accident situation management (essentially on the initiative of ASN).

In addition to this, ASN's chairman André-Claude Lacoste was asked to join the committee of international experts tasked with examining the work of the government inquiry commission on the Fukushima accident. Mr. Lacoste took part in the first meeting of this committee from 23 to 25 February 2012.

Involvement of foreign experts in the CSA's conducted in France

At the request of the Governments of several bordering countries (German states of Saarland and Rhineland-Palatinate, Belgium, Luxembourg, the Netherlands and Switzerland) and with the approval of the French Government, ASN associated experts from these countries with the Complementary Safety Assessments (CSAs) conducted in the light of the Fukushima Daiichi accident on the NPPs close to their respective borders (namely Bugey, Cattenom, Chooz, Fessenheim, Gravelines).

The mandated experts attended as observers the meetings of the advisory committees of experts called by ASN (committee for nuclear reactors - GPR, and for laboratories and plants - GPU) on 6 July 2011 (study of the methodology proposed by the French licensees) and from 8 to 10 November 2011 (study of the implementation of the CSA procedure by the French licensees). These experts were also able to attend several inspections conducted under the CSAs as observers.

Technical meetings were also organised between the Belgian nuclear regulator (AFCN), ASN and the French and Belgian licensees (EDF and Electrabel respectively). These meetings enabled the stress test methods implemented in the two countries to be compared.

6.3 Action undertaken by IRSN

6.3.1 Visits of Japanese delegations to the IRSN – IRSN missions in Japan: Since the Fukushima Daiichi accident, the IRSN has received many official Japanese delegations, and has carried out several missions in Japan (radiation protection, environmental protection missions, etc.).

6.3.2 EUROSAFE: The Fukushima seminar of 8 November 2011 was held on the margins of the EUROSAFE Forum 2011 (co-organized by the IRSN): 5 papers were prepared by 5 working groups comprising members of ETSON (European TSO Network) and EUROSAFE (JNES participated in each of the groups).

6.3.3 ETSON: A 13th working group has just been created by ETSON following the Fukushima accident (Post Fukushima NPS Follow up Task force ("Emergency preparedness")).

6.4 Summary table: Topic 6 - International cooperation

Activities	Activities of the Licensee			Activities of the Regulator		
	Activity Completed In progress? Envisaged	**Calendar** or steps for the activities envisaged	**Result Obtained** Yes? No?	**Activity** Completed In progress? Envisaged	**Calendar** or steps for the activities envisaged	**Result Obtained** Yes? No?
Topic 6: International cooperation						
Participation in seminars and sharing of experience feedback : ISONS 2011 (JAES) - INPO - WANO	Completed	2011	Yes			
Relations with licensees: ESKOM, REA, CEZ, ENISS, KEPCO, ENEL, Electrabel, TEPCO, WANO PC (visit to Reitnau in Switzerland)	Completed	2011	Yes			
Examination of SOERs issued by WANO (2011 - 2, 3 and 4)	Completed	2011	Yes			
Participation in the development of European stress-tests specifications within WENRA and adoption within ENSREG				Completed	2011	Yes
Realization of stress-tests Presidency of the Council of peer reviews - Reception of the European peer reviewers				Completed	2011 2012	Yes
Involvements in the HERCA actions on thinking about emergency situations				In progress	2012	
Participation in the IAEA mission to Japan in June 2011				Completed	2011	Yes
Participation in the IAEA ministerial-level conference in June				Completed	2011	Yes

2011.						
Involvement in the RANET meetings				In progress	2012 and beyond	
Organisation of an international meeting with the Nuclear Energy Agency (NEA) - 7 June 2011 Organisation of and participation in an international forum – 8 June 2011				Completed Completed	2011 2011	Yes
Participation in the *Senior-level Task Group on Impacts of the Fukushima Accident* set up by NEA				In progress	2011 and beyond	
Participation in 3 localised AEN missions in Japan				Completed	2011-2012	Yes
Participation in audio-conferences between regulators				Completed	2011	Yes
Reception of Japanese delegations in all French entities including ASN				In progress	2011-2012	
Participation in the committee of international experts of the Japanese government inquiry commission				In progress	2012	Yes
Participation of IRSN_in the seminar on the margins of the EUROSAFE Forum				Completed	2011	Yes
Participation of IRSN in the ETSON working group				In progress		

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Faire progresser la sûreté
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