IAEA Workshop

Implementation of lessons learned from the Fukushima Dai-ichi accident Research Reactors

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ASN immediate actions

- **Campaign of targeted inspections**
- **"Stress test" analysis of the safety of nuclear facilities**
  - Complies with the European Council conclusions (March 2011)
  - Applies to 150 nuclear installations in France (58 NPP, NPP under construction, fuel cycle facilities, research reactors, etc.)
  - Covers:
    - extreme natural events (earthquake, flooding,…)
    - loss of the ultimate heat sink or loss of electrical power
    - severe accident management
  - Is complementary to existing safety improvement processes
    - periodic safety reviews (PSRs)
    - integration of operating experience feedback

Proportionate Approach

- Priorization is needed for CSA :

All nuclear facilities targeted

Nuclear power plants	Other nuclear facilities
58 reactors	About 90 facilities

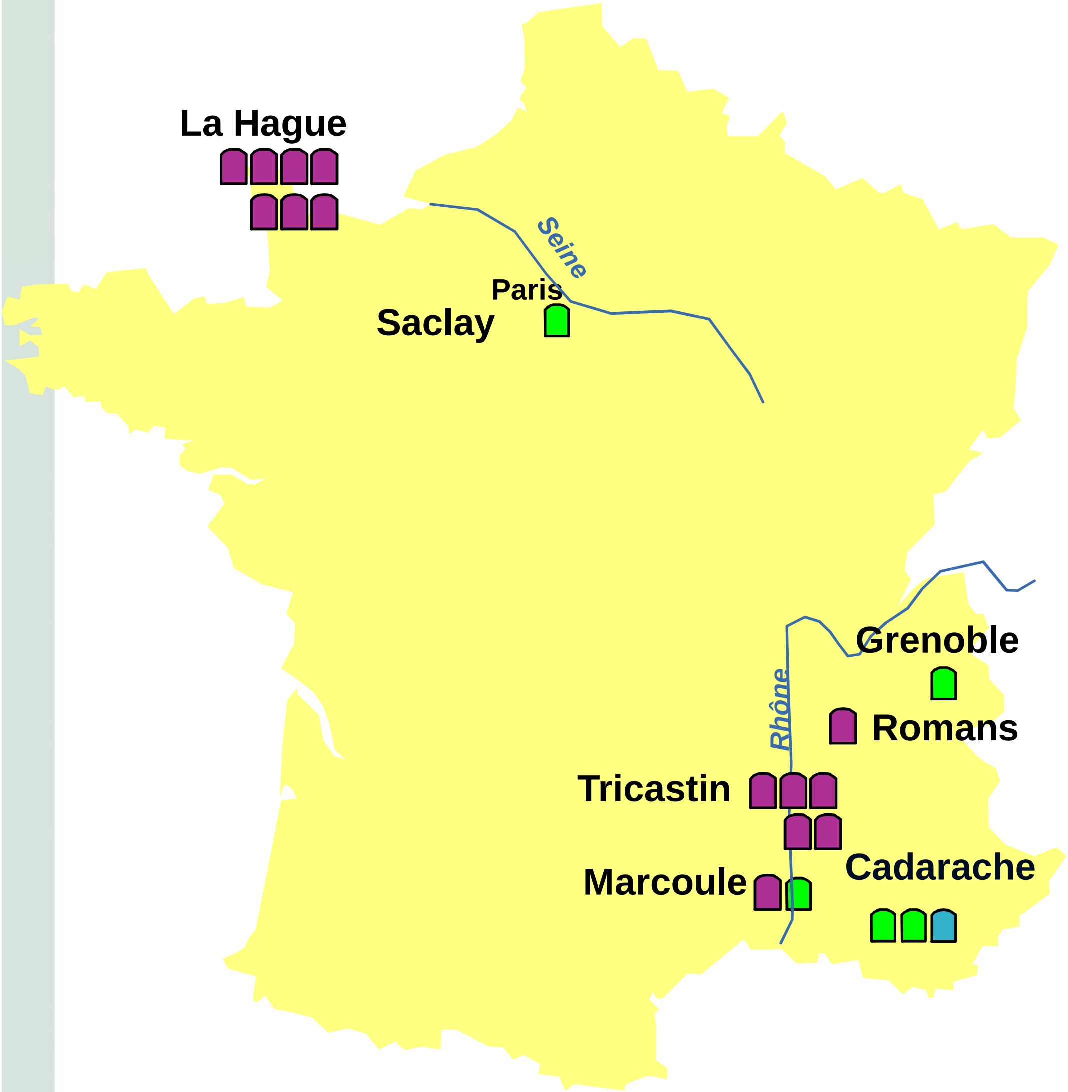
Priority facilities
(First batch)
All NPPs
20 other nuclear facilities
→ CSA in 2011

Second batch
22 other nuclear facilities
→ CSA in 2012

Other nuclear facilities
With periodic safety reports
→ CSA until 2019

- Classification taking in account :
  - Type of facility : nuclear reactors → thermal power
  - Amount of radioactive material and hazardous substances
  - Potential off-site realeases
  - Robustness and independence of the containment barriers

20 priority facilities in 2011



14 FCFs

- 7 BNIs at La Hague :
  - UP3
  - UP2-800
  - UP2-400
  - STE 2 A
  - HAO
  - Elan 2B
  - STE3
- 5 BNIs in Tricastin :
  - Eurodif (GB I)
  - SET (GB II)
  - AREVA NC – TU5
  - Comurhex
  - Socatri
- Melox, Marcoule
- FBFC, Romans-sur-Isère

5 Research Reactors

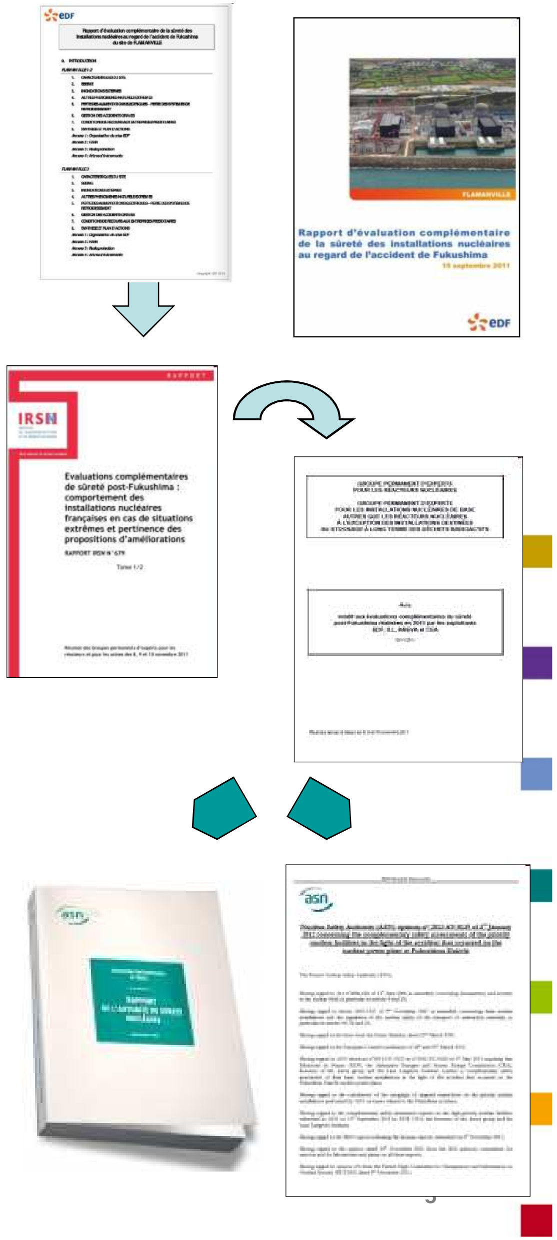
- RJH et Masurca (CEA Cadarache)
- Phénix (CEA Marcoule)
- Osiris (CEA Saclay)
- RHF (ILL Grenoble)

1 Research Lab

- ATPu (CEA Cadarache)

Complementary Safety Assessment (*Batch1*)

- May 5th 2011: **ASN decisions** defining the requirements specifications of the assessment:
  - Based on the WENRA and ENSREG workshop from March to May
- September 15th 2011: **Licensees' Report**
- September - December 2011: **Technical review**
  - **TSO Review & Assessment reports**
  - Advisory committees of experts
  - Participations of several stakeholders (high committee for transparency and information of nuclear safety, local information committee, NGO, international experts,…)
- January 3rd 2012: **ASN Report**
- June 26th 2012: **ASN** decisions requiring safety improvements to the batch 1 of nuclear installations



Complementary Safety Assessment (*Batchs 1 & 2*)

- June 2012 - March 2013: **AREVA & CEA complementary assessment to define a post-Fukushima set of safety features**

- April 2013 Batch 1: **Technical review**
  - **TSO Review & Assessment reports**
  - Advisory committees of experts

- July 2013 batch 2 : **Technical review**
  - **TSO Review & Assessment reports**
  - Advisory committees of experts

- January 8th 2015 : 14 **complementary ASN decisions** defining additional safety requirements to define and implement *Hardened Safety Core* arrangements for the AREVA & CEA nuclear facilities

French Research Reactors

(Critical mock-up, neutron beam supplier reactor, safety test reactor, prototype or technological irriadiation reactor, teaching reactor)

Site approach :
CEA Cadarache Site
CEA Marcoule Site
CEA Saclay Site

CEA Research Reactors

Cadarache Site

RÉACTEUR JULES HOROWITZ - Technological irradiation reactor – 1st batch – *in construction*
Masurca - Critical mock-up – 1st batch – *currently stopped*
Rapsodie - RR for the SFR line – 2nd batch - *decommissioning*
CABRI – Safety tests reactor – 2nd batch
Eole/Minerve – Critical mock-up - 3rd batch
Phébus - Severe accident studies reactor - 3rd batch - *currently stopped*

Marcoule Site

PHENIX - Sodium-cooled Fast Reactor (SFR) Prototype – 1st batch – *currently stopped*

Saclay Site

OSIRIS - Technological irradiation reactor - 1st batch - *currently stopped*
ORPHEE - Neutron beam reactor - 2nd batch
ISIS - Teaching reactor – 3rd batch

Laue-Langevin Institute RR

High Flux Reactor (HFR) - Neutron beam reactor – 1st batch

Review and Assessment

Review and Assessment

3 volets

Hazards	Robustness against hazards
Losses of functions	Robustness against loss of heat sink and loss of electrical supplies
Severe accident	Robustness of the arrangements to manage a severe accident and an emergency

« Real » state

Possible Configurations

Pool / Core

Site level

Facility level

Graded approach

Engineering judgement

Review and Assessment findings

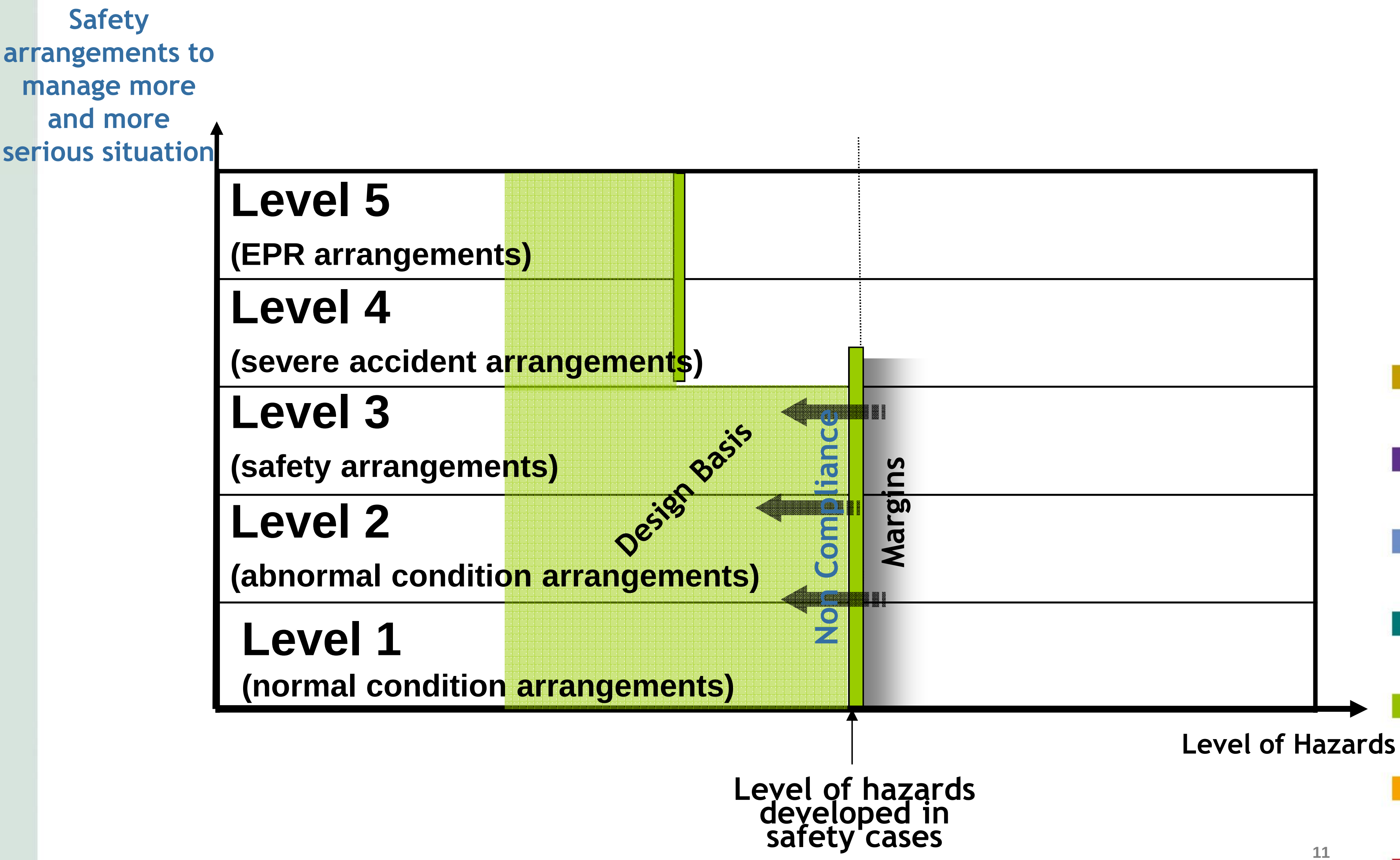
- Non-compliance with autorisations, design requirements and safety cases of existing safety features → Process to detect and manage deviations

- Assessment of design and construction margins for complex safety features against hazards levels beyond design basis

→ Nuclear facilities able to withstand to accident scenario developped in the safety cases. But also, some cases need works to reach compliance

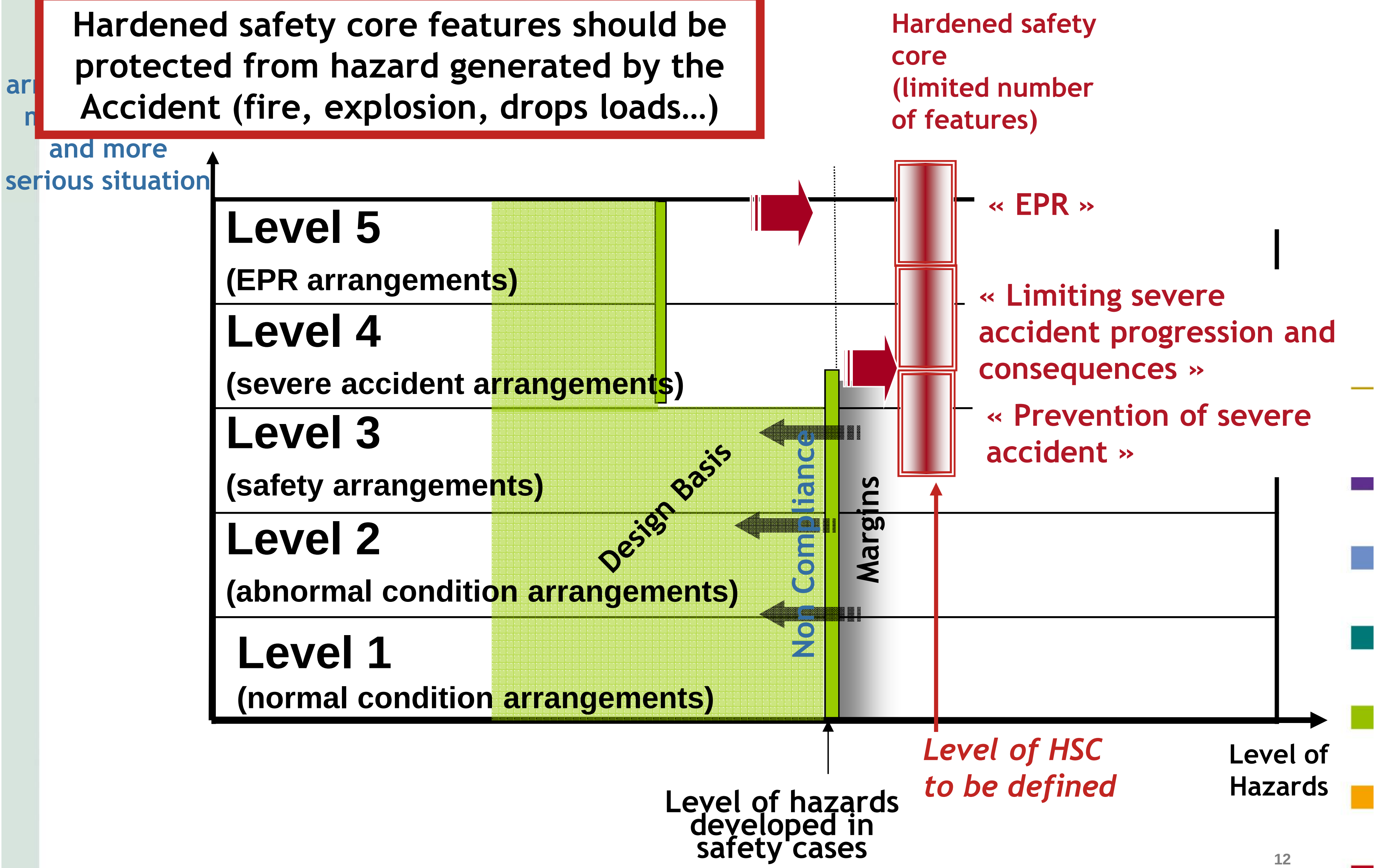
To define a complementary approach to take into account extreme (natural) hazards and large accident scenarios (duration, number of facilities)

Review and Assessment



Review and Assessment

Hardened safety core features should be protected from hazard generated by the Accident (fire, explosion, drops loads…)



26th June 2012: ASN resolutions
the hardened safety core (1/5)

- ASN requirement : safety goals for the hardened safety core for the situations considered in the stress tests
  - To prevent or mitigate the progress of a severe accident
  - To mitigate large-scale radioactive releases
  - To enable the Operator to perform its emergency management duties

Same as NPP

- System, structure and components (SSCs)
  - **designed with significant margins** in relation to the requirements currently applicable
  - composed of **independent and diversified SSCs.** The licensee shall justify the use of undiversified or existing SSCs

Same as NPP

- Emergency arrangements
  - **Emergency Control Room** with greater resistance to hazards and being accessible and habitable at all times and during long-duration emergencies

Same as NPP

26th June 2012: ASN resolutions
the hardened safety core (2/5)

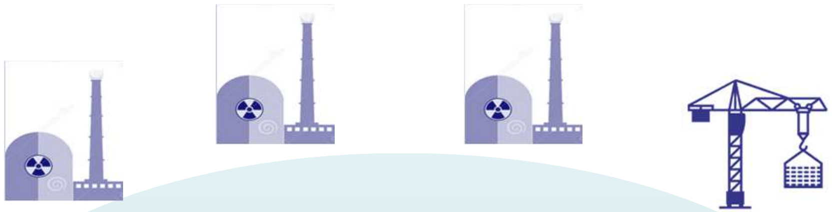
- Emergency Preparedness
  - To develop a site approach considering accidents in several facilities
- CSA complements
  - To assess identified cases of accident specified by ASN "feared situations"
- ASN requirements to each BNI
  - Following the CSA, to define additional arrangements to cover :
    - loss of cooling
    - loss of electrical supply
    - Internal & external hazards

26th June 2012: ASN resolutions
the hardened safety core (3/5)

- CSA complements, Examples of additional studies :
  - Study of the seismic hazard:
    - **PHENIX**: assessment of the cranes robustness beyond the conception level.
    - **OSIRIS**: strengthening of one floor.
    - **HFR**: assessment of the pool's liners vulnerability.
    - **JHR**: assessment of the robustness of the cranes of nuclear auxiliaries building beyond the seismic design basis
  - Study of the flooding hazard:
    - **PHENIX**: reassessment of the Rhône flow margin and the heavy rain scenario.

26th June 2012: ASN resolutions
the hardened safety core (4/5)

- Example of a "Site approach" with several installations :
  - ✓ CEA Cadarache site

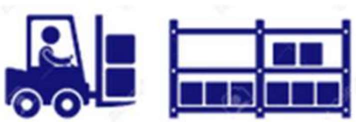


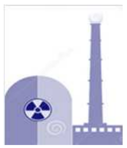
16 BNI (RRs, Waste facilities…)

1 Defense nuclear installation

35 Chemical Plants, classified for industrial hazards and environment protection

4 Decommissioning / 2 Construction

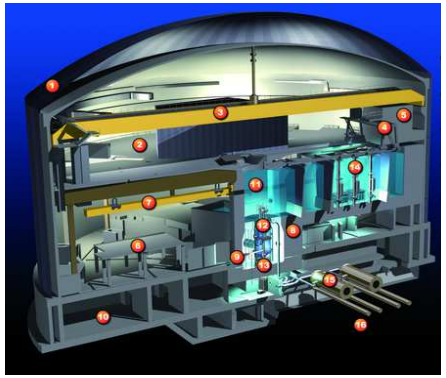




Examples of Site arrangements:

- Complementary studies on fire & explosive hazards for facilities closer than 50m,
- Definition of safe paths for the rescue teams through the site considering the radiological conditions,
- Two additional water tanks seismic qualified on site considering the safe paths.

26th June 2012: ASN resolutions
the hardened safety core (5/5)

	Research Reactor	Feared Situations
	**Material Test Reactor** Cooled and moderated with water 100 MW th currently in construction	- reactor core-melt-down under water with a breath in the containment - reactor core melt-down after vaporization of water in the Reactor Building pool - criticality accident in the spent fuel storage
	**High Flux research Reactor** Cooled by heavy water 58 MW th in operations	- reactor core melt-down after a breath in the primary coolant system and a breath in the pool - several core-melt in the spent fuel pool

8th January 2015 : ASN resolutions
the hardened safety core (1/3)

- ASN resolutions :
  - ✓ specific for a BNI
  - ✓ specific for a site with several installations but adressed to one Licensee

- The resolution sets more detailed safety goals for the hardened safety core
  - ✓ Level of external hazards (seismic)

Same as NPP

- **The resolutions request the Operator to:**
  - Define the list of SSCs composing the hardened safety core and their qualification requirements
    - ✓ New SSCs designed according to industrial standards
    - ✓ Existing SSCs verified according to industrial standards, or verified according to methods allowed during PSRs

Same as NPP

8^{th} January 2015 : ASN resolutions
the hardened safety core (2/3)

- Emergency Preparedness and Response

  ✓ Arrangements to ensure the ability of the hardened safety core SSC to work the first 48hrs without any external support and supplies

  ✓ Availability in the Emergency Control Room of key parameters related to the safety functions of the facilities (level of water in a pond, T°, …)

  ✓ Arrangements to provide external support (human resources, additional materials and supplies) to a site affected by an extreme event (similar than the EDF Nuclear Rapid Response Force):

  - AREVA : FINA (*force d'intervention nationale AREVA*)
  - CEA : FARN

Similar to NPP

8^{th} January 2015 : ASN resolutions
the hardened safety core (3/3)

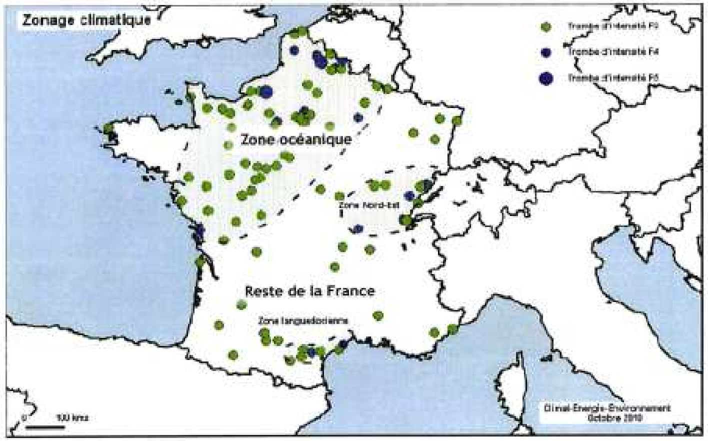
- Target dates & Licensees' programmes

  - Target dates are settled in the ASN decisions for each BNI and Sites, to provide a trend :
    - ✓ Additional studies → ≈ 2015 - 2016
    - ✓ Additional emergency arrangements → ≈ until 2018
    - ✓ Additional material → ≈ until 2018

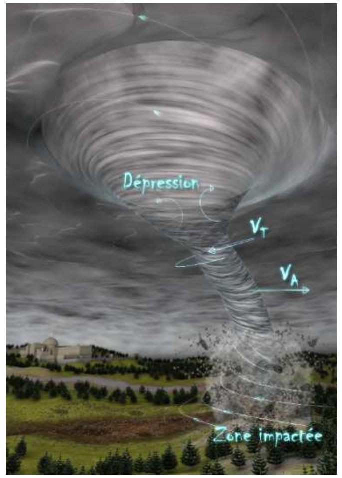
  - Target dates could be related to *Periodic Safety Review*

The implementation of the post-Fukushima Daiichi Accident Enhancement programme to comply with ASN Resolutions

Extreme natural Hazards - Tornado



- **Phenomena in France:**
  - 800 events since the 12th Century
  - 90 level EF3 events, 15 level EF4 events and 2 levels EF5 on the Fujita scale
  - 40-50 tornado per year ; EF2 – EF3 5%
  - Tornado hazard is homogenous for low and moderate intensity event (EF0 to EF3)



- **Modelisation and standards:**
  - State of art : US NRC regulatory guide and guidance,
  - AFCEN construction code
- **Torando Hazards levels:**
  - Compliance with WENRA reference level for design basis
  - Consistant with the level of extreme natural hazards for HSC (earthquake)
  - The Research Reactor Operators selected:
  - o for design basis, a reference tornado EF1: speed of 45 m/s, pressure drop of 1,27 kPa, an annual frequency of exceedance lower of 10^{-4},
  - o for extreme situations, EF3, 65 m/s, 2,65 kPa, 10^{-6}.

CSA Findings & Hardened Safety Core

- **Laue Langevin Institute:**
  - Private company
  - Partnership of 3 countries: UK, Germany, France
  - Operate only one BNI

- **High Flux Reactor (HFR) :**
  - Power 57 MW th
  - Neutron flux used for international scienific experiences
  - Fuel : HEU (93%) uranium-aluminium
  - First start up in 1971, new autorisation in 1994 due to new Reactor pressure vessel

- **Site :**
  - Located in Grenoble
  - Mountainous area : sismic risk and several dams in the upper reaches
  - Urban areawith several companies and reserach centers (CEA**)**

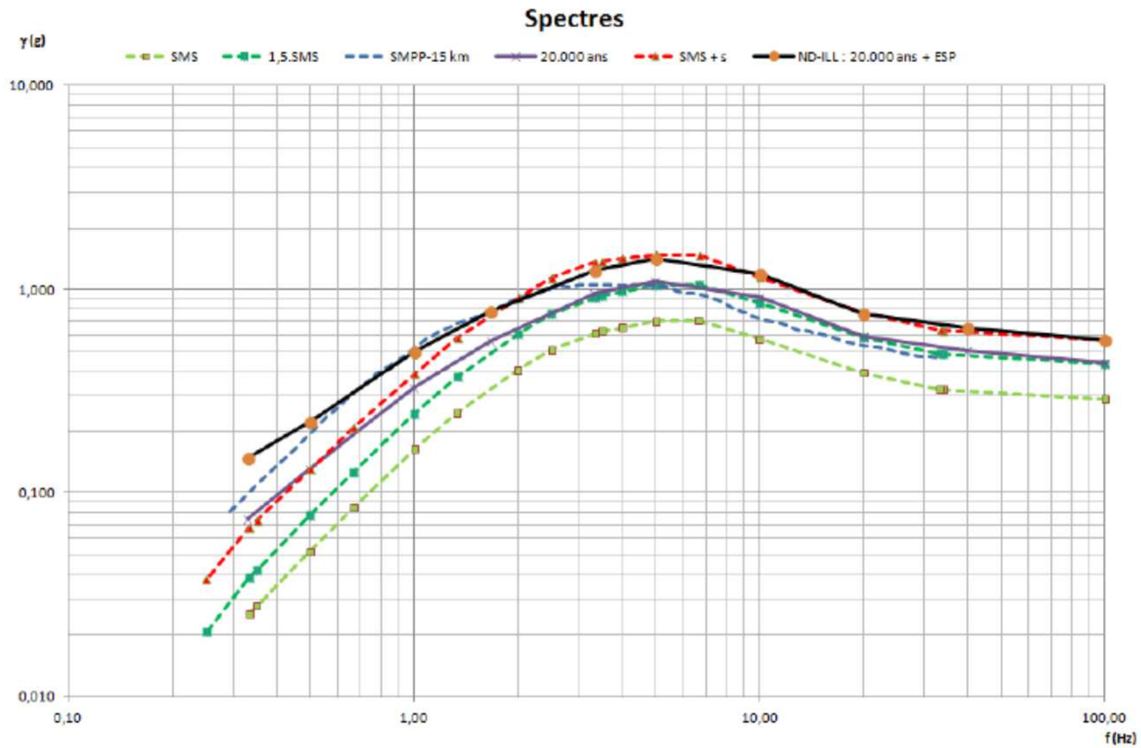
CSA Findings & Hardened Safety Core

- **Loss of electrical supplies and Loss of heat sink**
  - No issue on the core cooling (reactor trip, natural convection)

- **Extreme flooding**
  - Failure of 4 dams on the Drac River, leading to consider an additional (+5,5 metres) to the design basis

- **Extreme Sismic level :**
- > 20 000 years and 1,5 DBE (site effects)

- **Review of the safety cases:**
  - Safety margins of the existing HSC features
  - New HSC features
  - Potential internal hazards



Hardened Safety Core Features

- **HSC Objectives:**
  - ✓ Mitigate cliff effects following an extreme event such as an extreme earth quake leading to an extreme flodding (failure of 4 dams on the Drac River)

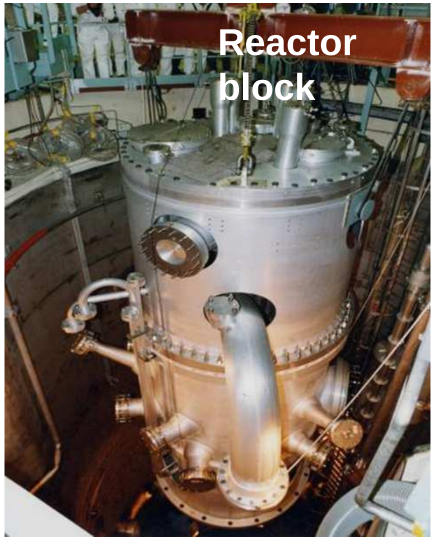
- **Passive HSC systems:**
  - ✓ Existing HSC features
  - ✓ Withstanding and ensuring sealing
  - ✓ Mainly 1st level of the Defense in Depth

- **Active HSC systems:**
  - ✓ Existing and New HSC features
  - ✓ Need electrical supply and C&I
  - ✓ Redundant systems
  - ✓ Belong to 3rd , 4th or 5th level of the Defense in Depth

Hardened Safety Core
Passive features

- To prevent core-melt under water
  - ✓ Reactor pressure vessel
  - ✓ Natural convection valves
- To prevent core-melt in air
  - ✓ Immersion sleeve
  - ✓ Reactor pond and channel 2
  - ✓ transfer basket and handling cask
- Mitigation de l'accident de fusion
  - ✓ Concrete reactor containment

Existing systems are examined considering extreme external hazards level



Hardened Safety Core
Active systems

- ❑ To prevent core-melt
  - ✓ Earthquake : automatic reactor trip and isolation of the non seismic qualified electrical supplies
  - ✓ Ultimate heat sink : 2 files to refill the pond or the channel from the groundwater table (250 m3/h each) (*from 2017*).
  - ✓ Ultimate cooling water system : from the pond in the case of a breach in the primary coolant system (untill 400m3/h) with pyrotechnic valves

- ❑ To mitigate core-melt
  - ✓ Containment vessel isolation system : seismic qualified
  - ✓ Seismic containment depressurised system (CDS) : to maintain the reactor building depressurised and to filter the releases to the environment

- ❑ Bunkerised emergency control room
  - ✓ Redundant electric supply, key plant and environment parameters survey, ability to operate safety systems

Conclusion

- ✓ The implementation of the HSC features prescribed by ASN resolutions
- ✓ With ambitious deadline which are mainly in compliance with the regulatory programme
- ✓ Some difficulties to build the new Bunkerised Emergency Control Room buildings which could have lead to delay.

Thank you for your attention