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French Post-Fukushima Complementary Assessments

General Approach and Resulting Safety Improvements for the High Flux Reactor located in Grenoble

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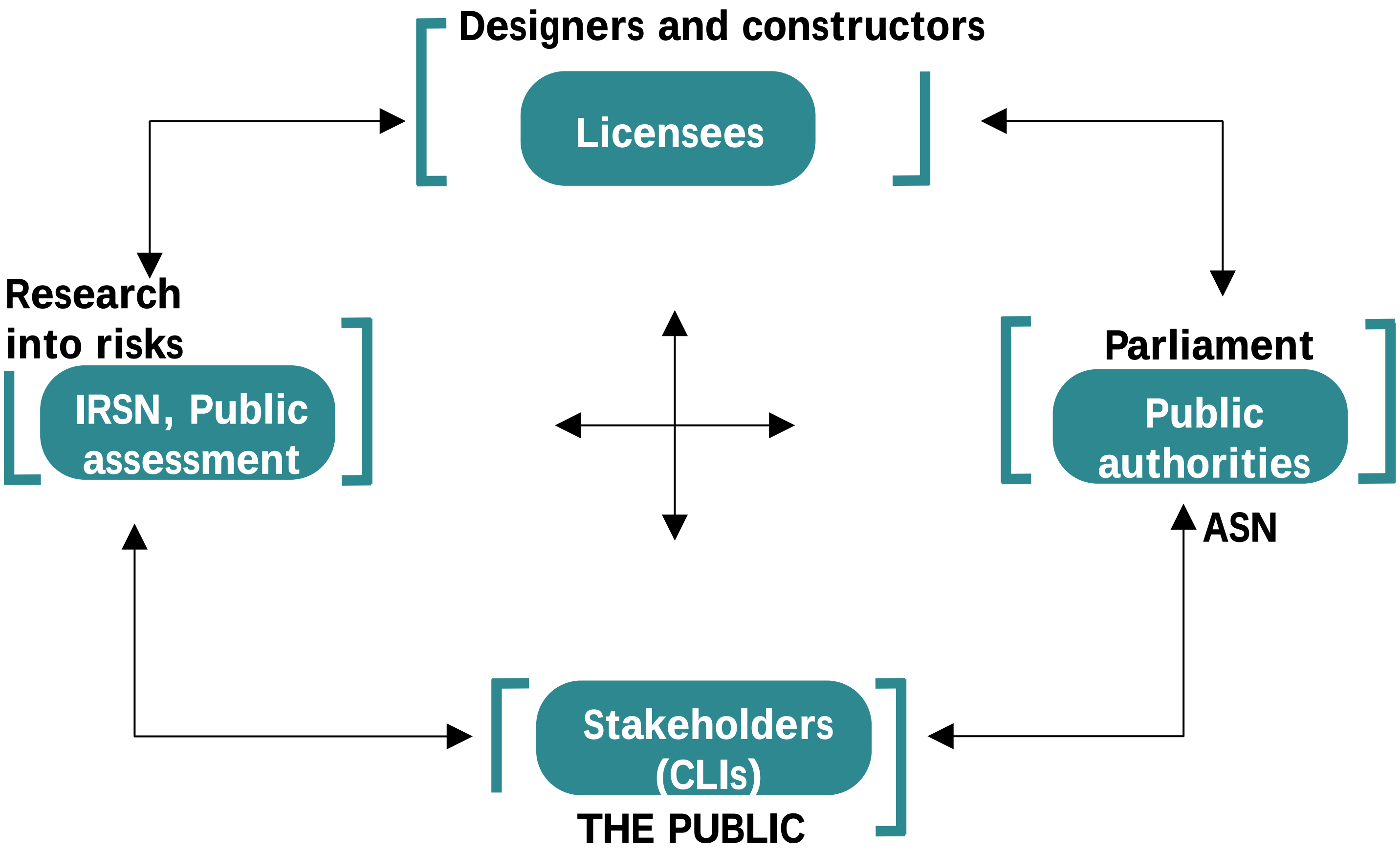
INTRODUCTION

- 11 March 2011: Accident on the Fukushima-Daiichi nuclear power plant
- 5 May 2011: Nuclear Safety Authority (ASN) decisions asking licensees of nuclear facilities to carry out a Complementary Safety Assessment (CSA)
- In France: all nuclear facilities have been concerned by CSAs (NPPs, fuel cycle plants, research reactors…) with a priority classification (3 categories)

THE ORGANISATION OF NUCLEAR SAFETY IN FRANCE



In the context of CSAs, the IRSN reviewed the analyses carried out by licensees

THE IMPLEMENTATION OF CSAs

- Main objective: to assess the response of nuclear facilities in the event of extreme natural hazards or extreme situations by analysing the risk of cliff-edge effect
- Cliff-edge effect: the risk that a small variation of a characteristic related to a hazard or to a degraded situation lead to a brutal change of the facility behavior with consequences exceeding the planned emergency measures
- Extreme hazards: earthquake, flooding and climatic phenomena with intensity higher than those considered until then in safety demonstration
- Extreme situations: total loss of electrical power and total loss of cooling

THE IMPLEMENTATION OF CSAs

- Licensees presented analyses of robustness of their facility based on an evaluation of safety margins of civil engineering structures and equipment
- Safety margins have mostly been evaluated by expert/engineer judgment from:
  - The design specifications and design studies of structures/equipement
  - The construction provisions actually in place in the facility (“”walk-down”)
- The analyses carried out by licensees for CSAs led to the identification of some weakness points (if existing) and needed reinforcements of facilities

THE ASSESSMENT OF THE IRSN

- The IRSN lauded the important work carried out by licensees in a very short time
- The CSAs permitted to identify SSCs whose failure in the event of an extreme situation or extreme hazard may lead to a cliff-edge effect with severe radiological consequences (exceeding those considered in emergency measures)
- These SSCs are directly involved in the control of basic safety functions and can be classified according to the defence-in-depth principle:
  - Prevention of severe accidents
  - Mitigation of these accidents
  - Emergency management

THE ASSESSMENT OF THE IRSN

- The IRSN has estimated in 2011-2012 that because of:
  - The uncertainties related to the levels/intensities of extreme hazards to be considered
  - The simplified approaches used by licensees for the evaluation of the facilities safety margins

It was not possible to conclude, with a sufficient degree of confidence, on the robustness of facilities under extreme conditions

- The IRSN concluded that a set of SSCs, allowing facilities to withstand extreme hazards, must be defined for facilities having a risk of cliff-edge effect:
  - This leads to define a new concept: the "Hardened Safety Core"

THE HARDENED SAFETY CORE CONCEPT

- The hardened safety core (HSC) must ensure ultimate protection of nuclear facilities according to the following objectives:
  - Prevent a severe accident or limit its progression
  - Limit large-scale consequences in the event of an accident which was not possible to control
  - Enable the licensee to perform its emergency management duties
- The HSC may be composed of existing SSCs (that might require to be strengthened) and new SSCs (that shall be designed and sized to withstand extreme hazards)

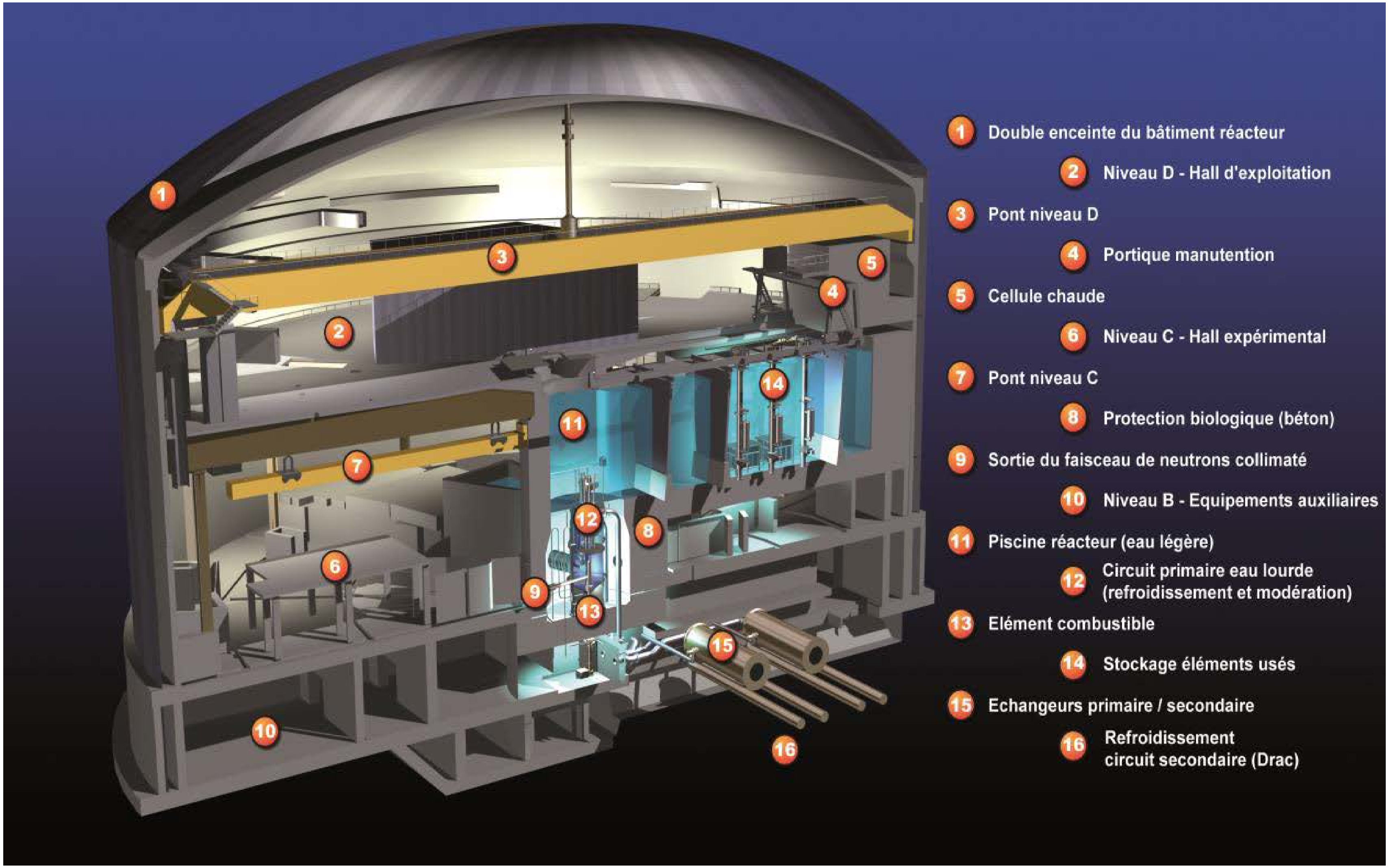
THE HARDENED SAFETY CORE CONCEPT

- The effective implementation of the HSC on the facilities implies:
  - The characterisation of extreme natural hazards (intensity, duration, magnitude, frequencies, etc.)
  - The use of robust methods to design new SSCs or to verify existing SSCs belonging to HSC
- This information shall be determined with the aim that the HSC will be able to ensure, with a high degree of confidence, its functions in case of extreme events

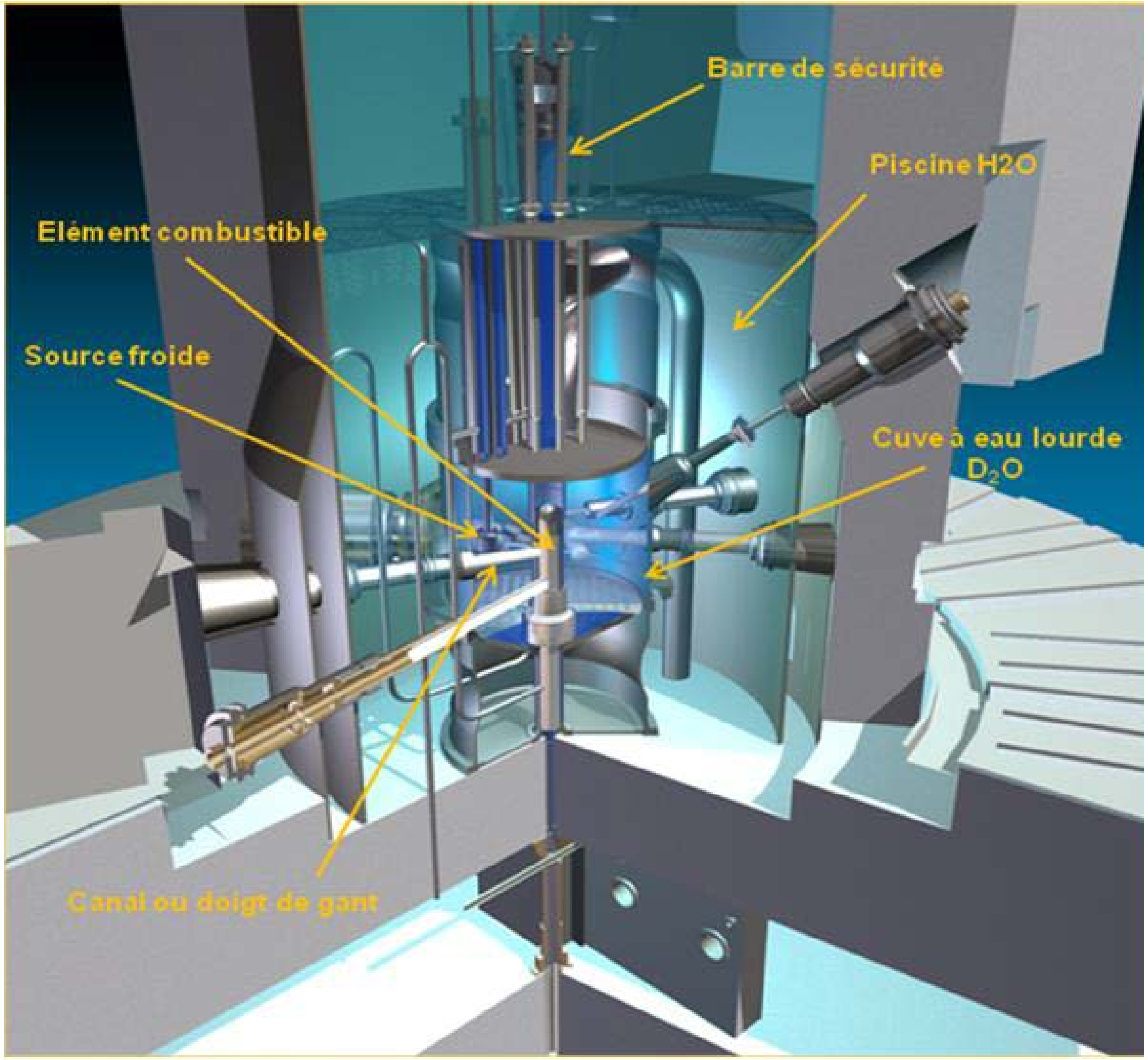
A CONCRETE EXAMPLE OF HSC IMPLEMENTATION - THE RHF REACTOR

- The High Flux Reactor (RHF), research reactor operated by the Laue-Langevin Institute (ILL), has been considered by the ASN as a top-priority facility for CSAs
- The RHF is located nearby the city of Grenoble, France, in a geographical area concerned by earthquakes (paleo-sedimentary valley) and flooding (several dams on rivers flowing in the mountains surrounding the RHF)
- The RHF is a 58 MW maximum thermal power reactor (the reactor core is made of one annular HEU-Al fuel assembly cooled by heavy water)

A CONCRETE EXAMPLE OF HSC IMPLEMENTATION - THE RHF REACTOR



A CONCRETE EXAMPLE OF HSC IMPLEMENTATION - THE RHF REACTOR



A CONCRETE EXAMPLE OF HSC IMPLEMENTATION - THE RHF REACTOR

- ILL defined the HSC of the RHF based on:
  - The safety functions that must be ensured in case of extreme events (reactivity control, fuel cooling control, radioactive materials containment)
  - The application of the defence-in-depth (DID) principle by "dispatching" SSCs of HSC on different levels of DID
- ILL determined SSCs to be included in the HSC of the RHF:
  - "Passive" SSCs (static equipment or civil engineering structures)
  - "Active" SSCs (non-static systems or systems requiring electrical power supply)

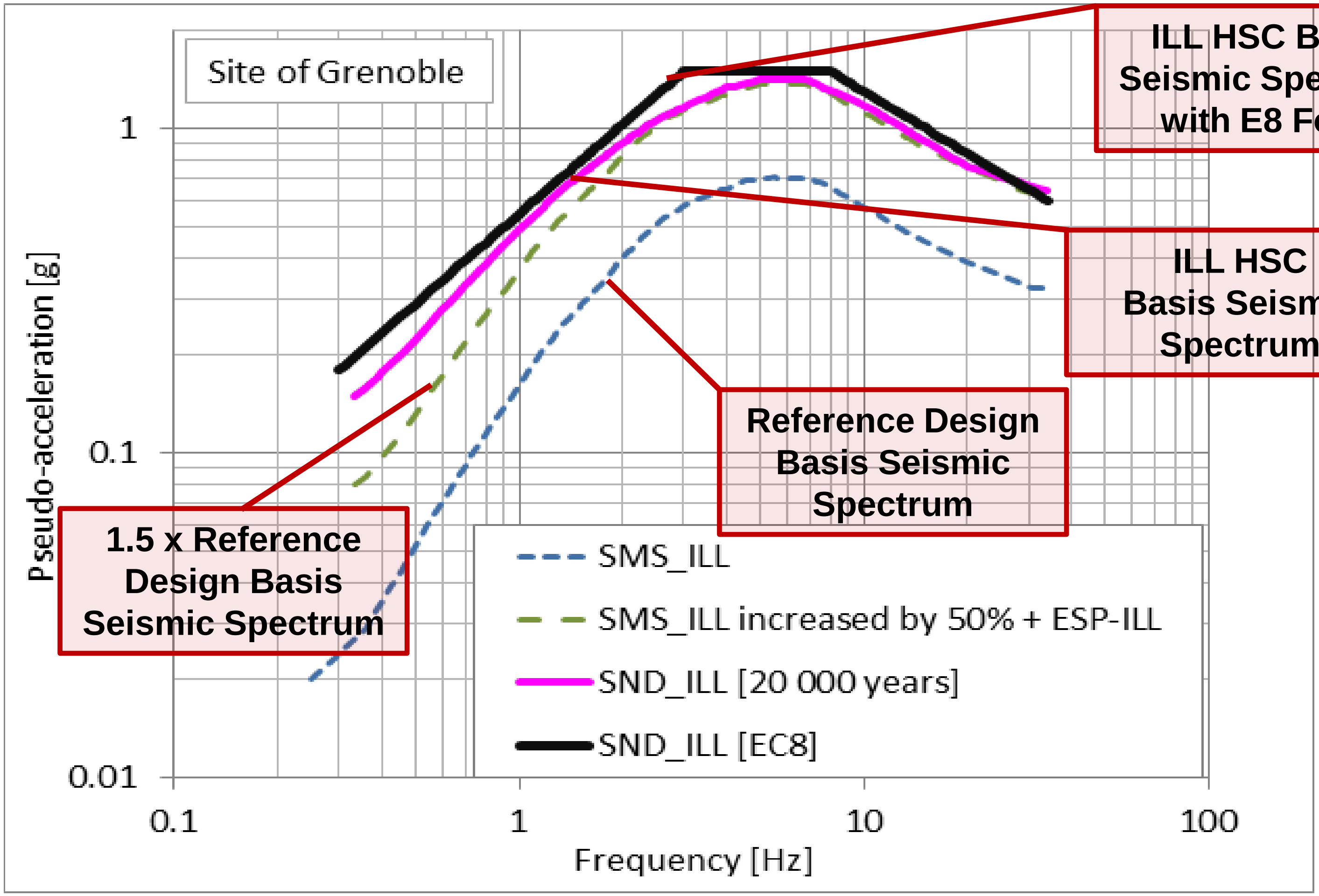
A CONCRETE EXAMPLE OF HSC IMPLEMENTATION - THE RHF REACTOR

- All new SSCs of HSC have been designed and sized to withstand:
  - Extreme earthquake (*see slides after*)
  - Extreme flooding (*see slides after*)
  - Extreme climatic phenomena (winds, rainfalls, tornadoes, etc.)
  - Secondary effects as explosions of fires (from internal or external origin)
- Existing SSCs have been justified (or are under justification) by ILL to these extreme hazards.

A CONCRETE EXAMPLE OF HSC IMPLEMENTATION - THE RHF REACTOR

- General requirements to determine the <u>extreme earthquake</u> for the HSC design have been fixed by ASN (regulatory decision)
- Licensees must define a HSC reference seismic spectrum meeting the <u>following requirements</u>:
  - Be 50% higher than the seismic spectrum chosen as a reference for the design of new nuclear facilities
  - Be conservative of spectra defined accordingly to a probabilistic manner with a return period of 20 000 years (PSHA)
  - Take into account the possible effects due to the facility location including the nature of the soil

A CONCRETE EXAMPLE OF HSC IMPLEMENTATION - THE RHF REACTOR

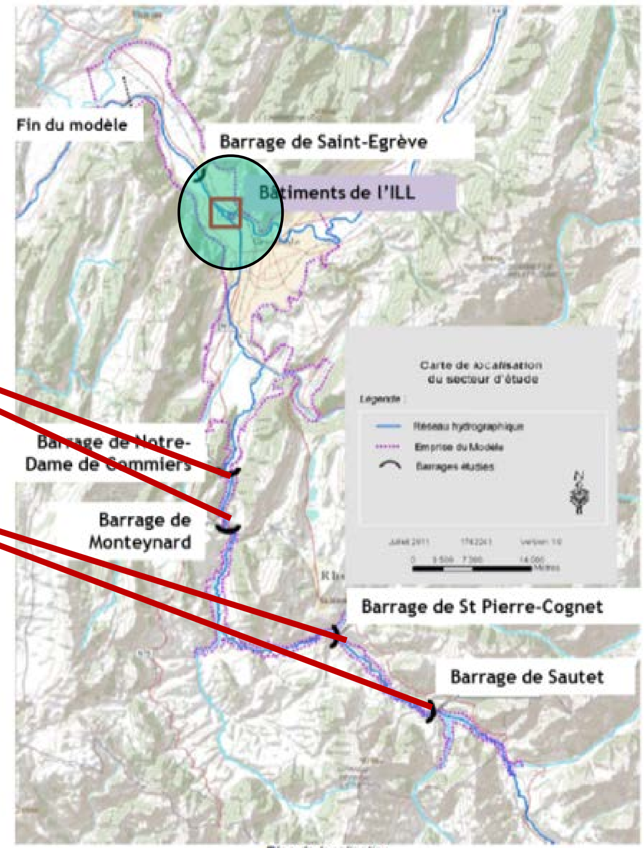


Spectra defined by ILL for the hard core of RHF(in pink: spectrum associated with a period of return target of 20,000 years taking into account specific site effects - in black: spectrum of simplified type "Eurocode 8" - in green dashed: the envelope of the SMS spectra for RHF, increased by 50 %, with specific site effects taken into account – in bleu dashed: the envelope of the SMS spectra for RHF)

A CONCRETE EXAMPLE OF HSC IMPLEMENTATION - THE RHF REACTOR

- Extreme flooding characterization: ILL assumed that all dams located on the Drac river upstream to the RHF site are breakdown

Four dams on Drac river upstream RHF site



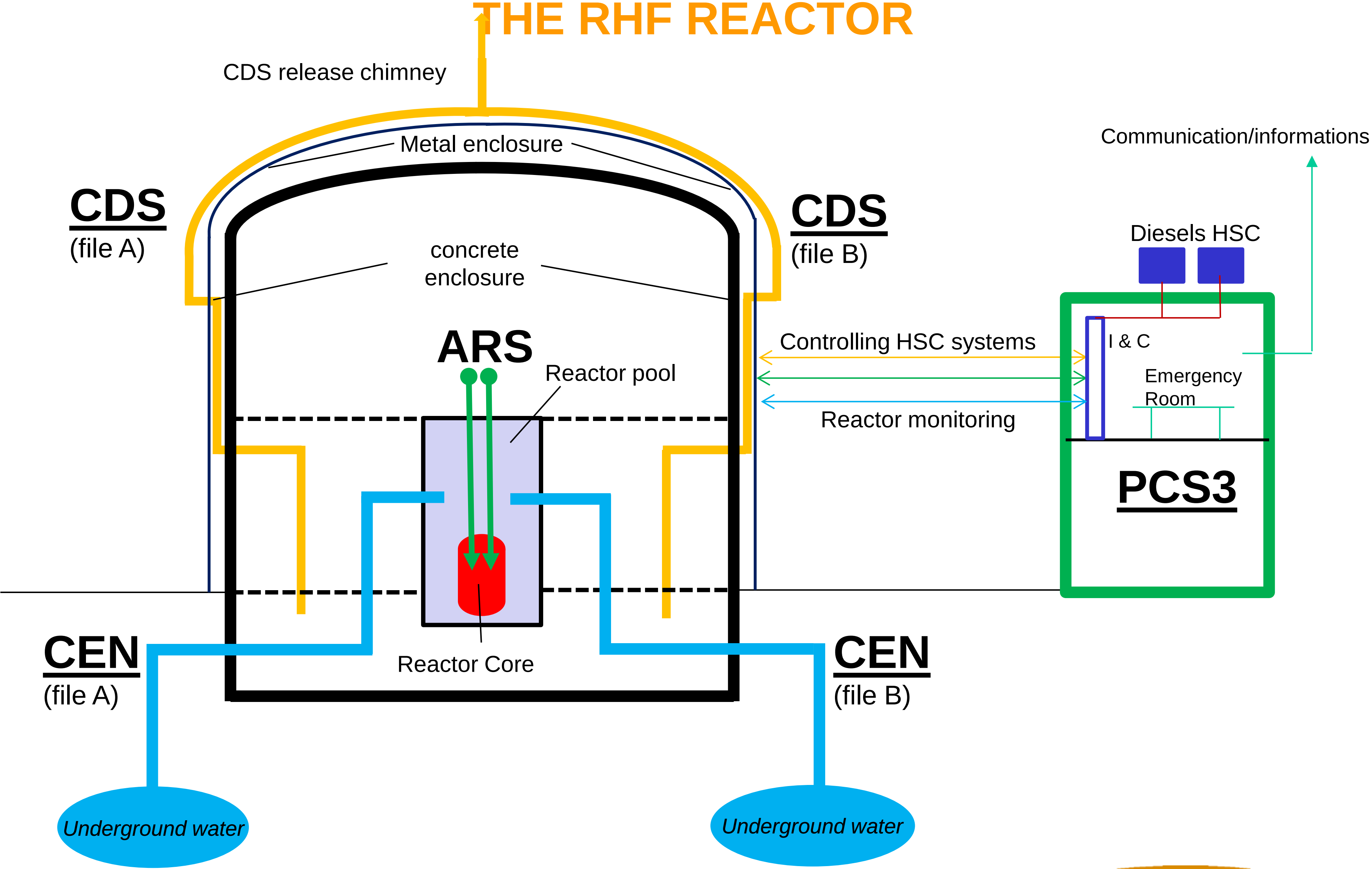
Plan de localisation

=> Assumption: 6m high wave of water flooding the RHF site!

A CONCRETE EXAMPLE OF HSC IMPLEMENTATION - THE RHF REACTOR

- Example of new SSCs of HSC implemented by ILL following the CSAs of RHF:
  - ARS: New emergency reactor shutdown system
  - CEN: Underground water supply circuit (core cooling control to prevent core melt)
  - CDS: Reactor building depressurization and filtration circuit (radioactive materials containment control to mitigate severe accidents)
  - PCS3: Emergency control building including:
    - provisions for managing SSCs of HSC
    - facility monitoring devices
    - emergency tools (communication, meteorological information…)

A CONCRETE EXAMPLE OF HSC IMPLEMENTATION - THE RHF REACTOR



A CONCRETE EXAMPLE OF HSC IMPLEMENTATION - THE RHF REACTOR

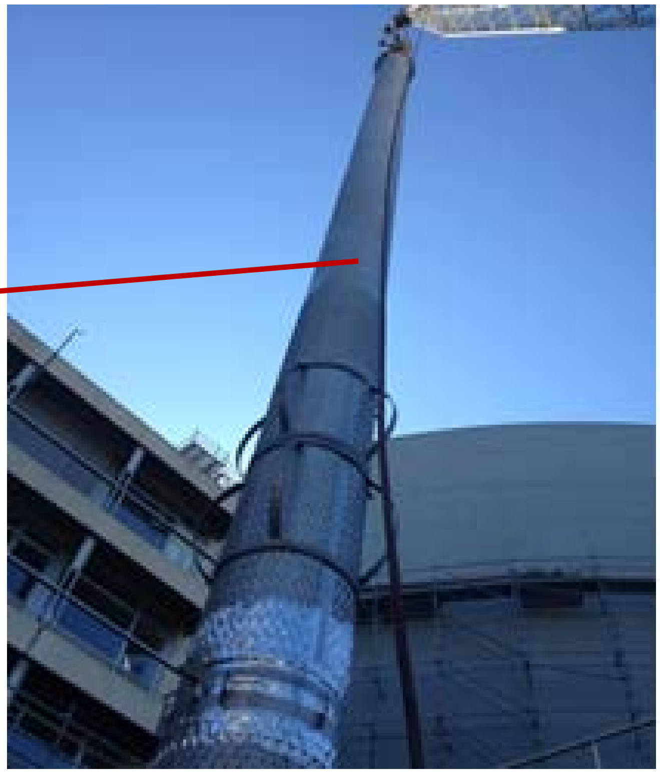
THE HARDENED SAFETY CORE OF THE RHF

« Active » HSC	« Passive » HSC
• Emergency reactor shutdown system (ARS) • Ultimate "drench" circuit (CRU) in association with the emergency water supply circuit (CES) • Underground water supply circuit (CEN) • Emergency fuel lowering system (PUC) • Automatic containment isolation system (SIE) • Containment depressurization seismic circuit (CDS) • PCS3 (means of control and monitoring required for the management of crisis)	• Primary core enclosure and related supporting structures • Fuel handling container • Natural convection flappers • Civil engineering structures and lining of the fuel storage channel and reactor pool • Neutron beam tube nozzles • Concrete reactor enclosure • PCS3 (room and supporting building)

A CONCRETE EXAMPLE OF HSC IMPLEMENTATION - THE RHF REACTOR

The new underground water supply circuit (CEN)

CEN Suction Strainers (being handled for setting)



CEN Suction Strainers (going down in its well)

A CONCRETE EXAMPLE OF HSC IMPLEMENTATION - THE RHF REACTOR

The <u>new</u> containment depressurisation seismic circuit (CDS)

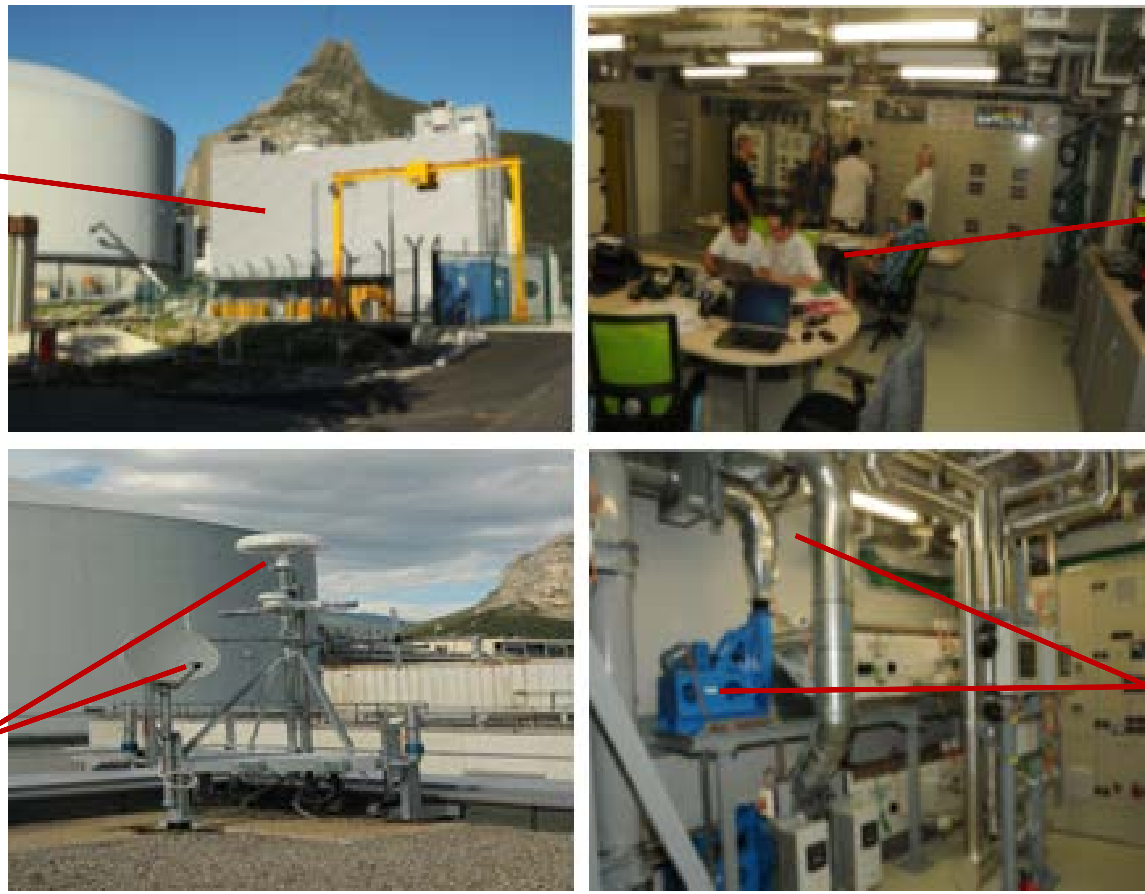
Release chimney of CDS

CDS circuit on RB roof

CDS circuit going out the RB

A CONCRETE EXAMPLE OF HSC IMPLEMENTATION - THE RHF REACTOR

The new bunkered emergency control room (PCS3)



CONCLUSION

- The Complementary Safety Assessments (CSA) carried out after the Fukushima accident for all nuclear facilities accident led the IRSN to define the concept of Hardened Safety Core (HSC)
- The HSC is currently being implemented on nuclear facilities for which a risk of cliff-edge effect in terms of radiological consequences has been identified following CSAs
- The Laue-Langevin Institute (ILL), operator of the RHF in Grenoble, has fully developed and implemented the concept of HSC, in agreement with IRSN opinion
- The HSC of RHF will be fully operational in 2016

THANK YOU FOR ATTENTION