

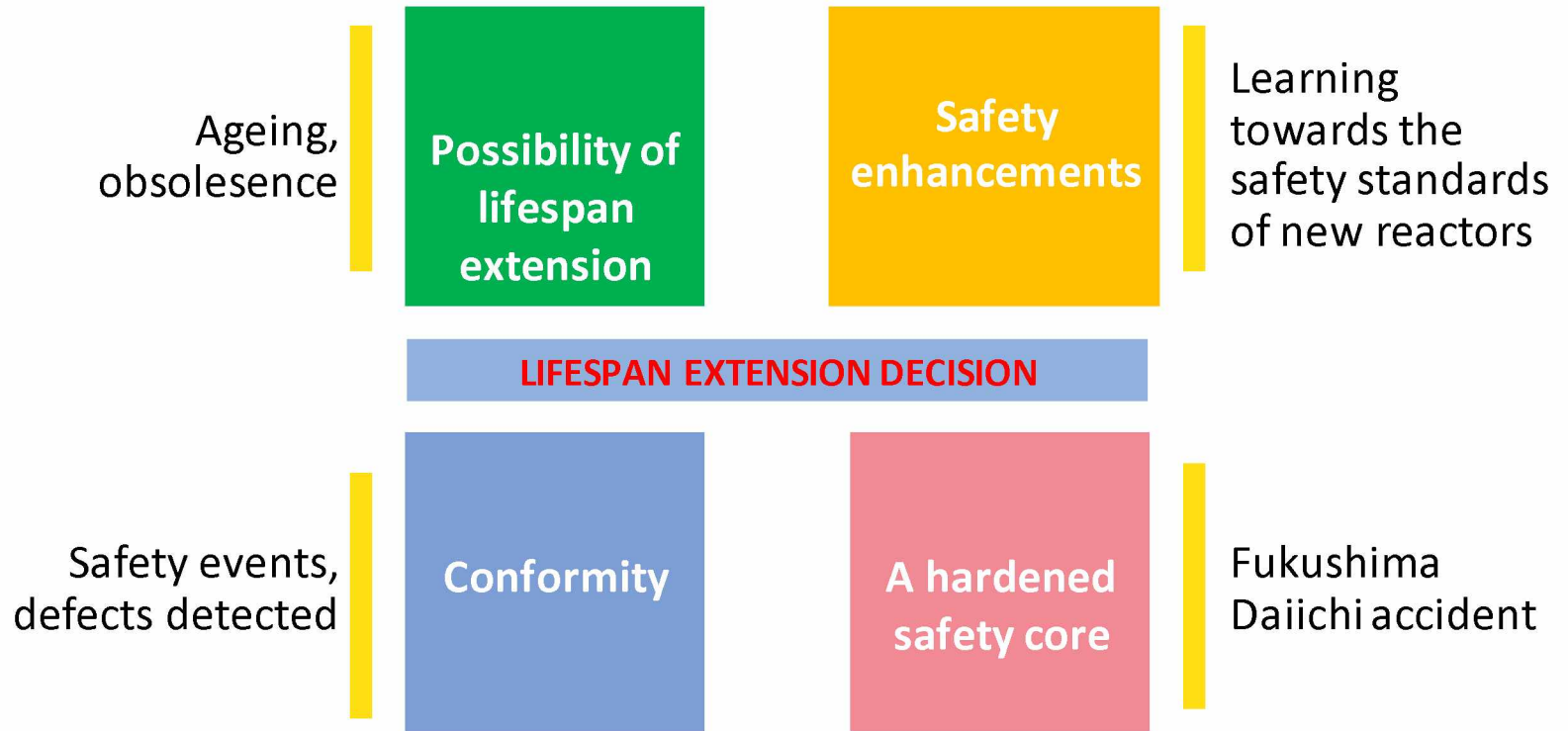
# TAKING INTO ACCOUNT FUKUSHIMA DAIICHI NUCLEAR ACCIDENT EXPERIENCE FEEDBACK: CONTRIBUTION FROM IRSN

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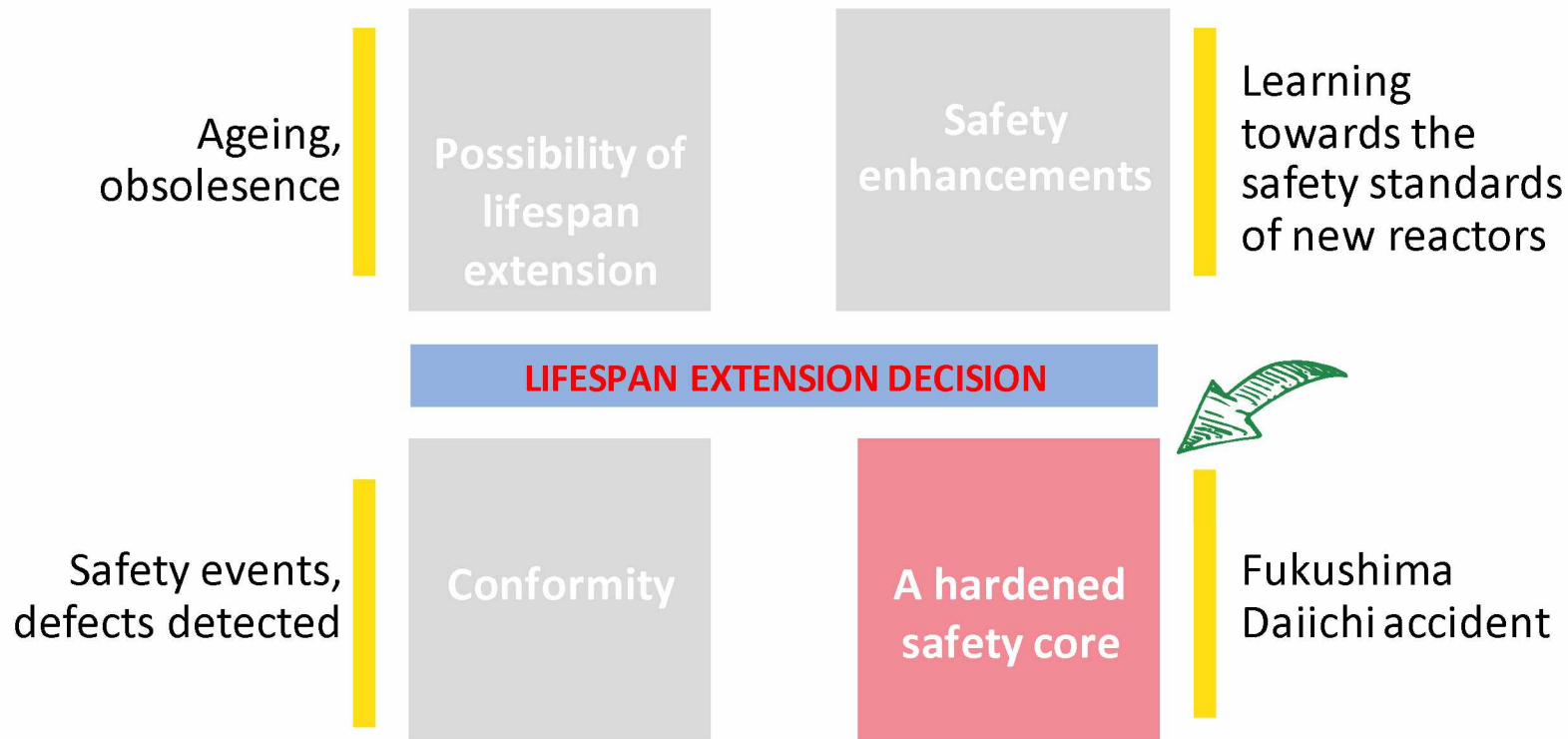
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## 4<sup>th</sup> periodic safety review (PSR) of the French 900 MWe reactors



## 4<sup>th</sup> periodic safety review (PSR) of the French 900 MWe reactors



## Outline

- What is the hardened safety core?
- Focus on one in situ modification
- Focus on mitigation of core melt accident consequences
- Conclusions

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# What is hardened safety core (HSC)?

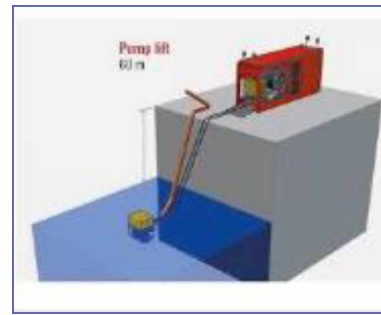
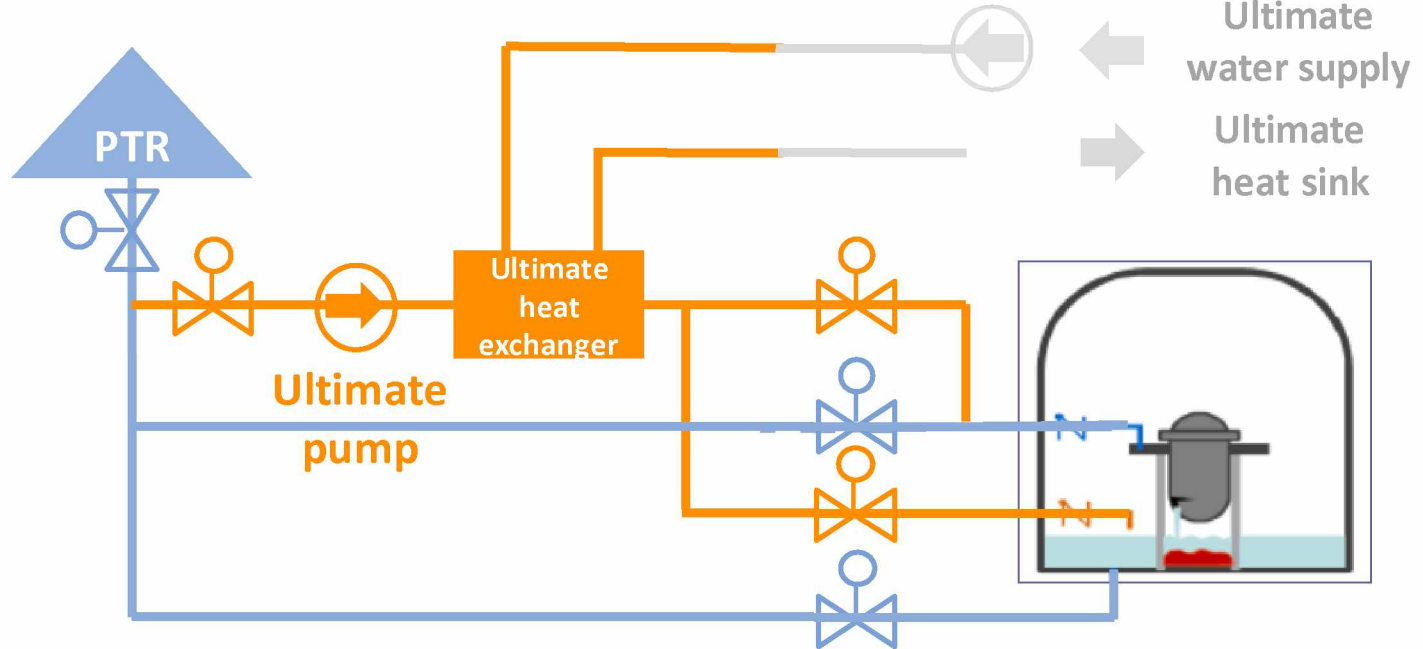
## [ ULTIMATE DIESEL GENERATORS (DUS)

- About 3 MW power
- Robust design
  - Electrical supply
  - Civil engineering
- Shall withstand extreme hazards loadings (earthquake, flooding and tornado)
  - Seismic pads
  - Lower floor above the design flood level
  - SSCs can withstand a design tornado

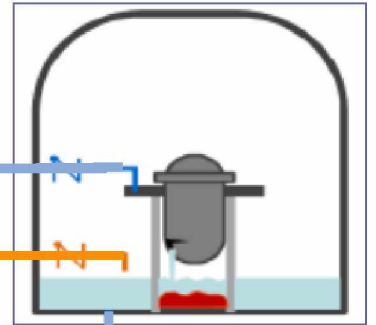


# What is hardened safety core (HSC)?

## [ ULTIMATE CONTAINMENT HEAT REMOVAL SYSTEM (EASU)



Ultimate water supply  
Ultimate heat sink



## What is hardened safety core (HSC)?

### [ ULTIMATE WATER SUPPLY (SEU)

- Different solutions
  - Implementation of freshwater reserve basins
  - Pumping from the groundwater table
- The SEU can bring water to:
  - The auxiliary feed water system tank
  - The spent fuel pool





# What is hardened safety core (HSC)?

## [ ULTIMATE HEAT SINK (SFU)

- Connected by the EDF rapid response force after 24h at most
- Using closed rivers or the sea
- Special pumps able to pump water even if there are debris or sediments in the water
- Pumps circulate cold water directly into the “EASU” exchanger



## Outline

- | What is the hardened safety core?
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## Focus on one in situ modification

### [ PREVENTING CORE MELTDOWN IN THE SPENT FUEL POOL

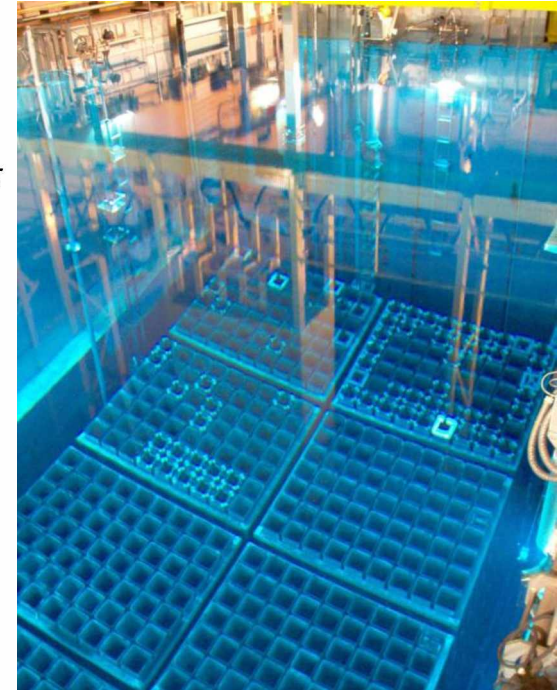
■ ASN defined the following objective: « *the possibility of extending the operations of reactors [beyond 40 years] shall be examined with respect to the **practical elimination of the risk of fusion of the fuel in the spent fuel building*** »

■ Main risks:

- Loss of spent fuel pool cooling systems
- Accidental drainage of spent fuel pool

■ Pool water boiling may result from the accidents considered

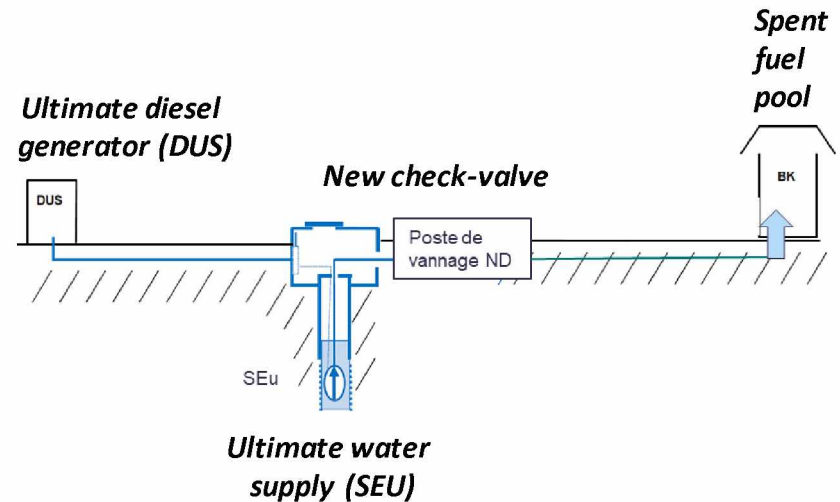
■ IRSN considers reaching a **safe state at the end of an accident requires a closed loop cooling system** and a water temperature  $< 100\text{ }^{\circ}\text{C}$  (**no boiling**), ensuring the end of radiological releases



## Focus on one in situ modification

### [ PREVENTING CORE MELTDOWN IN THE SPENT FUEL POOL

- Safety enhancements
  - **New ultimate water supply system (SEU) and ultimate diesel generators (DUS)**
  - **Emergency trip** of the fuel pool cooling system pumps in case of “very low” water level in the pool
  - **New independent cooling system** which can be connected to the emergency heat sink by the nuclear rapid response force



## Focus on one in situ modification

### [ PREVENTING CORE MELTDOWN IN THE SPENT FUEL POOL

#### IRSN assessment

- PSA showed a **probability of fuel fusion in pool  $< 10^{-8}$  / year / reactor**



IRSN considered the objective is reached

- EDF demonstrated the possibility of reaching a safe state (no water boiling) in case of loss of normal spent fuel pool cooling systems or in case of accidental drainage, except for some residual probability scenarios
  - EDF committed to study these residual scenarios and to propose solutions that could be implemented after such accidental scenarios to reach a safe state



IRSN considered the objective is reached

## Outline

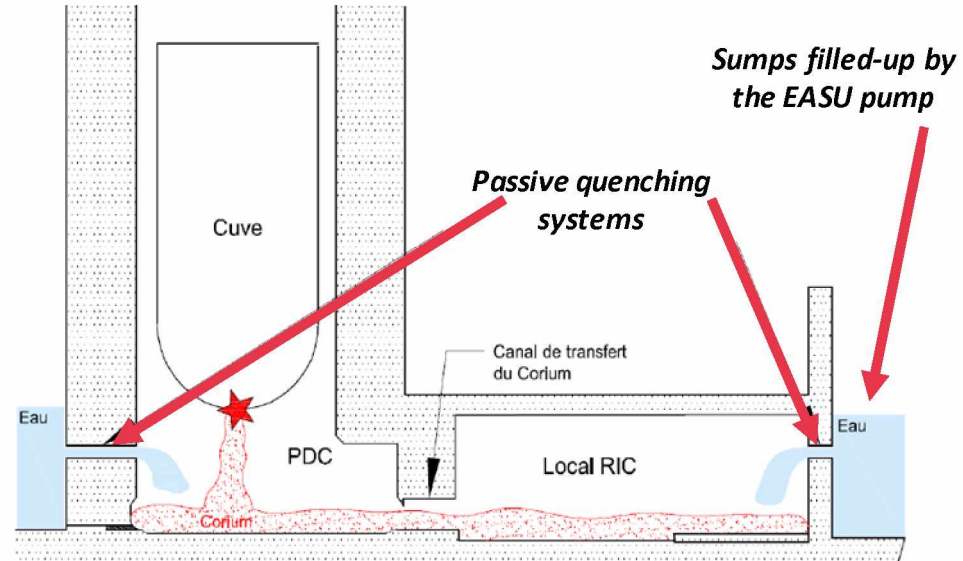
- | What is the hardened safety core?
- | Focus on one in situ modification
- | **Focus on mitigation of core melt accident consequences**
- | Conclusions

## Focus on mitigation of core melt accident consequences

- ASN defined the following objective: « *Make very unlikely the risk of accident with core melt which **would lead to early and large releases** and avoid long lasting effects in the environment* »
- Technical objectives
  - Ex-vessel molten core coolability in case of accident leading to core fusion
  - Containment heat removal without venting in case of severe accident

## Focus on mitigation of core melt accident consequences

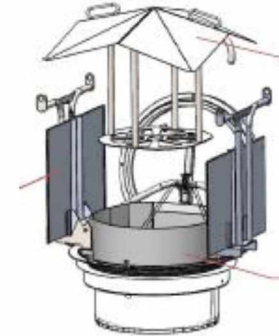
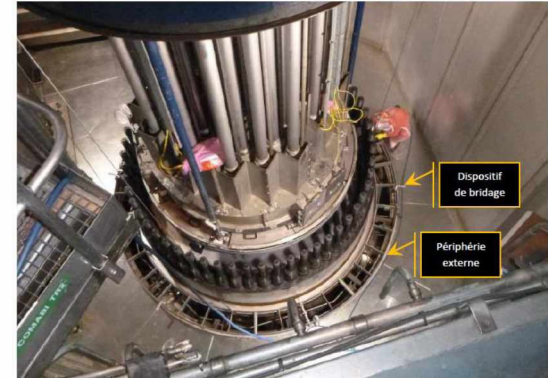
- Ex-vessel core coolability
  - A large area for the corium spreading (reactor pit and adjacent in core instrumentation system area)
  - Areas must stay dry until the vessel failure to ensure efficient corium spreading





# Focus on mitigation of core melt accident consequences

- Modifications to ensure the corium spreading area is dry before vessel rupture
  - new annular structure to prevent water from flowing through the space between the vessel and the reactor pit
  - new system to prevent water from flowing through the access pits to the neutron flux chambers
- IRSN assessment
  - ✓ The modifications are efficient



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## Conclusions

- EDF designed and planned many modifications within the 4<sup>th</sup> periodic safety review (PSR) of its 900 MWe reactors fleet.
  - ambitious industrial program
- The implementation of post-Fukushima modifications in reactors is planned by EDF in different phases
  - the latest ones corresponding to some reinforcements for extreme seismic events
- IRSN and ASN consider that these enhancements should enable EDF to reach the safety objectives set by ASN, for this PSR which will allow the lifespan extension of 900 MWe reactors
  - some complements are necessary and will be asked by ASN