DE LA RECHERCHE À L'INDUSTRIE

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Expert panel on "Monju" decommissioning

July, 2017

DECOMMISSIONING OF SODIUM FAST REACTORS:

Presentation of French experience

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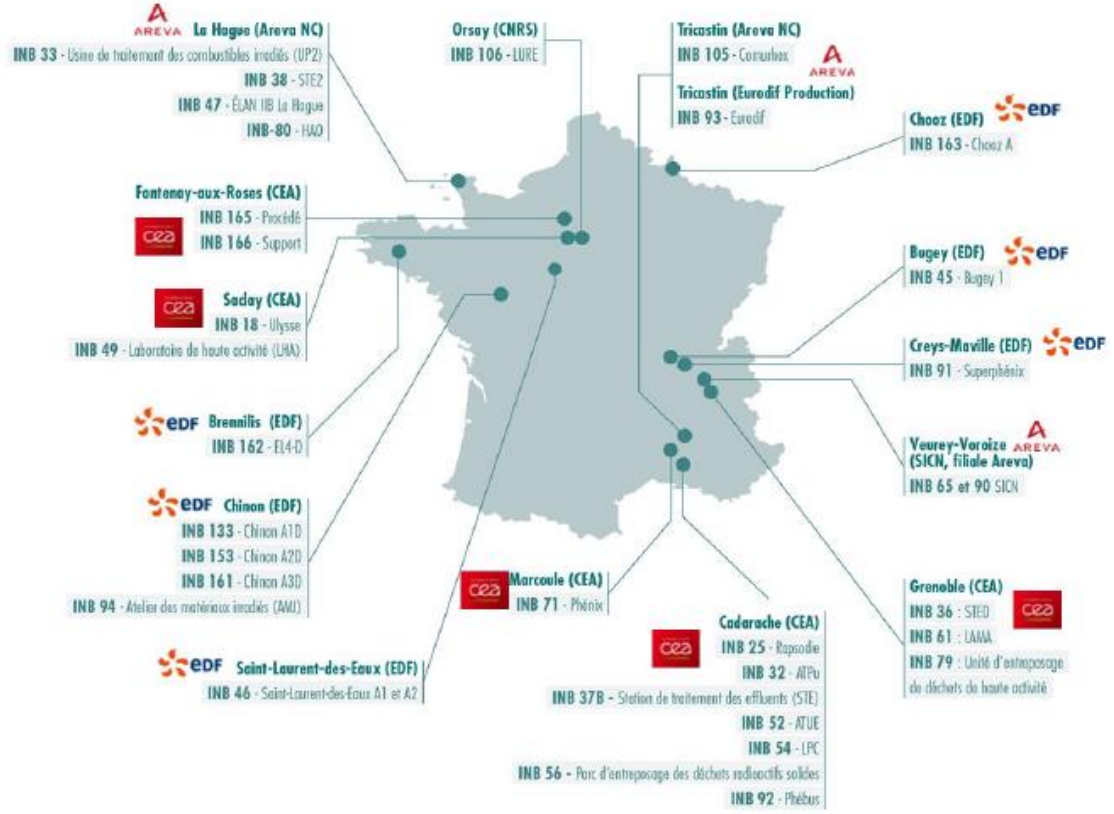
Introduction to French nuclear decommissioning experience

Overview of the French nuclear sites under decommissioning



- *A strong experience in Decommissioning and Dismantling, and radioactive waste management*
- *A massive D&D Program to manage diverse, complex issues (waste retrieval, ponds, silos, hot cells, sodium treatment, concrete buildings, process equipment, …) in high radioactive environment*

Introduction to French nuclear decommissioning experience

- *French nuclear operators are responsible all along the nuclear lifecycle (from design, construction, operation, dismantling, waste management)*
- *French regulatory framework requires decommissioning to be completed as soon as possible with 3 priorities :*
  - *Facilities safety*
  - *Workers safety*
  - *Environmental protection*
- *Operators are responsible for technical and financial decommissioning operations*
  - *Dedicated financing is placed under French State control*

French experience in Sodium fast reactors decommissioning

Three sodium fast reactors currently under decommissioning in France

RAPSODIE (CEA/Cadarache)

- **1967-1982**
- 24 to 40 MWth
- 37 tNa in primary circuit, 22 tNa in cooling circuits

PHENIX (CEA/Marcoule)

- **1973-2009**
- 250 MWe
- 1 500 tNa

SUPERPHENIX (EDF/Creys-Malville)

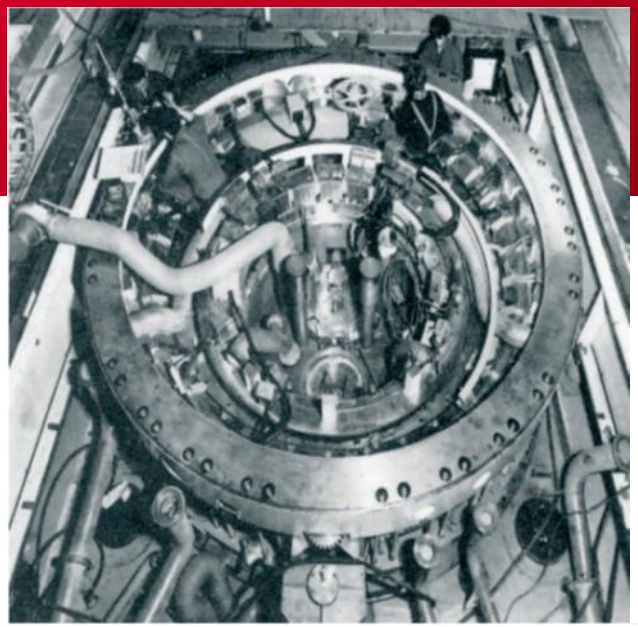
- **1985-1997**
- 1 200 MWe
- 5 500 tNa

RAPSODIE

RAPSODIE (CEA/Cadarache)

- First divergence on 28 January 1967 (50 years ago)
- Loop design with two cooling circuits
- Final shutdown on 15 April 1983
  - Unloading and removal of fuel, draining of primary and cooling sodium circuits in 1983,
  - treatment of primary sodium in the DESORA facility by the NOAH process in 1994,

- In March 1994, an accident occurred during the cleaning of a residual Na contained in a tank, caused by a sodium - ethylcarbitol reaction. Consequently:
  - the damaged building was rebuild from 1998 to 2003
  - and the use of **heavy alcohol** was definitively forbidden
- Since 2004, work has been underway to restore facility compliance, to disassemble all equipment not required for operation, and to collect and remove waste
- In 2008 and then in 2014: Request for ASN's decommission authorization with submission final shutdown and dismantling file
  - Following the examination of the 2008 dismantling file by the relevant authorities: Implementation of the recommendations
  - Examination of the 2014 version is underway.



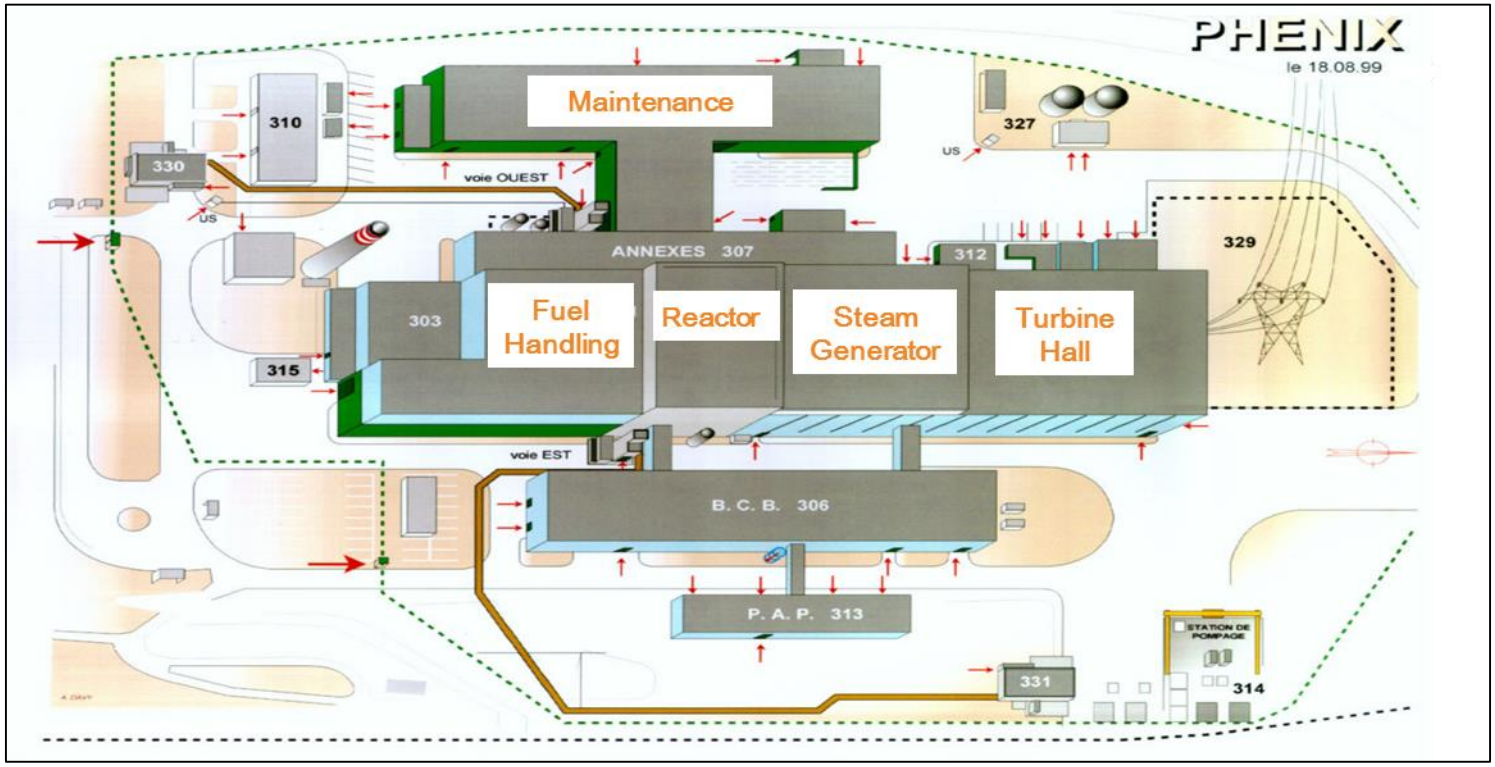
Unloading of the core and removal of the fuel

- **Next actions to be carried out as February 2017 (within 5 years):**
  - Shipment of the sodium waste (type 1 & 2) to Phenix : end 2016 (done)
  - Completion of the dismantling of the hot cell (LDAC) by 2018
  - Shipment of the sodium waste (type 3, 4 & 5) to Phenix by end 2018
  - Study on the removal of the sodium remaining in the facility (2017)
  - New decree to allow the final dismantling: expected in 2019
  - Removal of the residual sodium present in the vessel. Estimated time to completion: 5,5 y
- **Final operations**
  - Clean-up of the buildings after the removal of the sodium in the vessel (9 years)
  - Dismantling of the block reactor and clean-up of the reactor building (15 years)
  - Buildings cleaned but **not demolished** (free for use)

PHENIX

PHENIX (CEA/Marcoule)

- In operation from 1974 to 2009
- Pool type with 3 secondary loops
- Dismantling operated by CEA, with EDF and AREVA



PHENIX

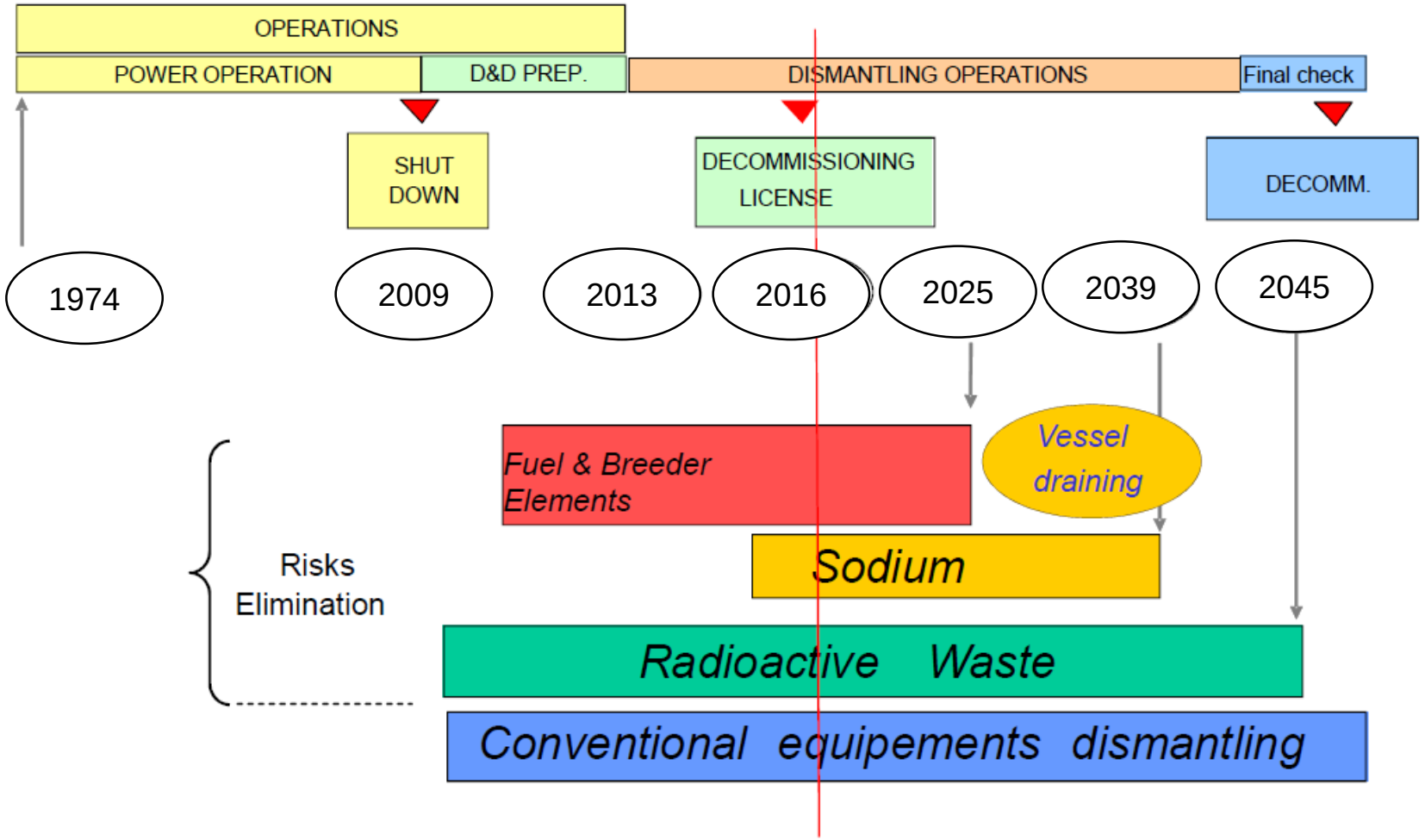
Main goals

- According to the French Safety Authorities, the objective is to start immediately and to **achieve as soon as possible decommissioning operations.**
- Final status
  - Decommissioning , declassification as non nuclear areas, buildings cleaned but not demolished (free for use),
  - Sodium neutralization,
  - Treatment of sodium contaminated materials

Regulatory points

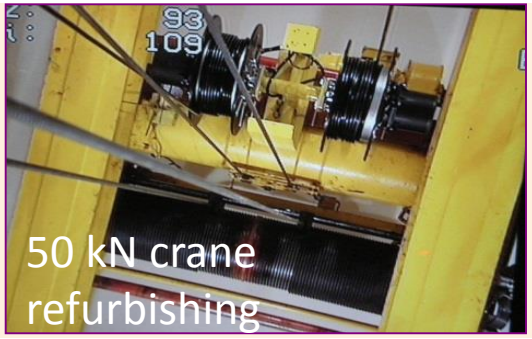
- 2008 to 2011 : discussions with Safety Authority on the PHENIX D&D
- End of 2011: Safety report sent to the Safety Authority to apply for the decommissioning license
- July 2013 to April 2014: **Instruction phase** by the TSO (IRSN): 20 meetings with IRSN and 400 questions
- June to September 2014: **Public inquiry**
- **June 2016: Decommissioning license obtained**

PHENIX : Main steps



PHENIX : Some major achieved operations

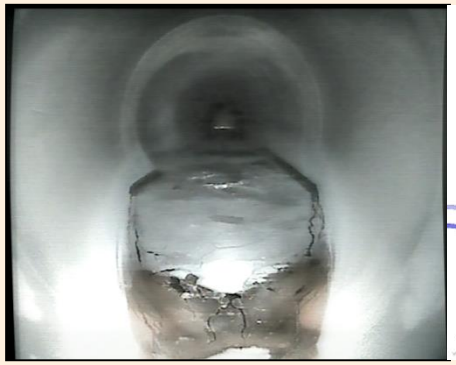
Turbin hall dismantling

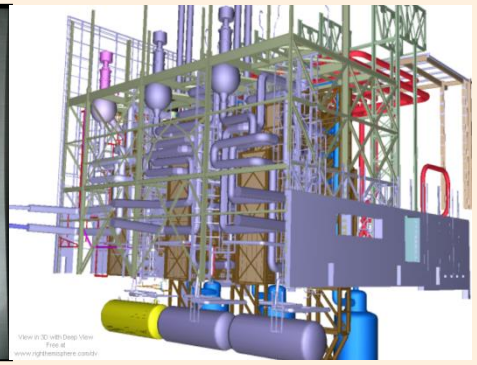


50 kN crane refurbishing

Sodium heaters

Secondary loops draining





Large components dismantling (pumps and heat exchangers)

PHENIX : Decommissioning strategy

Program : 2015 - 2045

- Refurbish the fuel processing line (47 equipment)
- Improve the defueling time

Mid-term main goals

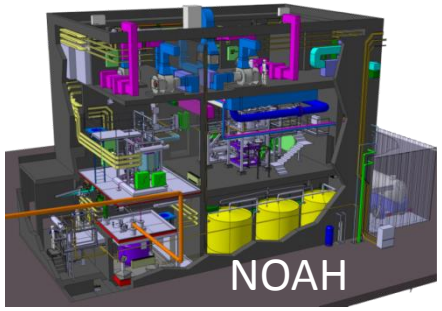
- Risk reduction
  - Activity reduction
  - Sodium processing
- Operating costs reduction
- Prepare the sodium and waste treatment

- **Evacuate spent fuel and large components**
- **Drain and neutralize sodium**

ELA

Build the dedicated facilities:

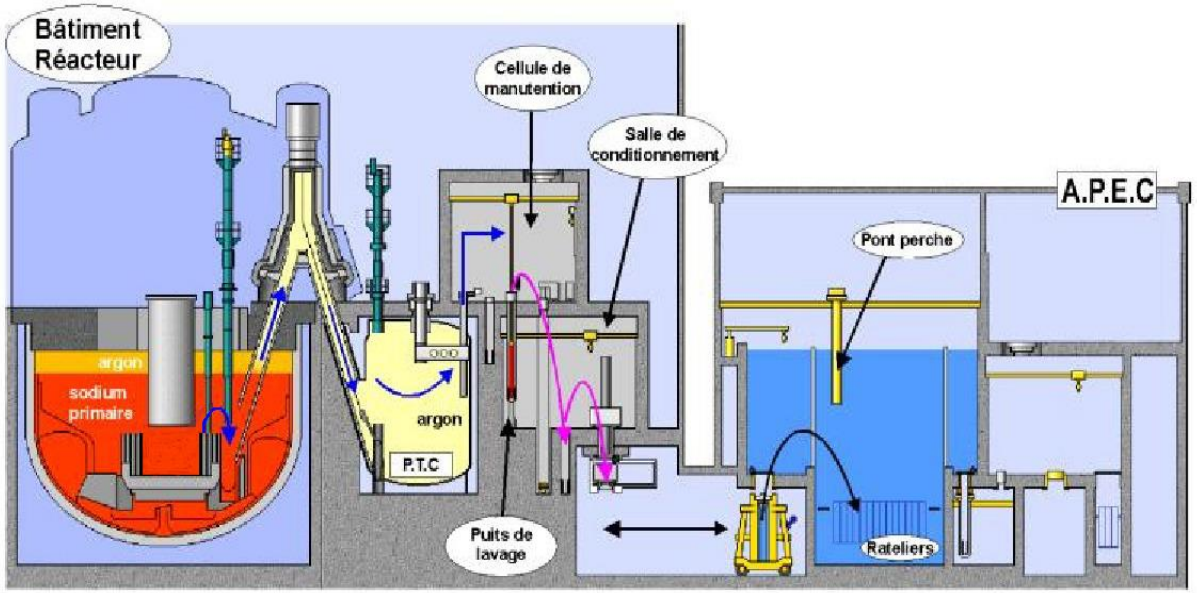
- **NOAH** (Sodium neutralization)
- **ELA** (Objects soiled by Na washing)
- INES (Soda neutralization)
- EROS (Storage of objects with sodium)
- IVAN-ICARE (Pumping and carbonation for Na capacities)



SUPERPHENIX

SUPERPHENIX (EDF/Creys-Malville)

- In operation from 1986 to 1997
- Pool type with 4 secondary loops
- Dismantling operated by EDF, with AREVA



SUPERPHENIX - Decommissioning scenario

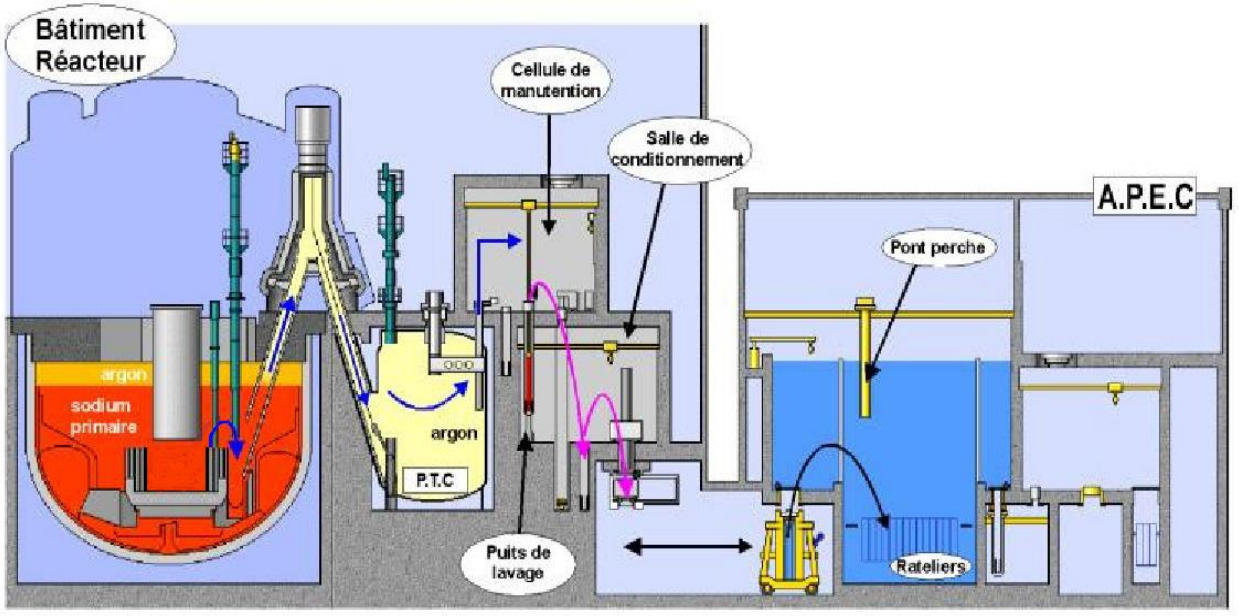
Decommissioning started in 1999

- Phase 1: Evacuation of the core and of all the lateral neutron shielding
- Phase 2: Evacuation, treatment and cutting of all the reactor vessel removable components
- Phase 3: Drained sodium destruction
- Phase 4: Cleaning and dismantling the sodium circuits (secondary and auxiliary circuits)
- Phase 5: Preparation of the main vessel carbonation and filling-in with water, and realization of these two operations
- Phase 6: Dismantling the reactor inner structures and the vessel
- Phase 7: End of dismantling operations: Radioactive disposal of premises and Buildings demolition

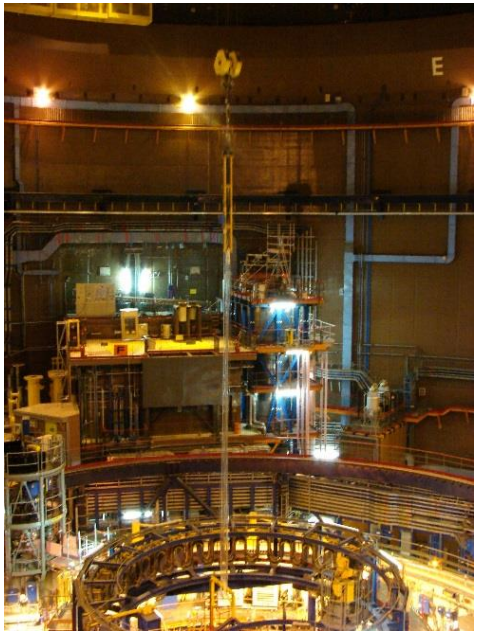
→ Estimated end: **2025 / 2030**

SUPERPHENIX - Decommissioning scenario

Phase 1: Evacuation of the core and of all the lateral neutron shielding



Evacuation of the fuel elements



Special equipment built for extraction of 82 non accessible lateral neutron shielding (14m long)

SUPERPHENIX - Decommissioning scenario

Phase 3: Drained sodium destruction

Sodium is transformed into sodium hydroxide.

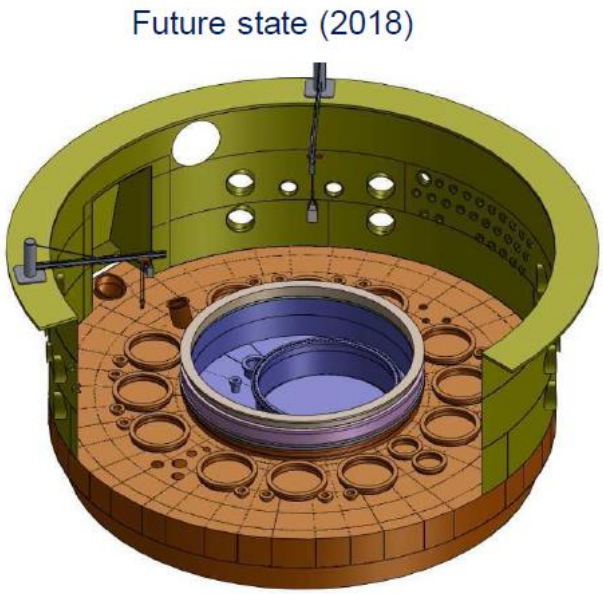
Built Facility: Reaction vessel producing sodium hydroxide from primary and secondary sodium and a water supply (NOAH process).

Then a concrete-making facility used this sodium hydroxide to produce concrete blocks (2 tons each).

Nearly 45,800 concrete blocks are thus stored in a 140×31-meter building, on 14 layers (about 14 meters high) as on-site interim storage.

SUPERPHENIX - Decommissioning scenario

Phase 5 : Preparation of the main vessel carbonation and filling-in with water, and realization of these two operations

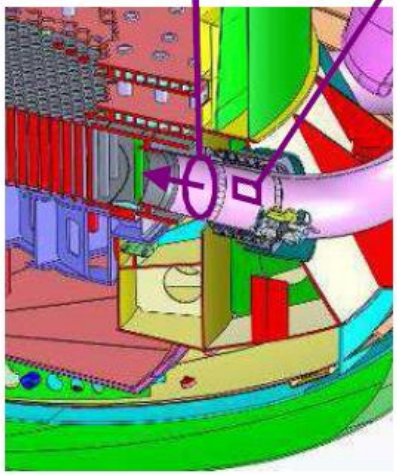


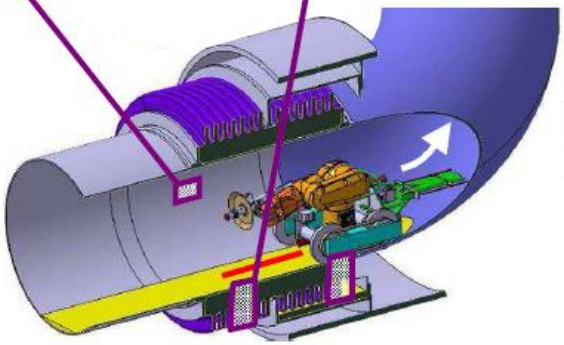
The CO_2 carbonation has started in November 2016.

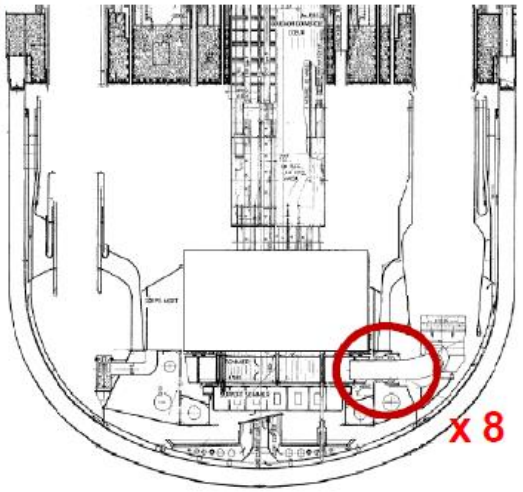
In 2017, all the residual sodium of the vessel will be eliminated with water (by filling-in the reactor by water).

SUPERPHENIX - An example of specific tools developed to treat sodium retentions (laser cutting)

First cutting







NOAH PROCESS

- **Process developed at CEA (1985-1989) and used to treat drainable sodium at industrial scale, in collaboration with AREVA :**

	Years	Flowrate	Mass
Rapsodie (Fr)	1993 - 1994	1 * 40 kg. h^{-1}	37 t
PFR (Dounreay – UK)	2004 - 2008	1 * 100 kg. h^{-1}	1500 t
SPX (Fr)	2011 - 2014	2 * 120 kg. h^{-1}	5500 t
PX	Years to come	1 * 120 kg. h^{-1}	1500 t

- **Based on a continuous reaction between liquid sodium and water of an aqueous solution of NaOH injected through spraying nozzles (10N, Countercurrent)**

$$Na_{liq} + H_2O_{liq} \rightarrow NaOH_{Aq} + \tfrac{1}{2} H_{2\,gas}$$

- **Management of final liquid effluents depends of project :**
  - From soda to concrete (SUPERPHENIX)
  - Recycled to La Hague reprocessing plant (RAPSODIE)
  - Neutralization, effluent and waste treatment facility (PFR, PHENIX)

Some lessons learned from French experiences

Fuel unloading

PHENIX	SUPERPHENIX
Fuel unloading in progress : • 30 sub-assemblies discharged and sent to AREVA/La Hague • 250 will be discharged before 2025	All Sub-assemblies were discharged: • 368 fuel sub-assemblies • 229 fertile assemblies • 50 absorbent assemblies The overall operations lasted 3,5 years
• Failure on the handling crane of the main hot cell. It needed 4 years to replace the crane and to obtain authorization to reuse the cell. • After this : Complete review of equipment and refurbishing of the sub-assemblies treatment line	• Drop of a fertile sub-assembly • Uncontrolled immersion of an absorbent subassembly • Overflow of Na into fuel transfer room

Some lessons learned from French experiences

Sodium treatment

PHENIX	SUPERPHENIX
• Na treatment by NOAH process • Soda used in effluent and waste treatment facility or treated by transformation to salt solution • Reject to the Rhone River, according to Phenix decommissioning license	• Sodium drained from primary and secondary circuits and transform to soda thanks to NOAH process • Soda mixed with Cement to make concrete blocks
• Noah building is currently being constructed	• New facility built, to treat sodium and soda, with calibration of injection pumps, and new modus operandi for the cementation
• Stabilization treatment of residual sodium in pipes and equipment after draining : ▪ Chemical treatment (Carbonatation and ricing) ▪ Conservation in an inert atmosphere (argon or nitrogen)	

Some lessons learned from French experiences

Reinforcing the relationship with safety authority

- Feedback of best practice approved, Safety cases analysis, Beforehand discussions

Waste management

- Inventory, characterization, treatment, available storage and disposal
- Environmental release : prediction and sampling results
- Treatment of sodium, soda and soiled equipment

Skills and competences

- Technical experts : developing durable specific skills (sodium, handling, safety, maintenance, waste management)
- Reinforcement of project management

Availability of funding throughout the dismantling operations

Reduce cost and delay, by operational control, optimization and use of innovative solutions and digital transition

Promote socio-economic impact on local communities **and inform regularly the population** for a better public acceptance

CONCLUSION

- *France has a huge experience in decommissioning of Sodium Fast Reactors*
- *AREVA, EDF and CEA wish to share their competences and experiences with Japan, in all the fields related to SFR decommissioning (dismantling, sodium treatment, safety, engineering, spent fuel reprocessing, new buildings, waste management, operation of facilities)*

Thank you for your attention

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Back-up

PHENIX : Decommissioning scenario