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Challenges and Innovative Technologies On Fuel Handling Systems for Future Sodium Cooled Fast Reactors

M.Chassignet AREVA NP

G.Prele EDF-R&D

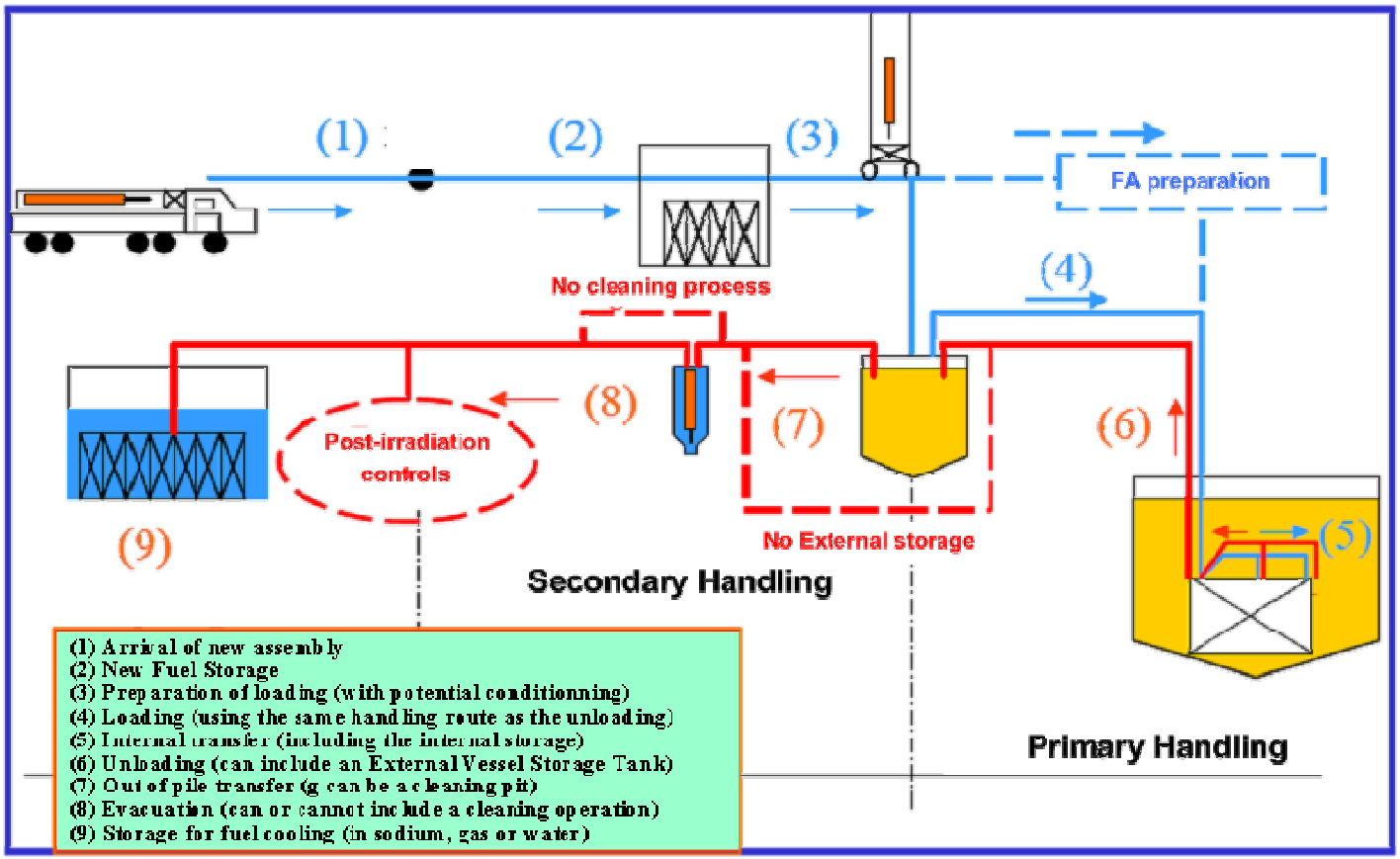
G.Rodriguez CEA Cadarache

Outline

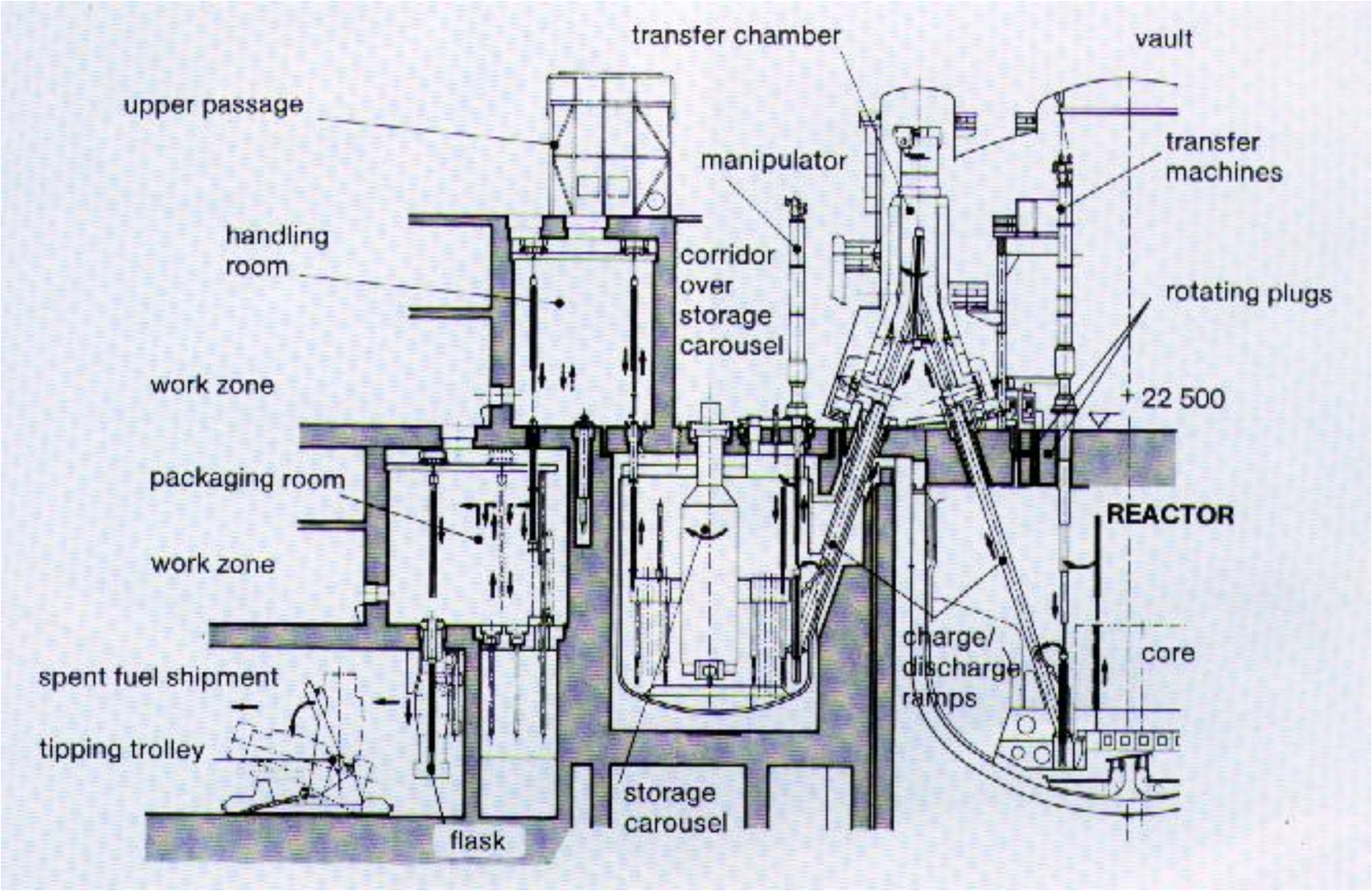
- General description & objectives of FHS for FBR
- Review of French FHS
  - Superphenix (sodium route)
  - EFR (gas route)
- Challenges and current works on French SFR project
  - Reduce of investments costs
  - Reduce of impact of refueling operations on scheduled outages
  - Fast Whole Core Discharge
  - Pooling of FHS
  - Research on fuel assembly cleaning process
  - Assessment of minor actinides impact on FHS design
  - Assessment of alternative solutions for FHS
- Synthesis and future works

Objectives of FHS in a FBR

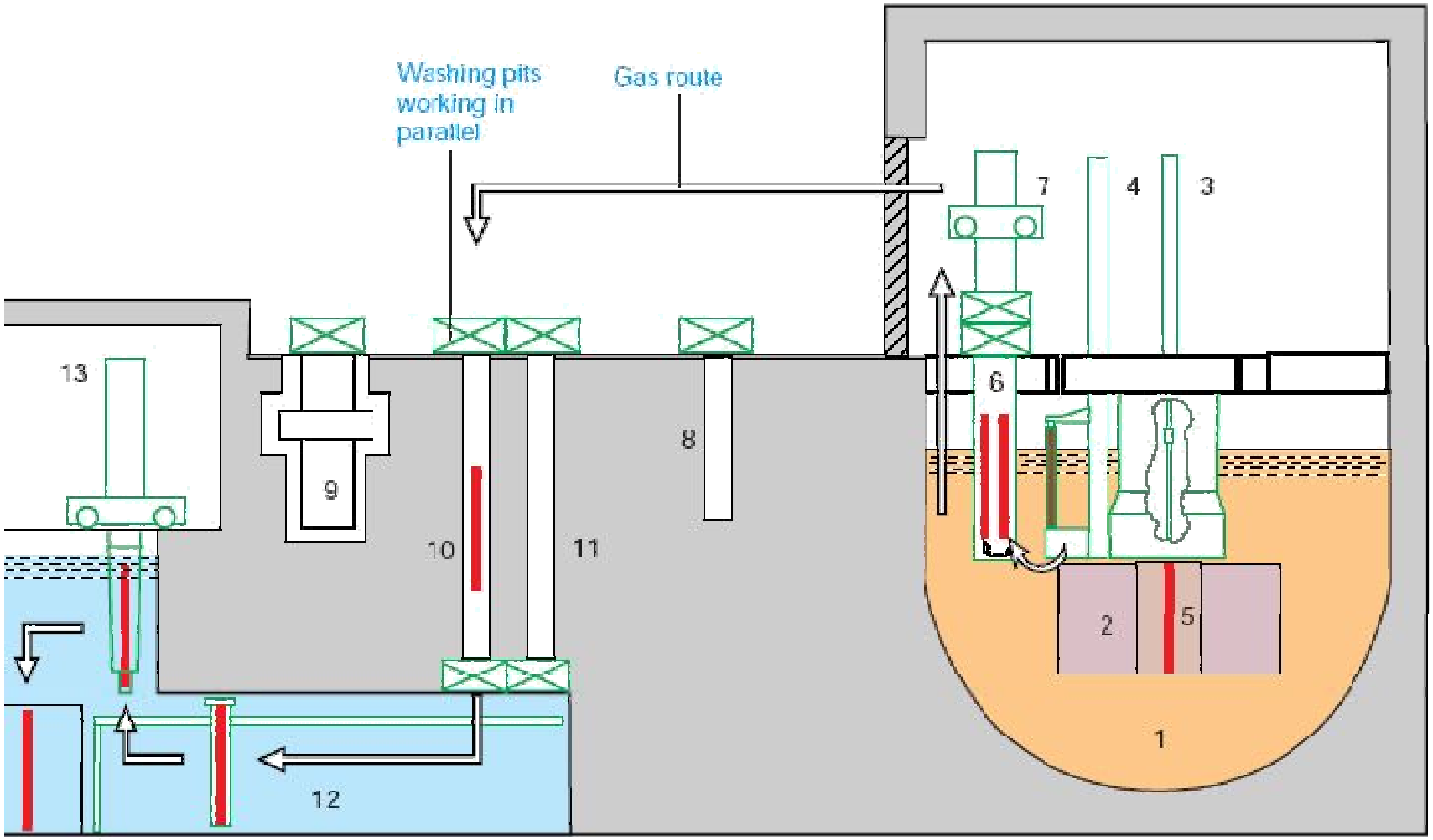
- **Reactor refueling system provides the means of transporting, storing and handling for reactor core assemblies, including fuel, blanket, control, and shielding elements**
- **FHS have to fulfill the following tasks :**

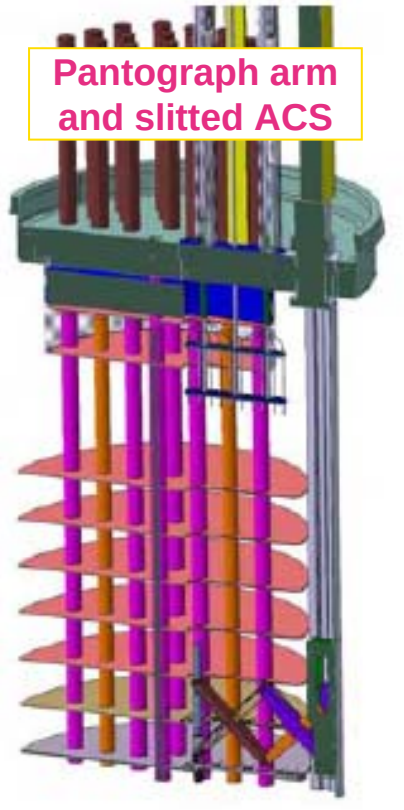


Superphenix
Example of French sodium route



EFR project
Example of French gas route

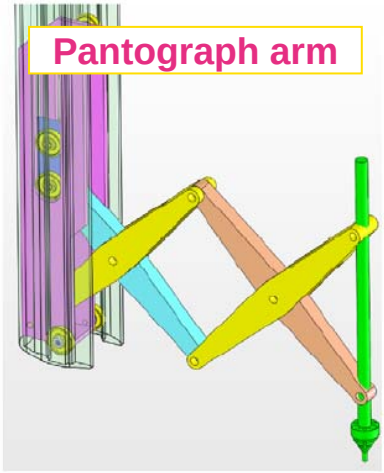




Reduce of investments costs

- A specific tool has been developed which objective is to find out the optimal rotating plugs diameters of different types of IVFH systems

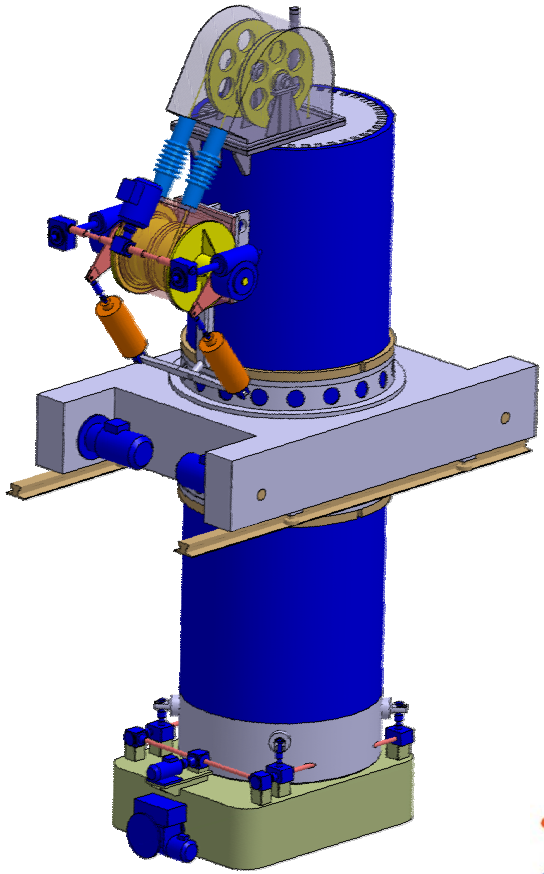
- From the viewpoints of primary vessel diameter optimization, two concepts reveal to be very interesting
  - 1) Two rotating plugs, a FACM in the LRP and a DLCM in the SRP
  - 2) One rotating plug and a slitted ACS with pantograph type FHM



- Design of a pantograph and slitted ACS has been performed
  - Pantograph arm with double scissors
  - Telescopic device for temperature monitoring of FA below slit
  - Compact and safe design

Reduce impact of refuelling operations on scheduled outages

- **Some tracks have been investigated aiming at reducing impact of refueling operations on scheduled outages duration :**
  - **Reduce unavailability time of refueling operations**
  - **To improve performances of FHS**
  - **To handle fuel assemblies with high residual power**
- **The sodium flask design is based on operating feedback from previous studies :**
  - **SPX's A Frame for sodium bucket**
  - **EFR's gas flask for design of the flask body and trolley**
- **This system allows handling in sodium of fuel assemblies with residual power of about 35-40kW**



Sodium flask proposed design

Fast whole core discharge
External Vessel Storage Tank

- **A Whole Core Discharge is an exceptional event which can be considered necessary in view of a comprehensive reactor inspection**

- **Not considered in normal outages plans, WCD could direct choices on FHS**
  - **Sodium route is the preferred solution for fast whole core discharge**
  - **Duration of a WCD has to be about 1 to 3 months**

- **Design of External Vessel Storage Tank**
  - **Filled with sodium (400m³)**
  - **800 storage positions in less than 8 meters**
  - **Total inspection is possible and all components are easy to maintain**

- **Final decision concerning context of WCD will include other considerations, such as global economy and safety optimizations**

External Vessel Storage Tank

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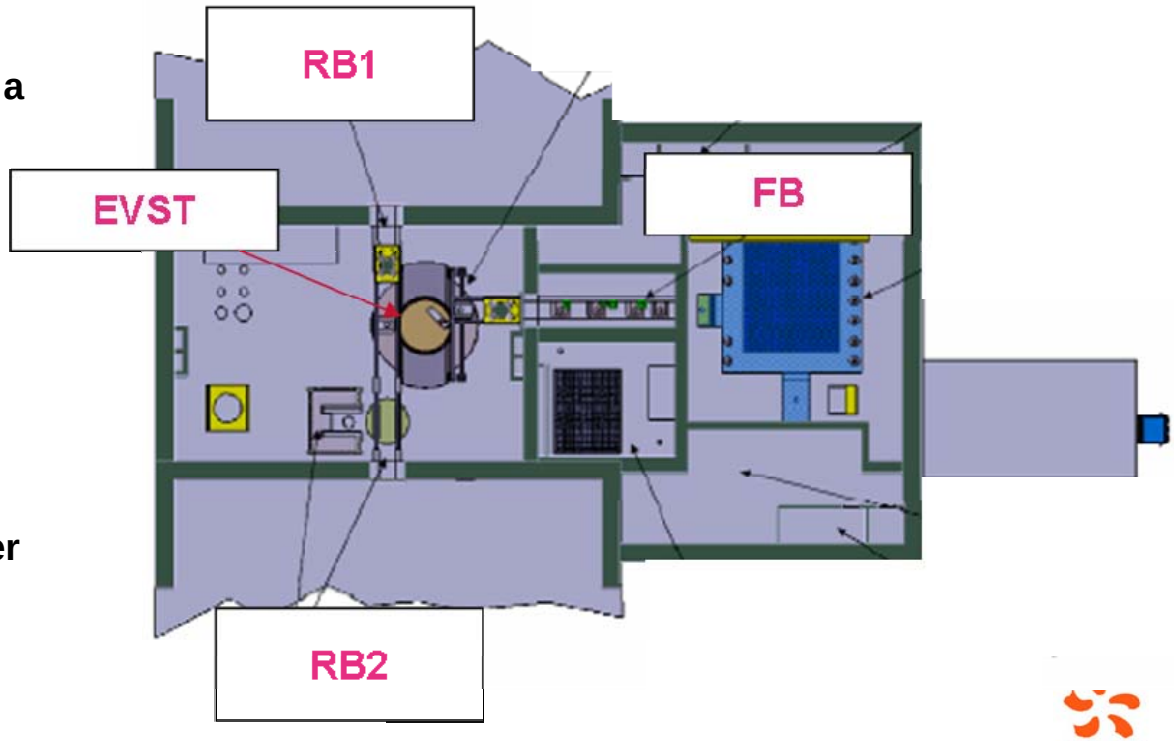
Pooling of FHS

- Pooling of FHS has been investigated in case of two units
- All FH equipments are located in a dedicated building
  - EVST
  - Fuel Pool
  - New Fuel Storage
  - New Fuel Examination and Receipt Facility
  - Washing pits
- A sodium flask allows the transfer of assemblies from the primary vessel to the EVST
- A gas flask allows the transfer of assemblies from the EVST to the cleaning equipments or the new fuel handling route



Pooling of FHS in two units

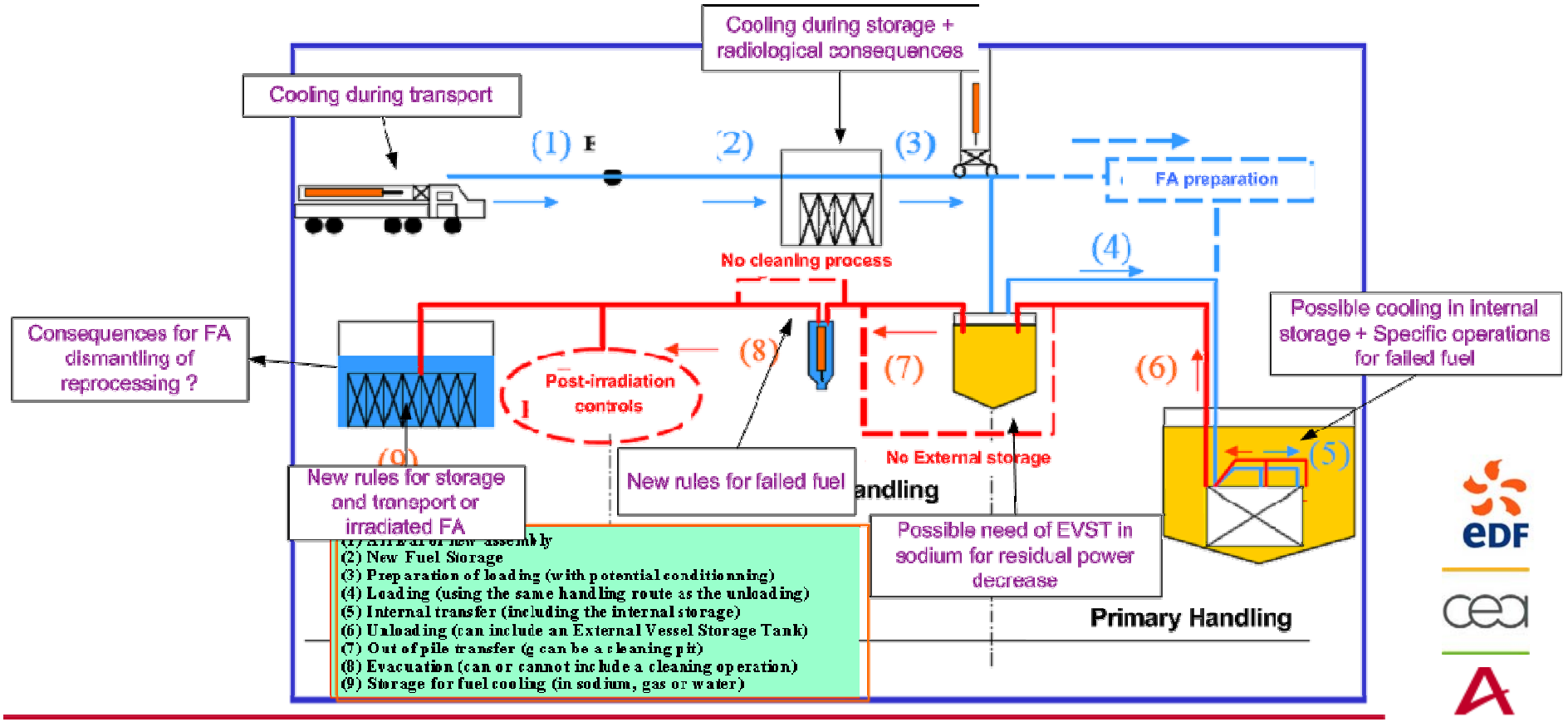
Research on fuel assembly cleaning process

- **CEA is working on improving the cleaning process for fuel assemblies with a fast immersion in a saline solution or in a sodium hydroxide solution**
  - **Objective : Quickly and safely remove of sodium with concentrated alkaline solution instead of pure water**
  - **Principle : Basis on the NOAH process**
- **First series of tests were done on small amount of sodium**
  - **Selection of most appropriate salt**
  - **Additional tests will be carried out in coming years**
- **Considering French experimental feedback analysis, several improvements could provide benefits on the load factor :**
  - **Potential advantages on hot drainage with inert gas blowing prior to cleaning => reducing sodium residual inventory**
  - **Integration of the experimental feedback of the PX and SPX cleaning processes => design of efficient and improved washing pit,**
  - **Validation at industrial scale of a quick immersion cleaning process => possible cleaning of FAs with high residual power by reducing the time for cleaning**

Kinetic experiment of sodium in alkaline solution

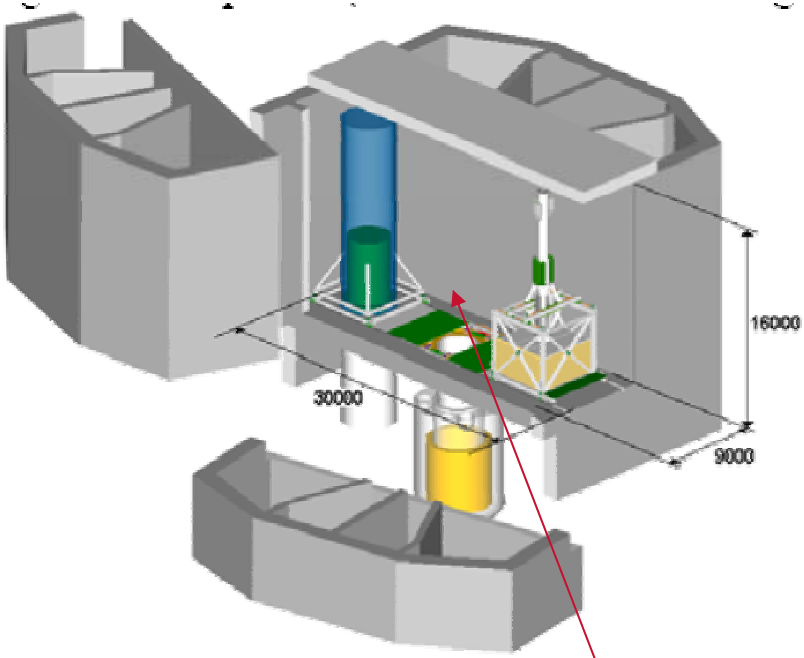
Assessment of minor actinides impact on FHS design

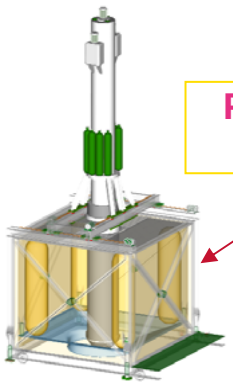
- **Fuel assemblies with minor actinides have different consequences following the recycling mode**
- **Whatever the considered recycling mode, MA have important consequences on transport and new fuel handling systems**



Assessment of alternative solutions for FHS

- **eDF has investigated an handling system in a cell with three ways of improvement :**
  - **Simplify fuel handling systems**
  - **Improve access for inspection of internal structures**
  - **Avoid problems of core compaction by introducing the ACS in the core**
- **Main principles of the concept :**
  - **Access to fuel assemblies is possible following removal of ACS during outages**
  - **Handling of fuel is performed in gas with a dedicated machine**
- **Due to technological difficulties it was decided not to pursue this solution**





Synthesis and future works

- **Fuel handling is a very important part in the design of a FBR because of its many stakes**

- **The design of FHS must be considered at the early stage to take into account several parameters such as:**
  - Reactor design and the choice between loop or pool type reactor
  - Core design and its policy in terms of breeding ratio, minor actinides burning, etc…
  - Size of the reactor: large scale or modular medium size scale reactors, and its purpose: irradiation, prototype, power
  - Targeted availability factor identified for the reactor
  - Safety requirements

- **Progress on R&D and engineering fields will orientate and provide a more accurate definition of the definitive Fuel Handling System for French SFR linked with the reactor and core concept.**

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Thank you for your attention !