Challenges and R&D program for improving inspection of sodium cooled fast reactors and systems

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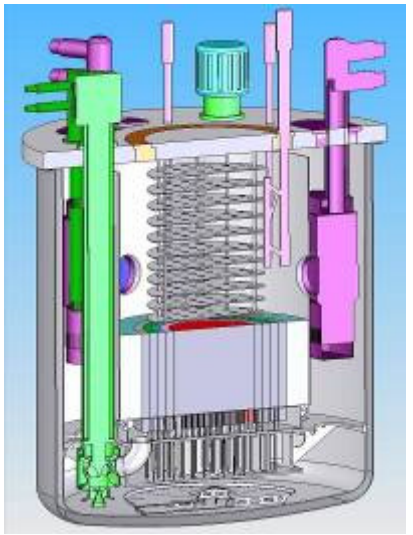
Objectives for In Service Inspection & Repair of Sodium fast Reactors

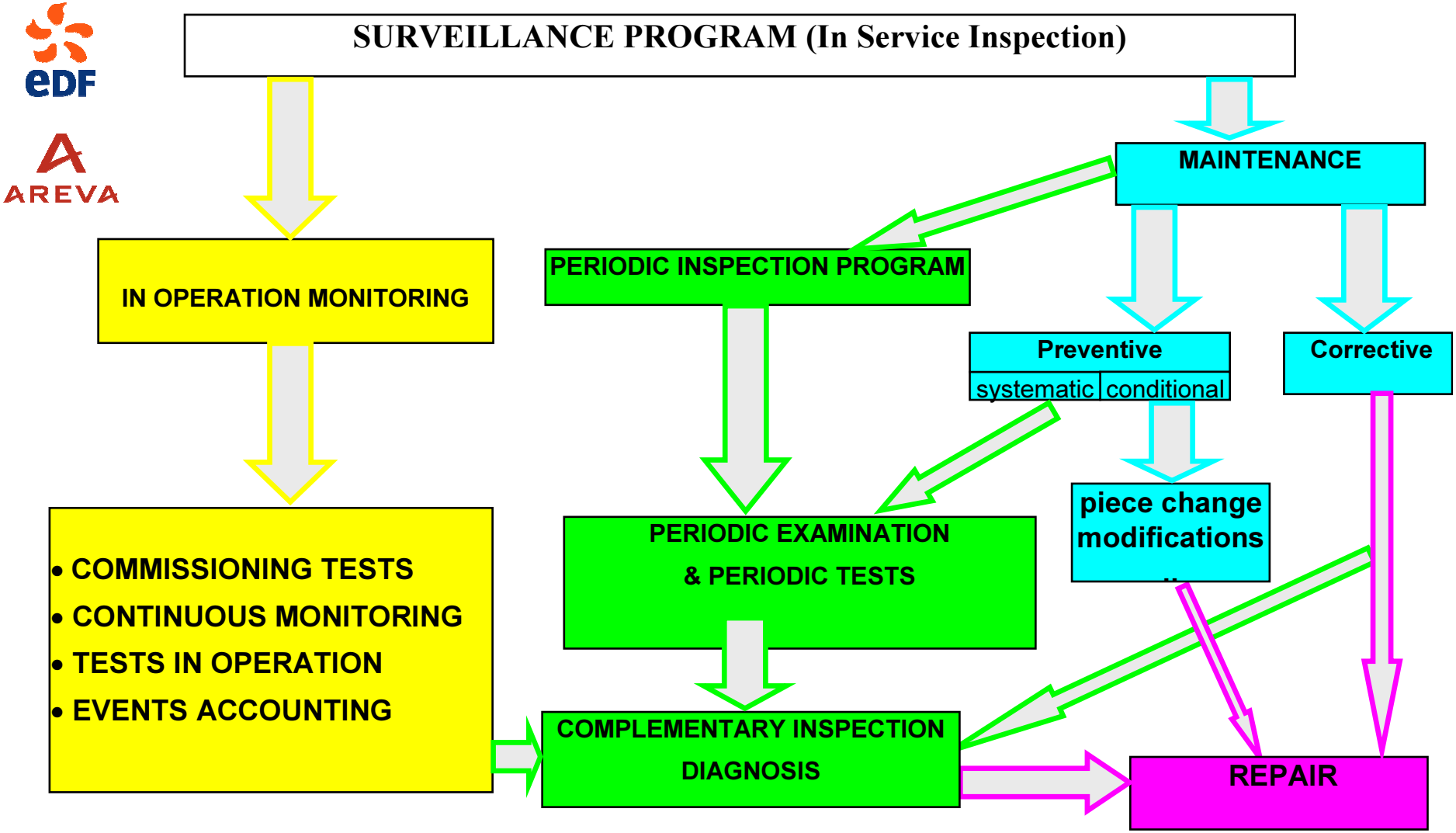
A tripartite project



- **Contribution for improvement of :**
  - **Safety,**
  - **Reliability,**
  - **Availability,**
  - **Lowering of operating costs,**
  - **Preservation of the investment.**

- **Thanks to :**
  - **Continuous monitoring, by diversified means, of all operating parameters,**
  - **Inspectability for all structures,**
  - **Possibility to identify all potentially damaged zones, with specific inspection program,**
  - **Possibility for repair or replacement, in case of structure failing,**
  - **Simplicity, rapidity for bringing interventions into operation, and efficency.**

NPP In Service Inspection and Repair ? … the general view



In Service Inspection and Repair ? … a simpler view

» ISI & R

» In Service Inspection & Repair

In operation monitoring

Complementary operations

» Continuous Monitoring

. Operating parameters at partial or nominal power

. Detection of deviations

» Periodic Inspection

. Periodic tests

. Periodic examinations

during normal shut-down periods

» Comple-mentary Inspection

And if necessary :

. Defuelling

. Sodium draining

At shut down conditions

» Repair

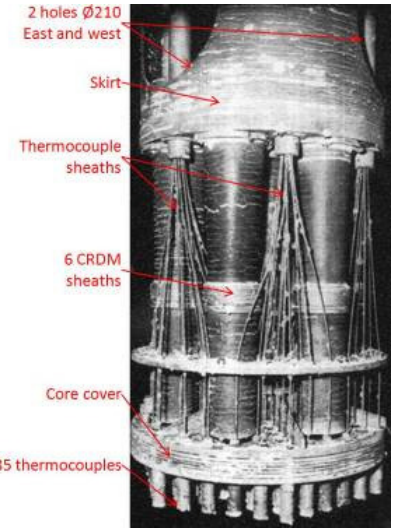
At shut down conditions

Experimental feedback from French SFRs : ISI&R point of view 1/3

RAPSODIE
1967 - 1983

***40 MWth**, No Steam Generators*

Mainly dedicated to core and fuel studies



ISI&R specific operation :
Replacement of Above Core Structure (1977)

6 m height, 4.5 tons weight, radiation source of several thousands of mGy/h

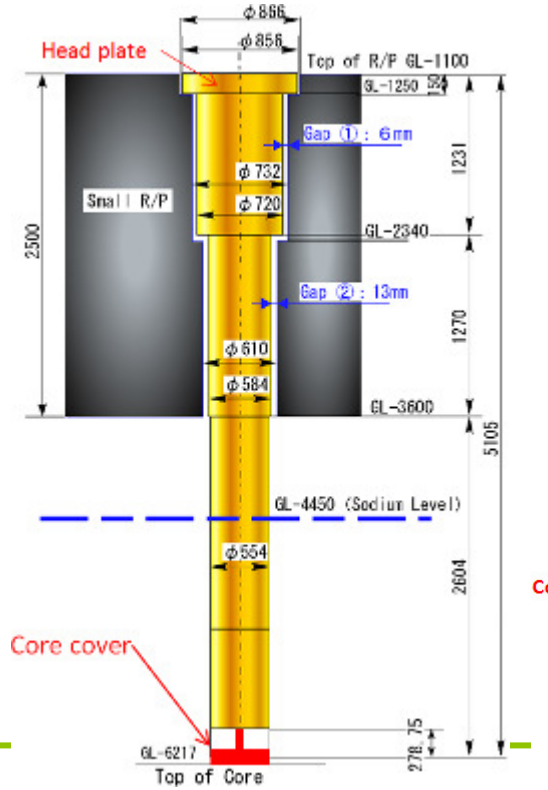
Specific experience of :

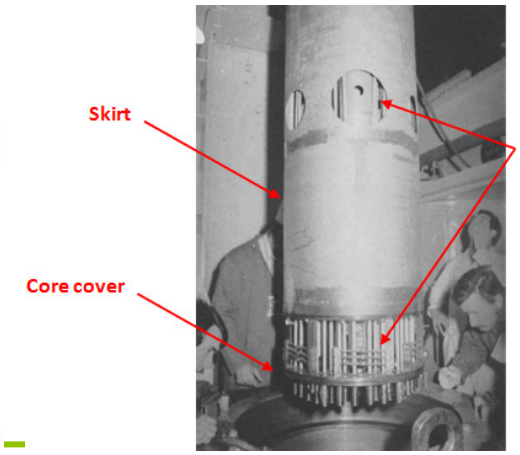
-Handling

-Radioprotection

-Contamination

-Sodium aerosols and deposits





Experimental feedback from French SFRs : ISI&R point of view 2/3

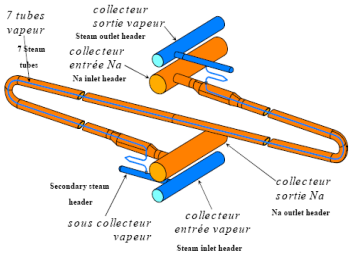
PHENIX
1973 - 2009

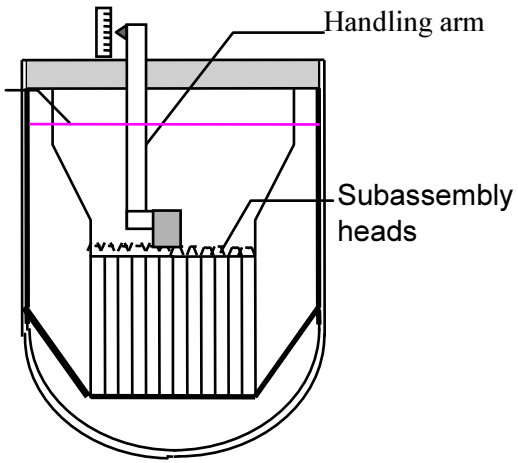
250 MWe, a large feedback experience : fuel, materials, closure of fuel cycle, technology (SGU, IHX), transmutation tests…
Demonstration of ISI&R possibilities

ISI&R recent progress :

1. ***Mechanical measurement of fuel assembly upper head altitude***
2. ***US Non Destructive Examination of core supporting shell***
3. ***Viewing of Fuel Assembly Heads and welding joins, after sodium partial draining***

And also : repair of SG modules, easy removing of large primary components…





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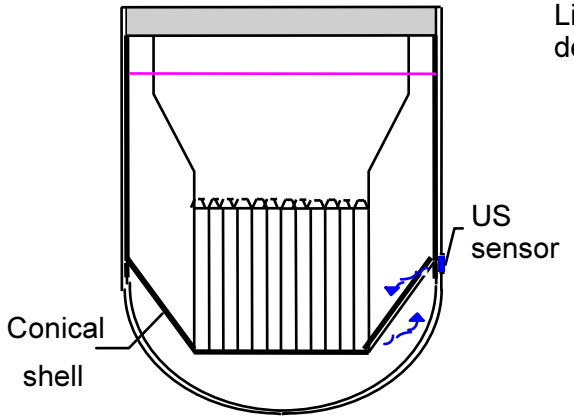

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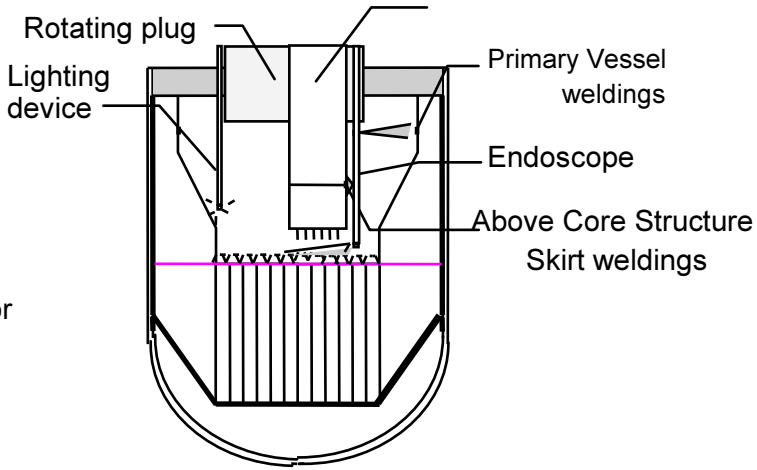


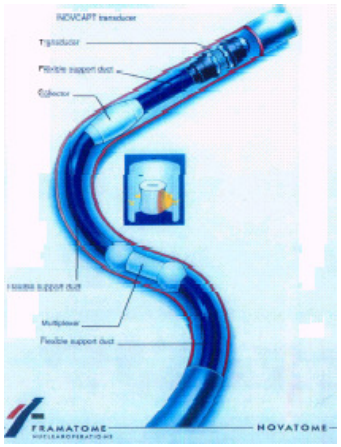
3.

Experimental feedback from French SFRs : ISI&R point of view 3/3

SUPERPHENIX

1985 - 1998

An industrial prototype
(1200 MWe, 5 500 t of sodium)



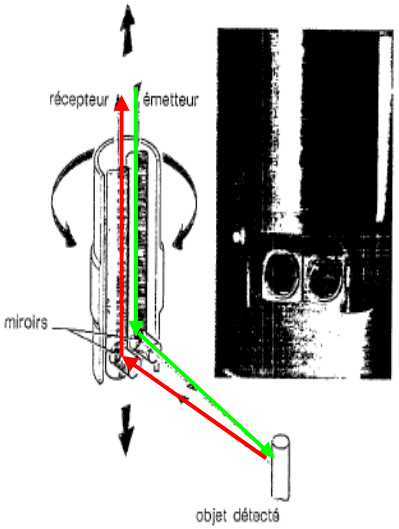
ISI&R specific operations :

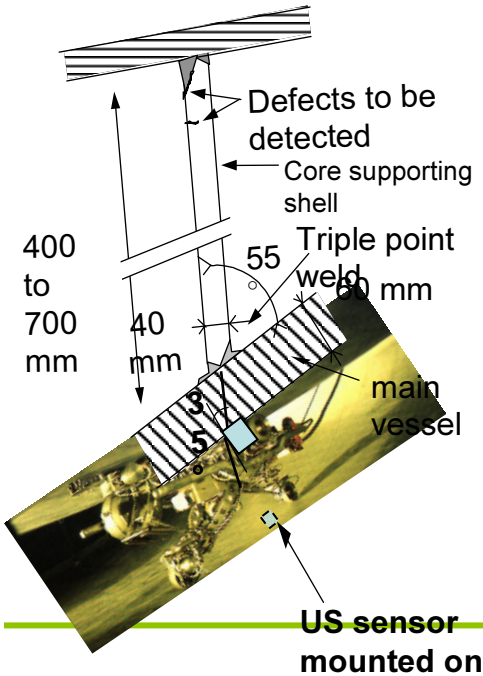
- ***US inspection of primary vessel (MIR machine)***
- ***US inspection of SGU tubes***
- ***US under sodium obstacle detection***

And also : complete replacement of intermediate fuel vessel, In situ repair of IHX (successfull but long)

But … some operations would have been difficult to be performed :

- ***Inspection of some primary structures (diagrid, cold plenum)***
- ***Handling of large primary component***

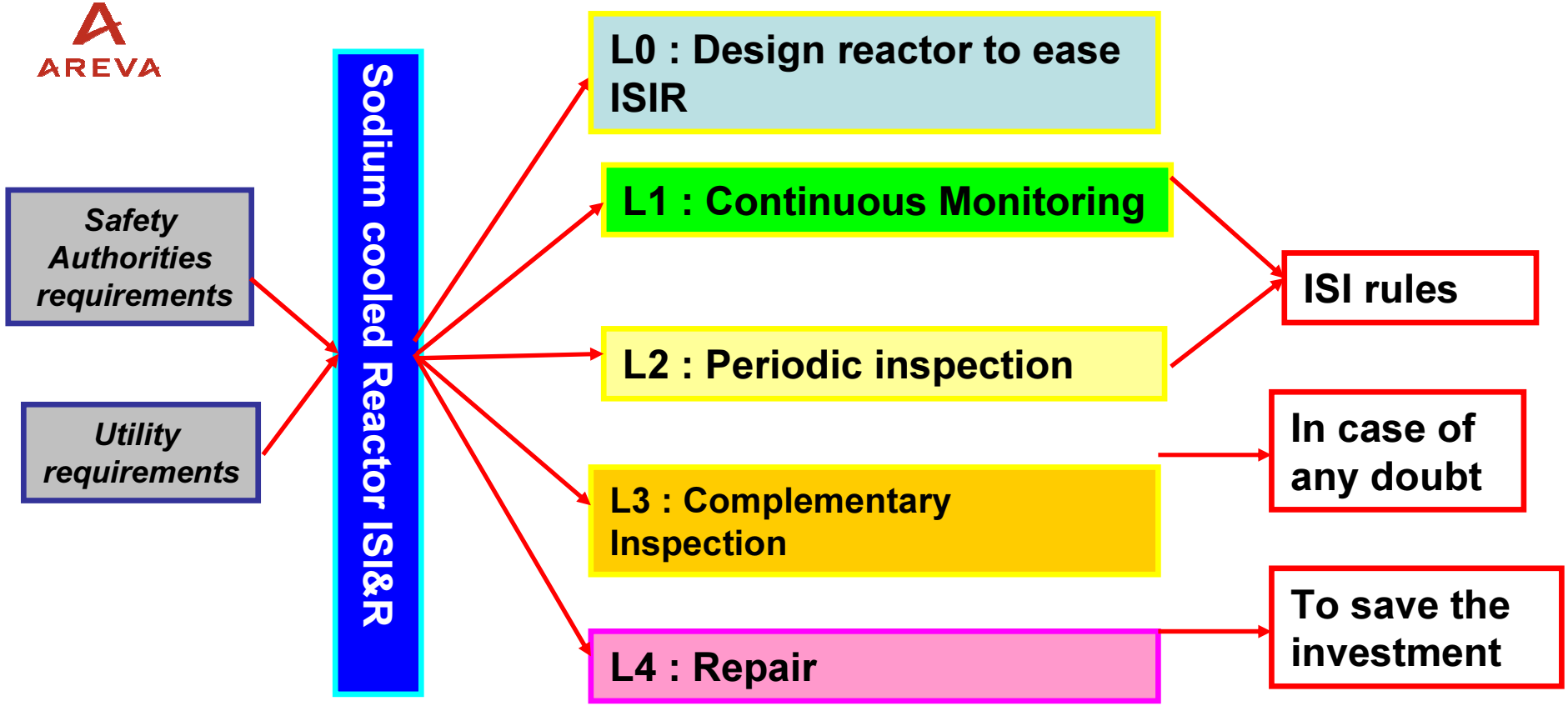




US sensor mounted on the MIR device

R&D ISI&R Program for future Sodium Fast Reactors
1. Improvement of primary system Conceptual Design

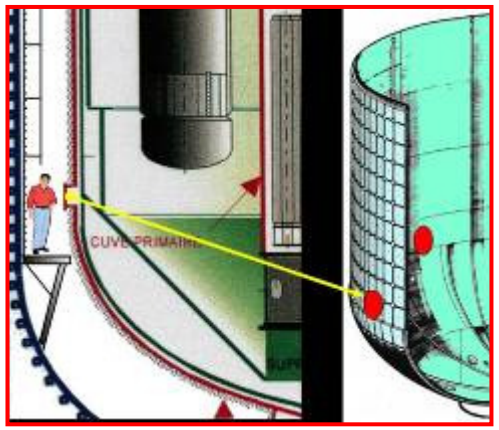
METHODOLOGY : organizing Engineering and R&D work

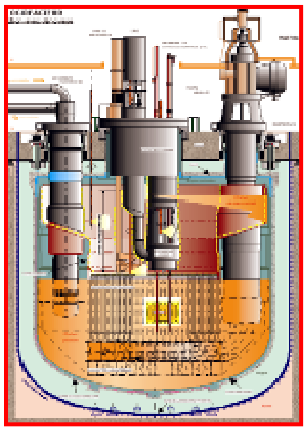


Compilation and analysis of feed back experience :

– Mastered Techniques vs identified gaps

- **Phénix (Fast removing of big components, Televisual inspection after sodium draining, Inspection of conical shell, VISUS, SONAR/ ISI&R was not planned at design phase)**
- **Superphénix (Machine for Reactor Inspection, US probes for SGU tubes / French Safety Requirements in 1992)**
- **Other reacteurs (Replacement of Rapsodie Control Plug / Inspections not planned at design phase)**





=> Definition of a strategy for ISI&R from early design phase and installation of a new methodology for future SFRs :

Looking after concepts making ISI&R easier :

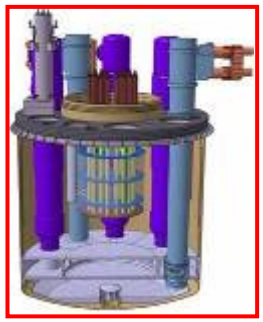
» Global Primary Loop

- **Design with increased accessibility**

No horizontal baffle

→ *Better Accessibility for the inspection of core supporting strutures*

- **Design with simplified internal structures**



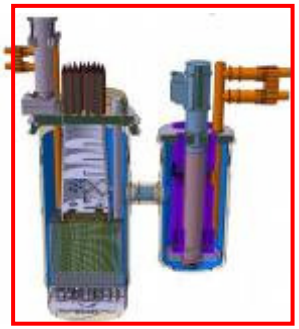
Simplified and fewer internal structures

→ *Lowering of the number of areas to be controled*

Better access

Easiness for in situ operations

- **Design with removable components**



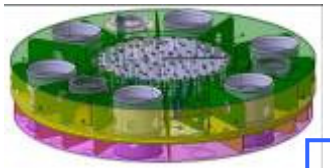
All components and structures : removable

→ *Increased possibilities for replacement of damaged component*

» Internal structures

- **« standard » optimisation of core supporting structures towards inspection**

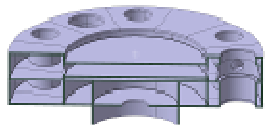
Optimisation of welding joint design and of acces

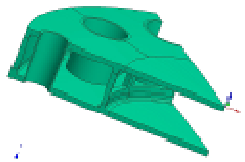


→ *Easier Periodical Inspection*

- **Specific Design of core supporting line**

Use of stronger structures and reduction of the number of welding joints





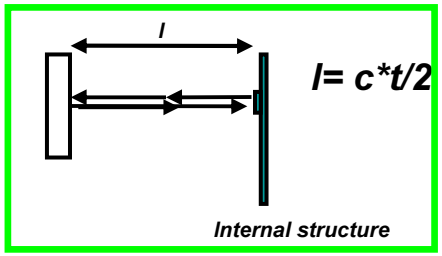
→ *Reduced Periodical Inspection*

- **Design study for simplification of big component removing operations**
- **Design study for Above Core Structure removing**

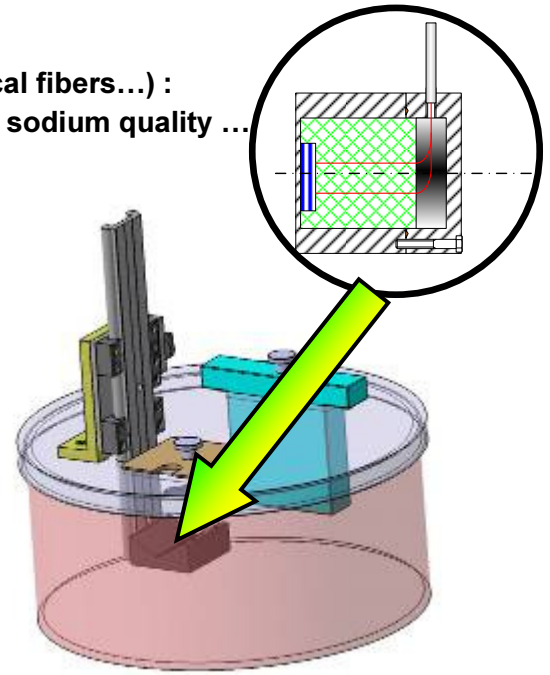
R&D running program (1/2) :

L1 Continuous Monitoring

Telemetry



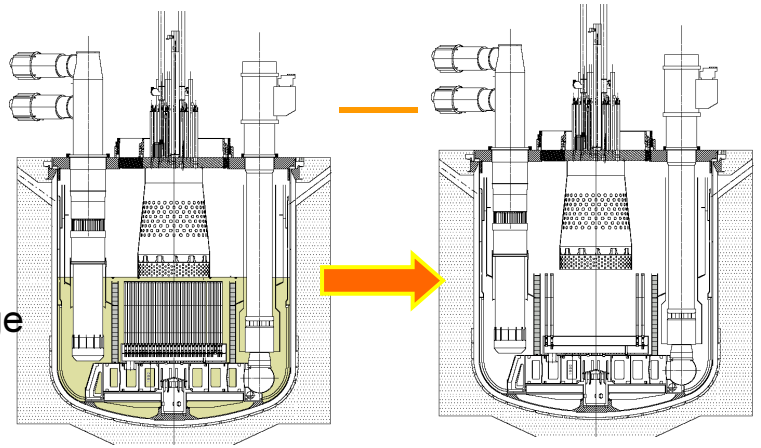
- **Surveillance of the core, of core supporting line and of internal structures**
  - Development of ultrasonic under sodium transducers at 550°C
  - Numerical modeling and simulation with CIVA code
- **Surveillance of internal structure vibrations**
  - Study of feasability for detection of acoustic signature variations
  - Analysis of various techniques for this détection (US, strain gauges)
- **Sodium leak detection**
  - Use and developt of qualified techniques (H2 detection) + in gas laser spectroscopy
  - New thermal insulation concept for pipes
- **Monotoring of operating parameters**
  - Looking after improvement of available techniques (ultrasonic, optical fibers…) :
    - Measurement of temperature, pressure, level, flowrate, speed, sodium quality …
    - Signal treatment
  - Innovating processes (ultrasonic, electromagnetic)
- **Measurement of gas into liquid sodium**



L2 Periodical Inspection

- **NDE of welding joints for core supporting structures**
  - Development of ultrasonic under sodium transducers at 200°C
  - Development of ultrasonic techniques from outside sodium medi
  - Numerical modeling and simulation with CIVA code
  - Development of lternative techniques such as EMAT
- **In sodium telemetry & surface metrology**
- **Need of under sodium robots**
  - R&D studies associated to L3 et L4 : see L4 program hereafter

R&D running program (2/2) :



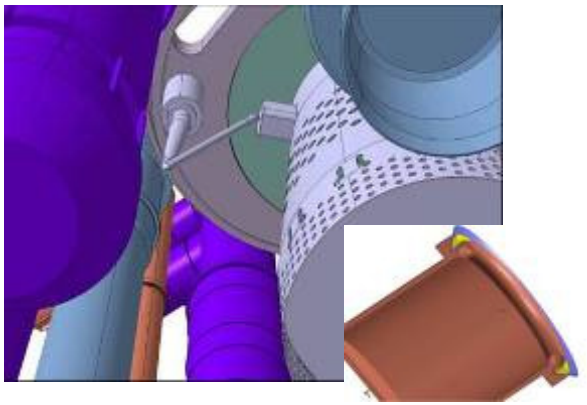
L3 Special Inspection

Study of a global intervention, with :

- **Defuelling :** see « Fuel Handling » studies
  - Need of in sodium handling with external storage
- **Sodium draining of reactor block :**
  - Analysis of needs ans associated durations
  - Need to prevent caustic corrosion
- **Televisual and volumetric inspection in radiating environment**
- **Sodium filling**
- **Refuelling**
  - Objective : duration for special inspection < 1 year

L4 Repair

- **Repair operations are done in gas atmosphere** (can induce defuelling and sodium draining)
- **Study of in sodium tightness** (design of under sodium bell)
- **Analysis of tools for repair :**
  - Sodium traces to be swept (gas blowing/brushing/laser…)
  - Machining (miling/grinding/laser…)
  - Welding (TIG/laser…)
- **Need of under sodium robots assuming efforts of repair tools :**
  - Analysis of available materials
  - Definition of specific robots
    - Objective : duration for special inspection < 1 year



– **Optimization of SFR primary circuit DESIGN** L1 L2 L3 L4

- Accessibility
- Less internal structures
- Less weak points / welds
- Proposition of specific design towards ISI&R

– **TECHNOLOGY of ULTRASONIC TRANDUCERS** L1 L2 L3

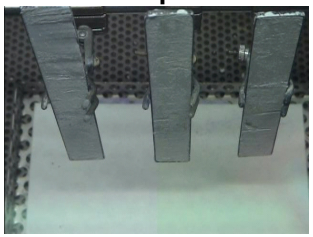
for both continuous monitoring & periodical inspection

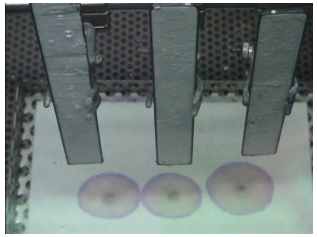
- Development
- Manufacturing
- In sodium tests
- Selection and validation of adapted techniques for :
  - In sodium telemetry at 550°C
  - In sodium Non Destructive Examination at 180°C
- Development of modelling for simulation of the controls

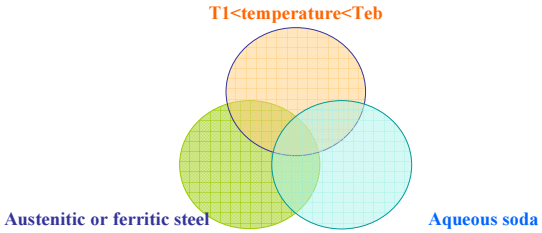
R&D program in 2010 – 2012 (2/2)

– **Special inspections** L3 L4

- Validation of procedures able to avoid caustic corrosion risk, during sodium draining of primary circuit
  – Feedback experience of Phénix SGU cleaning







- Consolidation of complete defuelling feasibility

– **Repair** L4

- Definition of repairability of the components
- Identification of adapted techniques and robots
- Repair is envisaged for : PP, IHX, Fuel loading machine, SGU, Above Core Struc. ?
- Definition of detailled scenarios for some representative cases

2012 => … :

– Qualification of design for the prototype and ISI&R techniques (in water, then in sodium), validation of CIVA new models

- The subject is wide -> the number of specialized organism is important :
  - NDE companies, universities, feedback from other industry

- ISIR program is also put in an international context
  - through GENIV SFR / Component design & Balance Of Plant PMB
  - through international exchange with partners

Thank you for your attention