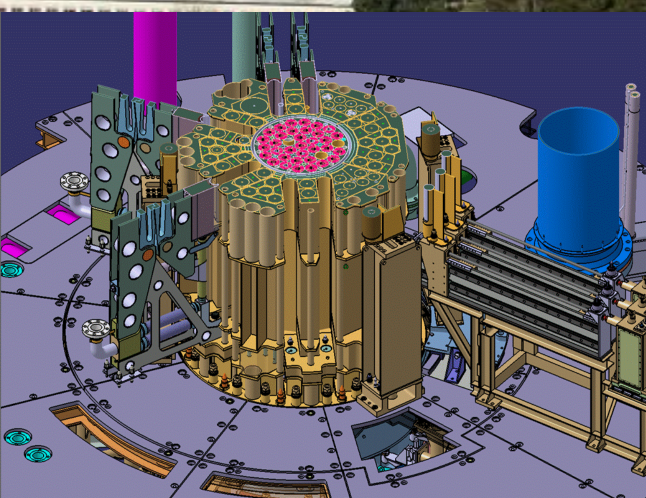
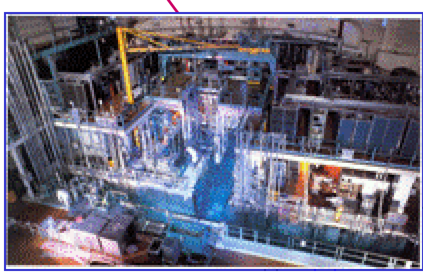
The Jules Horowitz Reactor: a new High performances European Material Testing Reactor (MTR) as an International Center of Excellence-Update status and focus on the modern Safety approach

Dr Gilles Bignan
CEA/Nuclear Energy Directorate
JHR User Facility Interface Manager
(France)



The ageing high performances Material Test Reactor (MTR) fleet in western Europe



Age of current E.U. main MTRs in 2011 (years)

BR2 (B)	48
HALDEN (N)	51
HFR (NL)	50
LVR 15 (CZ)	54
MARIA (PO)	47
OSIRIS (F)	45
PHENIX (F)	shutdowned
R2 (S)	shutdowned

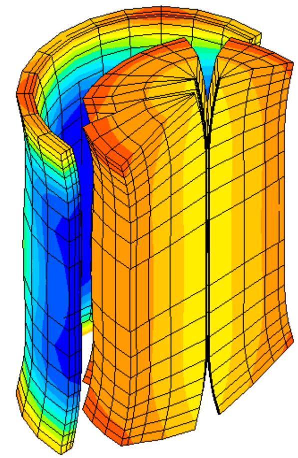
JHR: Research Infrastructure labellised by European road maps (ESFRI,SNE-TP…)

★ Under construction

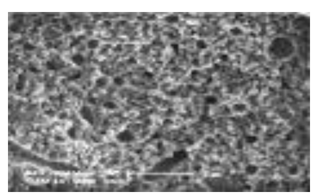
CEA Strategy on MTR: Sustaining Material Testing Capacity in France from OSIRIS to JHR

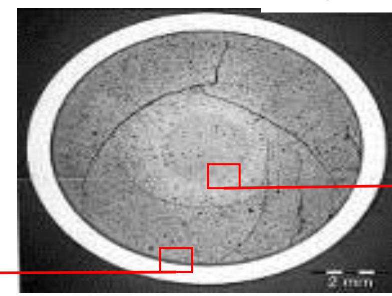
The needs: Major Scientific Challenges

- Material Ageing under irradiation
  - ✓ dpa, …
  - ✓ Corrosion, Radiolysis …

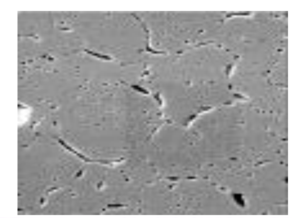


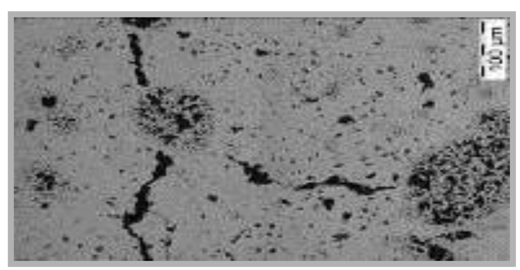
- Fuel Behaviour under irradiation (PCI,FGR…)

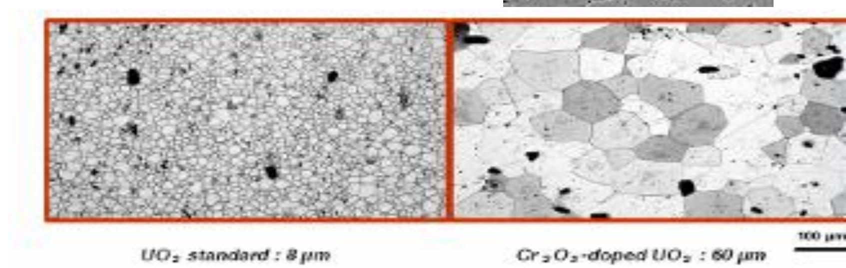




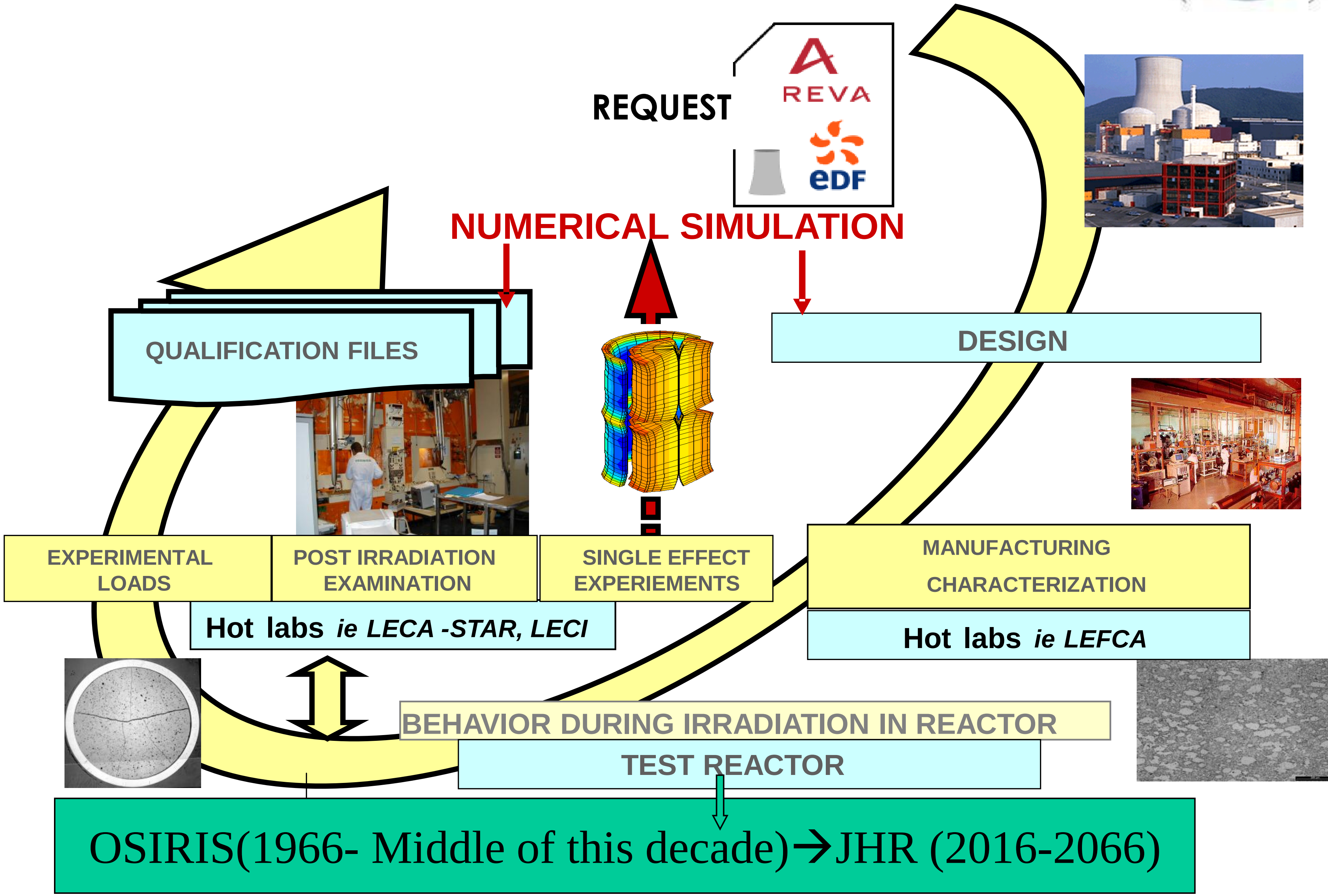
FG
At the grain boundaries





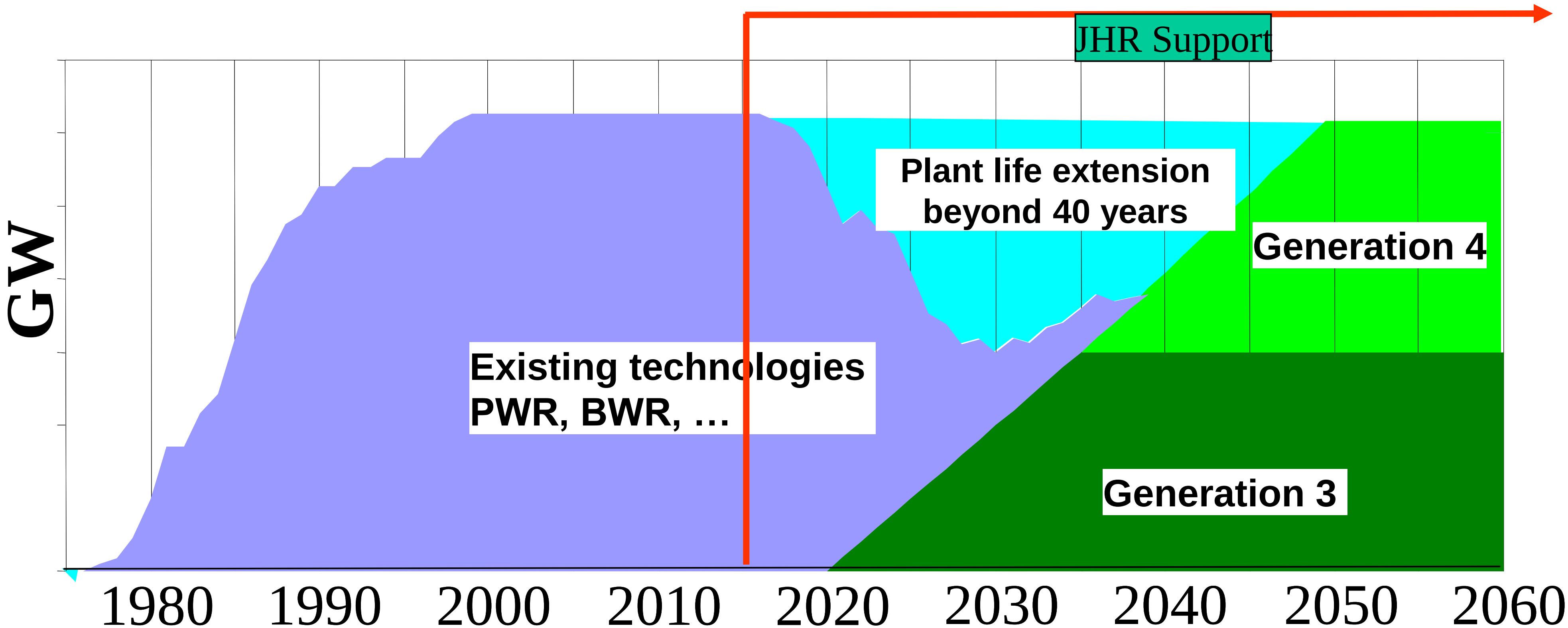


Design and qualification of new fuel or material :
the classical Loop of R&D cycle



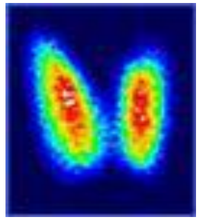
JHR Objectives: an MTR optimised to support industrial & public needs

- Safety and Plant life time management (ageing & new plants)
- Fuel behaviour validation in incidental and accidental situation
- Assess innovations and related safety for future NPPs



JHR : Others Main Objectives

- **Radio-isotopes supply for medical application within Western Europe**

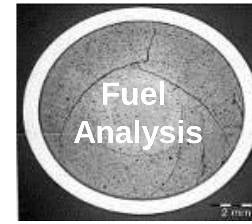


  - ✓ **MOLI production**
    - ☞ JHR will supply 25% of the European demand (today about 10 millions targets/year) and up to 50% if specific request –(Twice OSIRIS's today production)

- **JHR will be a key tool to support expertise**
  - ✓ Training of new generations
  - ✓ Maintaining a national expertise staff and credibility for public acceptance
  - ✓ Assessing safety requirements evolution and international regulation harmonisation

JHR status

JHR : a 100 MWth, pool-type, light-water MTR optimised for fuel and material testing for the benefits of industry and public bodies
Will also provide significant MOLFI production for medical purposes (25 % to 50 % of European needs)



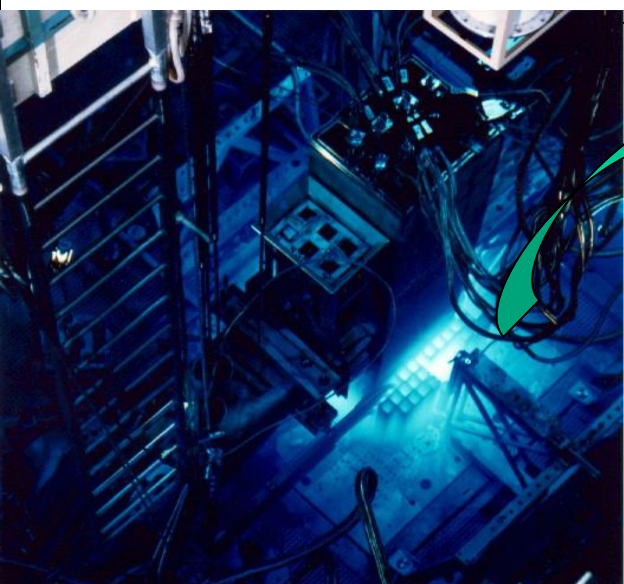
- Now under construction
  - ✓ Design completed, Site excavation completed
  - ✓ First concrete : August 09 ; Upper basement done in 2010 (Nuclear Auxiliary Unit : June 2010, Reactor Building Unit: December 2010)
  - ✓ Current operations : Primary and secondary exchangers building, Electrical Storage building, pool tank…
- On going procurement process
  - ✓ Engineering for the realisation phase, civil work, pumps for the primary circuit, …
  - ✓ **More than 95% of construction contracted**

- Licensing process: Preliminary Safety Analysis Report assessment
  - ✓ Start of the process: public consultation 2005, public enquiry 2006
  - ✓ A large effort in the technical assessment (2007, 2008)
  - ✓ **Nuclear Installation Decree: 12th October 2009 - Commissioning in 2016**

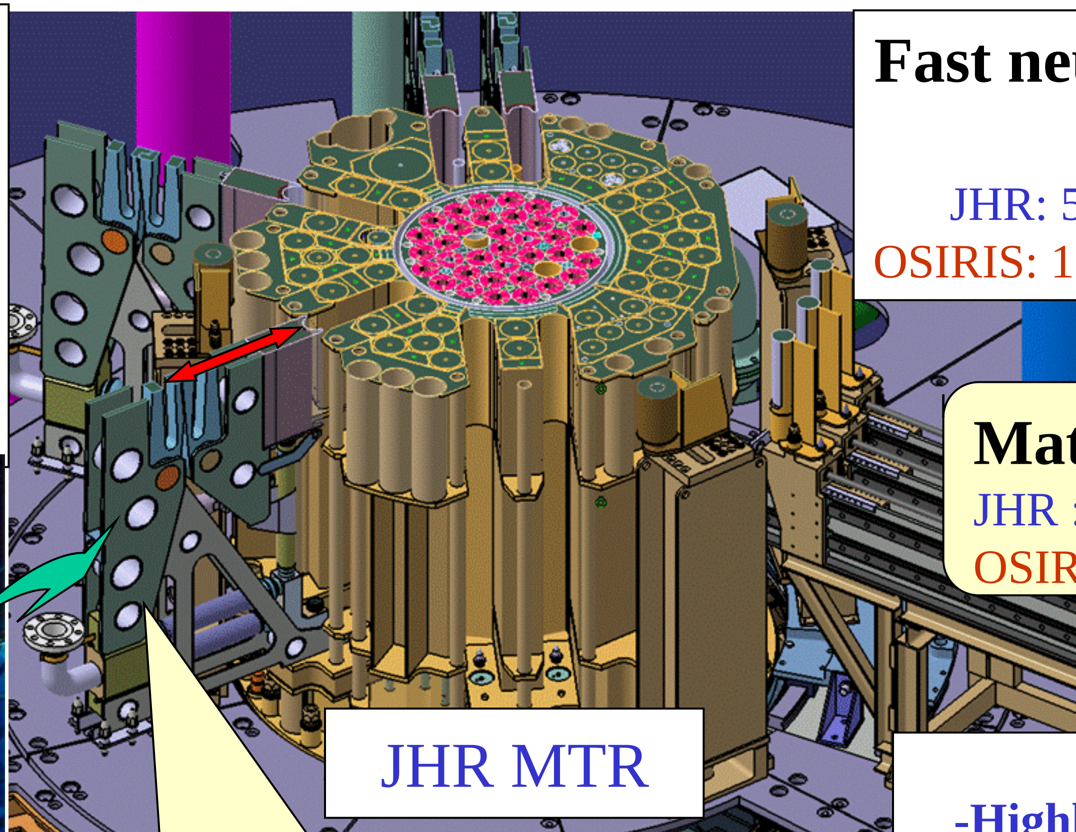
JHR: a successor of OSIRIS

Thermal Neutrons flux In reflector

JHR: 5.5 10^{14} n/cm².s
and 6 displacement systems
OSIRIS: ~ 1.5 10^{14} n/cm².s
and 1 displacement system



OSIRIS MTR



JHR MTR

Fast neutrons flux in core

JHR: 5.5 10^{14} n/cm².s
OSIRIS: 1.5 10^{14} n/cm².s

Material ageing

JHR : up to 16 dpa/y
OSIRIS : ~ 5 dpa/y

Displacement systems in JHR to:

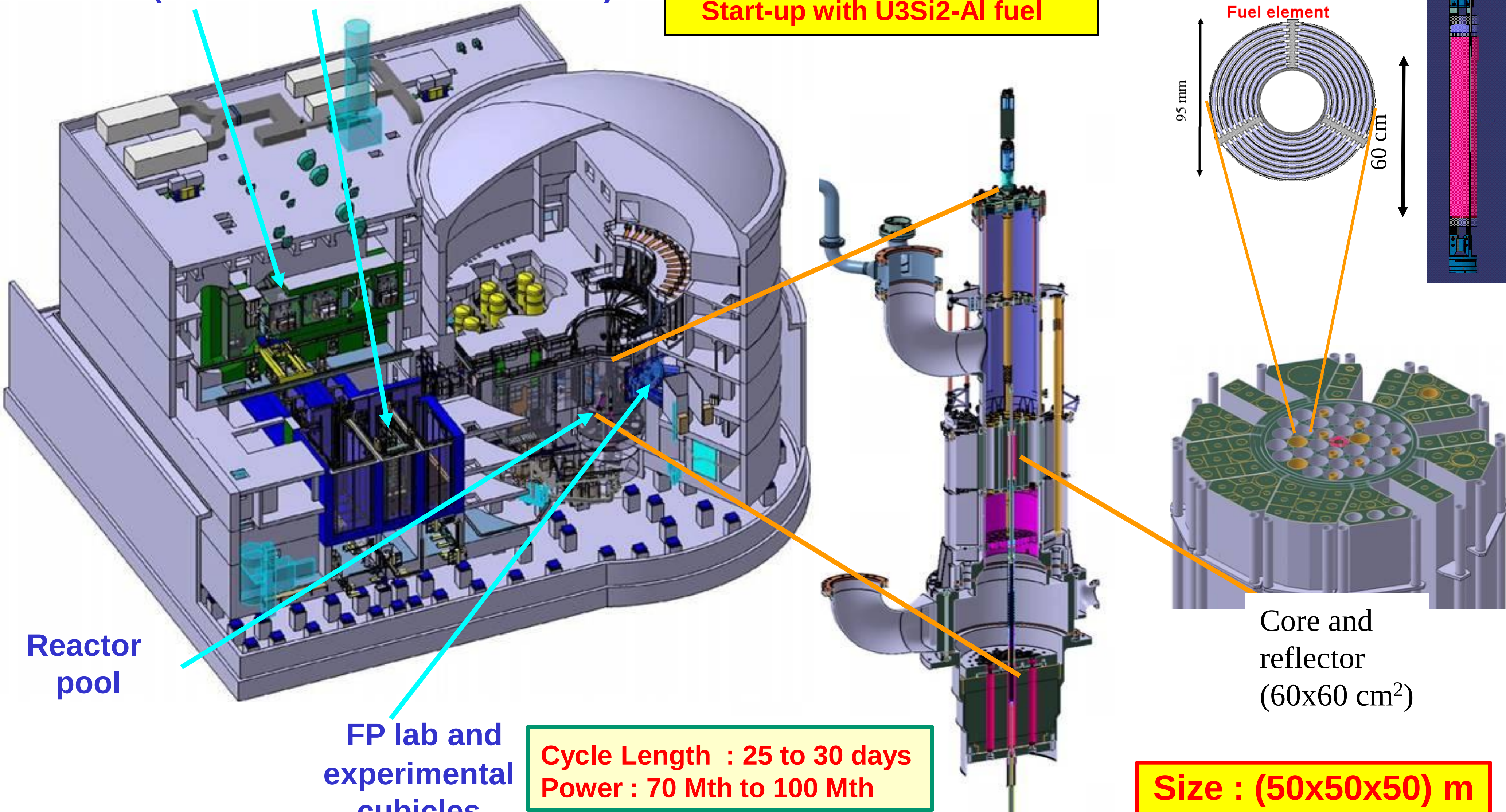
- Adjust the fissile power
- Study transients

In JHR :

-Highly Instrumented Experiments
- On-line fission Gas analysis
- 20 simultaneous experiments

JHR General presentation

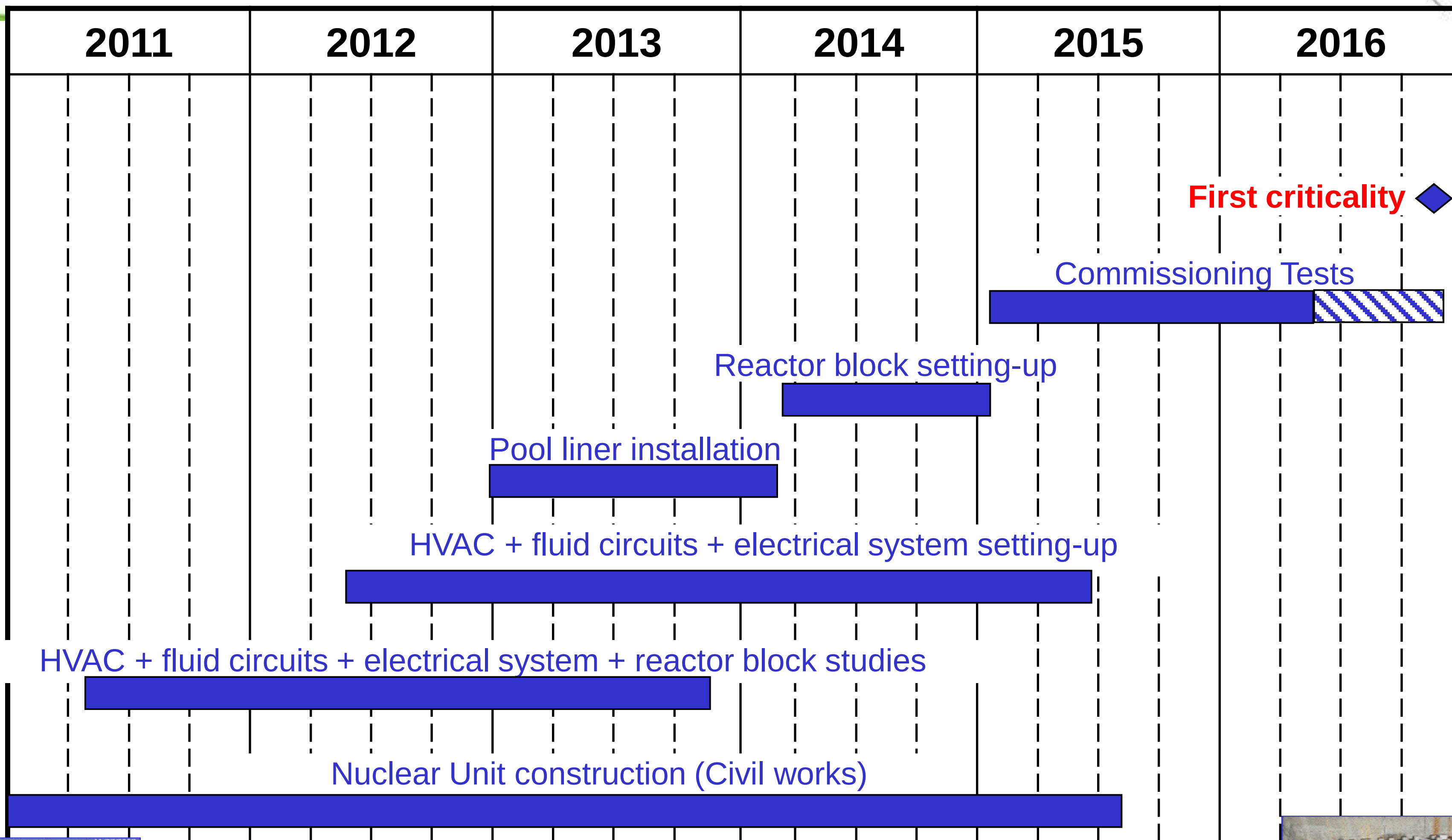
Core Designed for UMo-Al fuel
Start-up with U3Si2-Al fuel



Cycle Length : 25 to 30 days
Power : 70 Mth to 100 Mth

Size : (50x50x50) m

Project steering schedule



Mid-2007-end 2008: Site preparation
First semester of 2009: civil work site preparation
Mid 2009-Mid 2011: civil work on Reactor Building and Nuclear Auxiliary Building

JHR project : organisation during the construction phase

International CONSORTIUM Governing Board

CEA
Owner and Contracting Authority

Fundings
(2005 M€)

CEA (French Government)	: 510
French Industrial Partners	: 150
Foreign Partners	: 100

Primary Works Supervisor:
Engineering Company
AREVA-TA

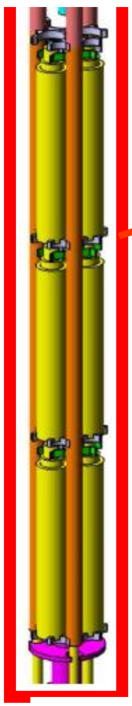
Sub-Contractors

JHR Building Site : Mid 2011

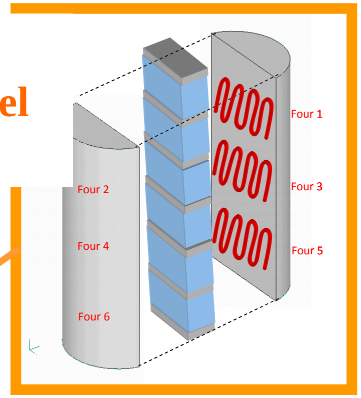
CEA developments for building the first JHR Experimental capacity

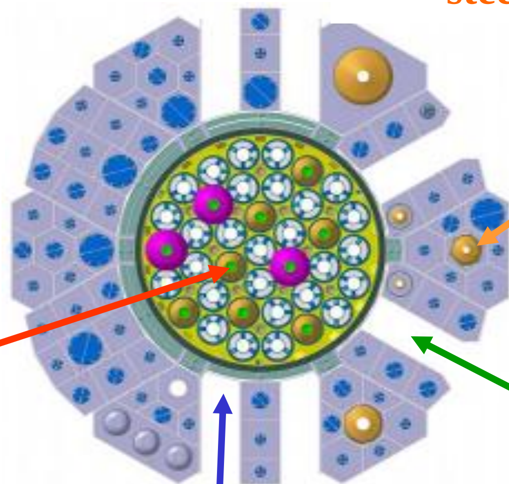
Experimental hosting systems under development

CALIPSO & MICA
For material testing under high dpa and controlled thermal gradient (250 – 450°C)

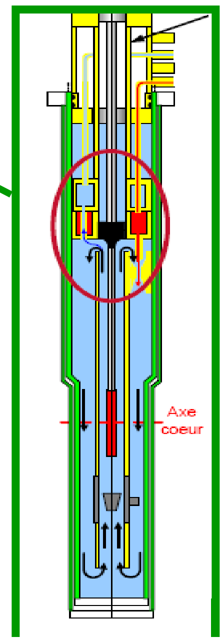


IRMA
For pressure vessel steel testing



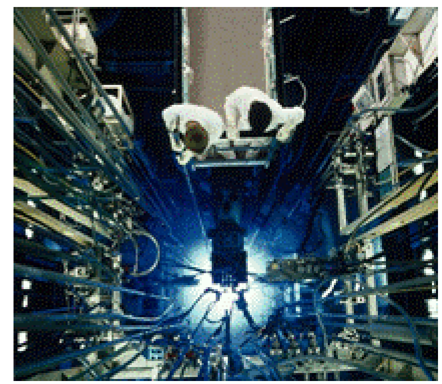


MADISON
For LWR fuel testing under nominal conditions



ADELINE
For LWR fuel testing under off-normal conditions

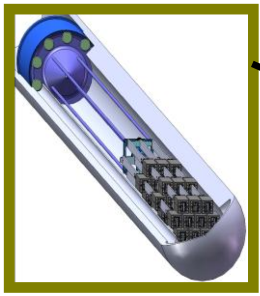
Large experimental feedback from OSIRIS MTR

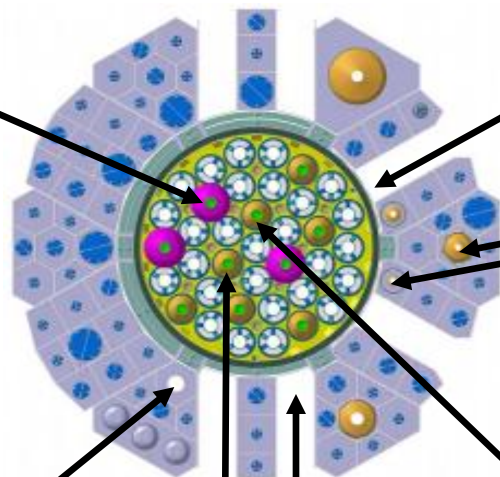


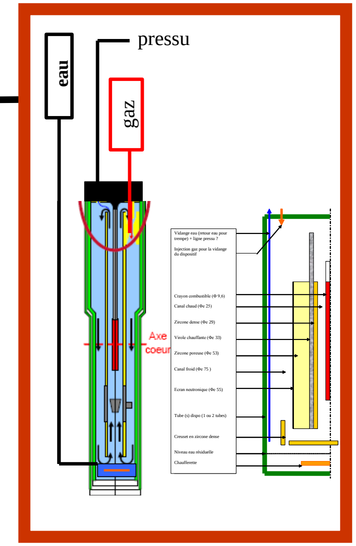
Fuel power ramp tests (Isabelle loop)
Material under controlled stress (GRIZZLY sample holder)
Etc.

Hosting experimental systems under feasibility studies

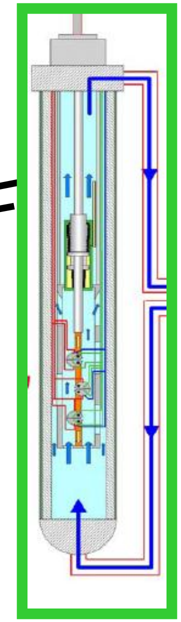
High temp. material irradiation (600-1000°C)
Large capacity





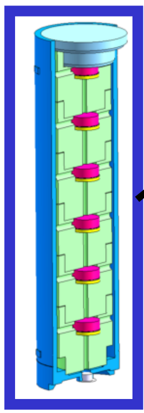


LORELEI fuel testing under accidental conditions (LOCA)



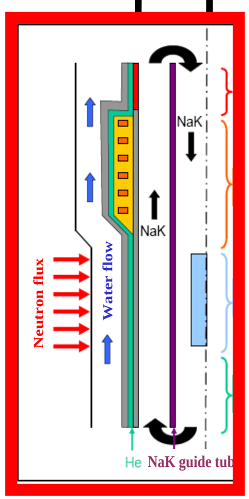
Corrosion loop for Zr alloy corrosion and IASCC

Transmutation studies



MICA (material) adapted to 1000°C gas conditions (Phaeton type – Osiris technology)

CALIPSO adapted to SFR fuel and material
Normal=> in core
Off normal => in reflector



Other topics

LWR : Adeline « FP » ; Adeline "power to melt" ; severe accident studies
GFR : fuel irradiation (normal and off-normal conditions)
Fuel characterization : basic properties under irradiation (thermal diffusivity, thermal creep,..)

JHR Safety Approach

General principles – MTR specificities

- **4 levels of Defence in Depth** (Prevention, Faults Detection, Back-up Systems, Management of Severe Accident), Barriers' approach, Optimisation principle (ALARA), and…
- A particular attention on confinement and homogeneous approach between installation and experiments,
- Feedback from past experience
- Specific features of an MTR : issues of **availability/safety and the reactor/experiments coupling**
- Human Factors
- Requirements in terms of equipment qualification
- In-service monitoring of Safety Important Component (SIC)
- Dismantling factors integrated as early as the design stage

in accordance with **regulations & standards**
relevant to nuclear facilities & equipment

JHR Safety from the design stage

- Deterministic approach for safety demonstration
- Seven types of risks: 4 **OC** and 3 **RLC**
- **Operating Conditions (OC)** characterized by Initial Condition (IC) and Initiating Event (IE) coming from systems itself and consequences on other systems
- OC are classified according to their Annual Frequency of Occurrence (AFO), by feedback and by expert opinion
- Specific prevention criteria for **Risk Limitation Conditions (RLC)**
- General safety objectives (GSO) in terms of staff and public dosimetry resulting from these OC are thus defined

Objective of the safety analysis : verify compliance with the general safety objectives in all OC and RLC after application of the single failure criterion

JHR Safety from the design stage

	Category	Name of category	***ANNUAL FREQUENCY OF OCCURRENCE***
Design basis OC	OC1	Normal conditions (1st category of OC)	AFO *(> 1/year)*
	OC2	Incident conditions (2nd category of OC)	10^{-2}/year < AFO *(≤ 1/year)*
	OC3	Rare accident conditions (3rd category of OC)	10^{-4}/year < AFO ≤ 10^{-2}/year
	OC4	Hypothetical accident conditions (4th category of OC)	10^{-6}/year < AFO ≤ 10^{-4}/year
Risk limitation conditions (RLC)	CC	Complex conditions	***SPECIFIC PREVENTION CRITERIA***
	MSA	Mastered severe accidents	Specific prevention criteria
	ESA	Excluded severe accidents	Specific prevention criteria

Impact on the JHR facility design

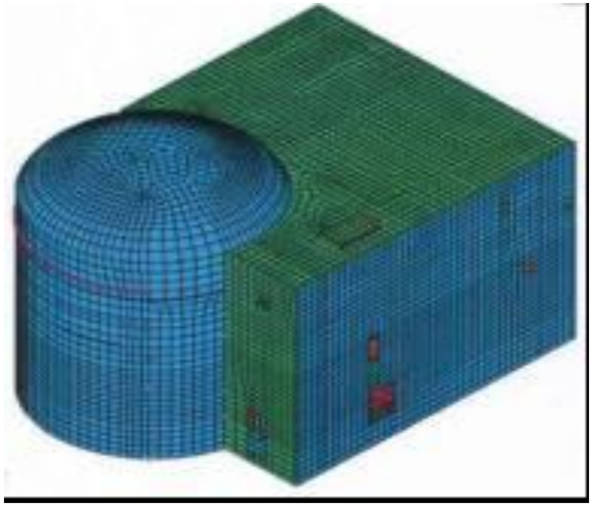
- The **iterative process between design and safety** leads to a satisfactory facility regarding GSO compliance.

Safety analysis from the design stage impacts design choices, often induced from past experience lessons on PWR or other MTR

- ✓ French Nuclear Power Park
- ✓ Design phase of ORPHEE, PHEBUS and CABRI,
- ✓ Safety re-evaluation processes of ORPHEE, OSIRIS and ILL,
- ✓ International Experiences…

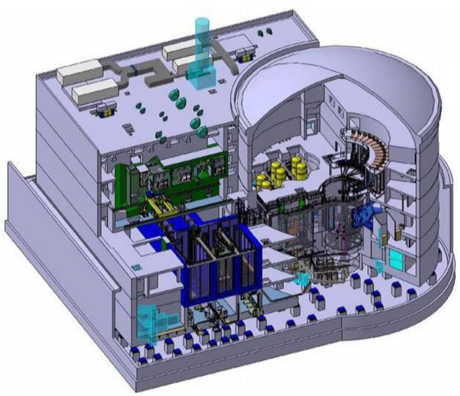
Example: Impact on the JHR facility design

↳ BUILDING

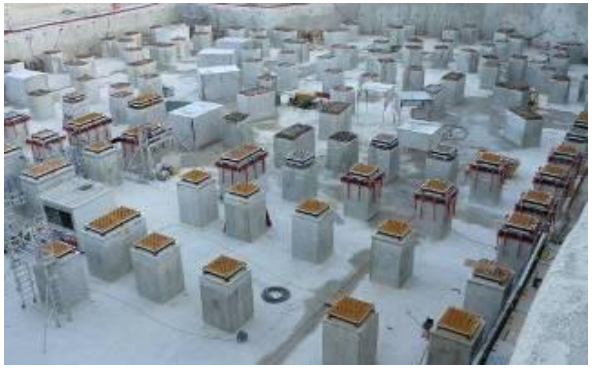


Confinement :

- Partially pre-stressed containment complying with large margins with leak tightness criteria, in case of Master Severe Accident (BORAX type)
- Automatic isolation in case of BORAX type accident
- Leak off zone and dynamic confinement with double isolation of penetrations



Installation on aseismic pads



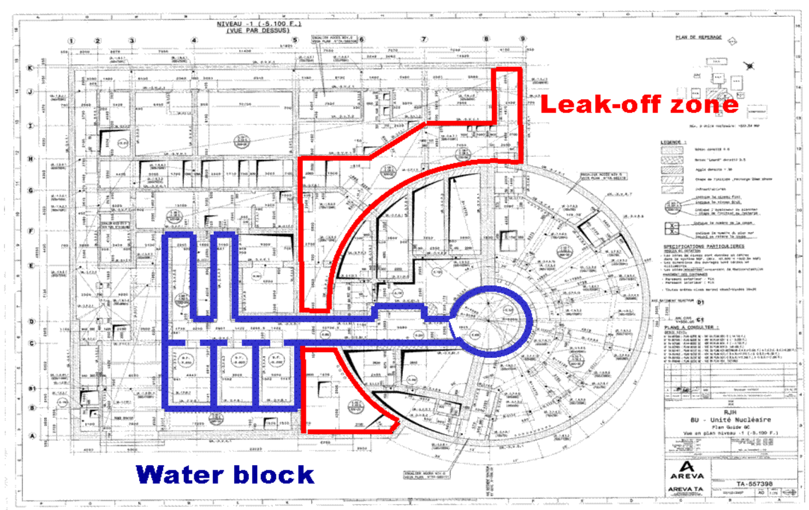
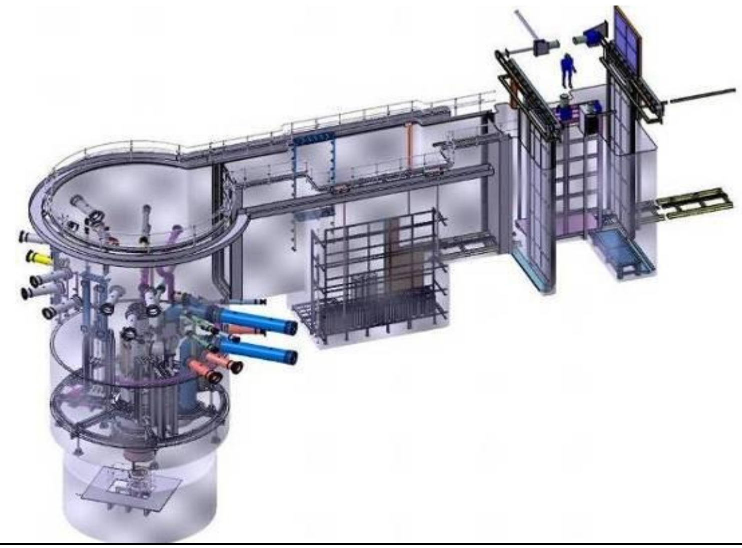
Columns bear and aseismic pads

Sismic risk :

- ~200 aseismic pads and suitable rebars
- Distorsion limitations and easier design of the water block

Example: Impact on the JHR facility design

WATER BLOCK

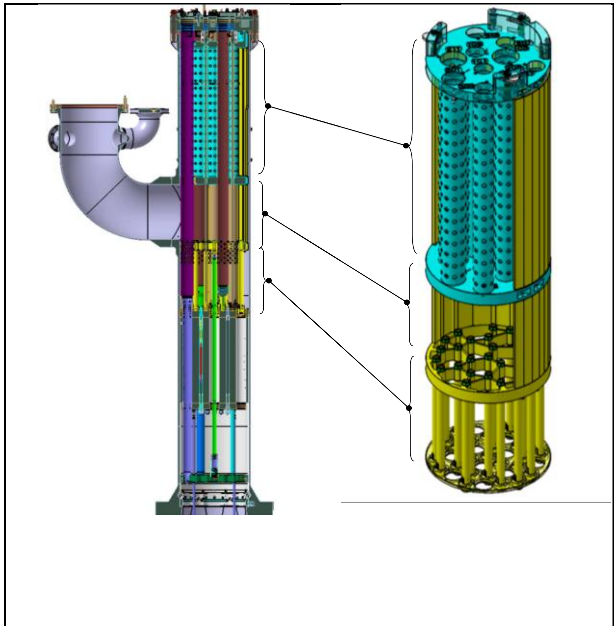
	
Leak off zone and water block	Reactor pool and crossings

- **More stringent requirements, favouring access via the upper parts with leak tight doors**

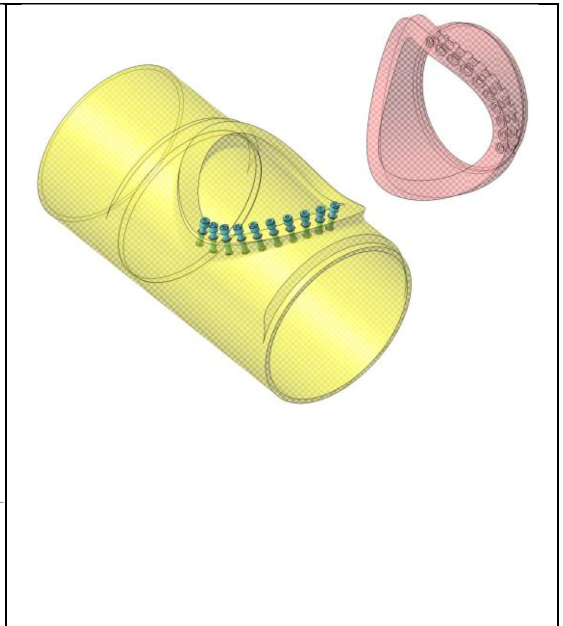
- **Suitable location and BORAX resistance of experimental penetrations for non-dewatering criteria of the core**
- **Low volume of water block peripherical cubicles**
- **Leak tightness (steel liner) and structural stability (concrete structure)**

Example: Impact on the JHR facility design

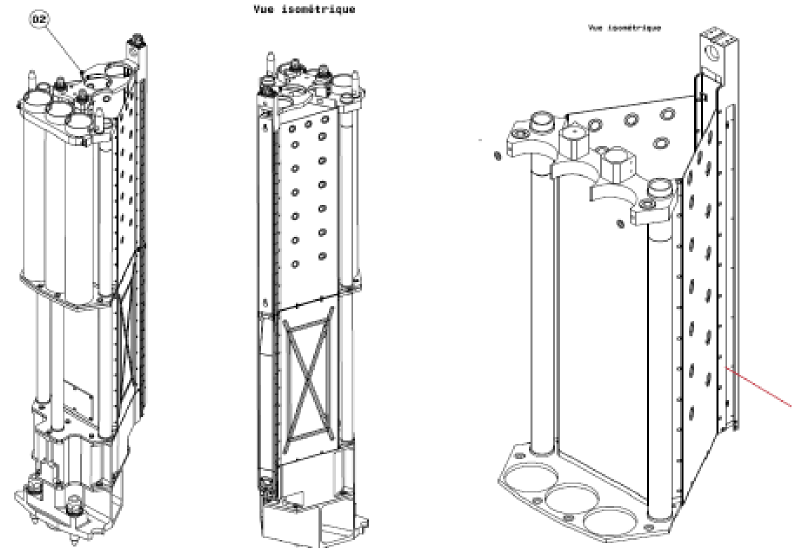
BLOC PILE INTERNAL STRUCTURES - REFLECTOR



Reactor internal structures



Galvanic decoupling

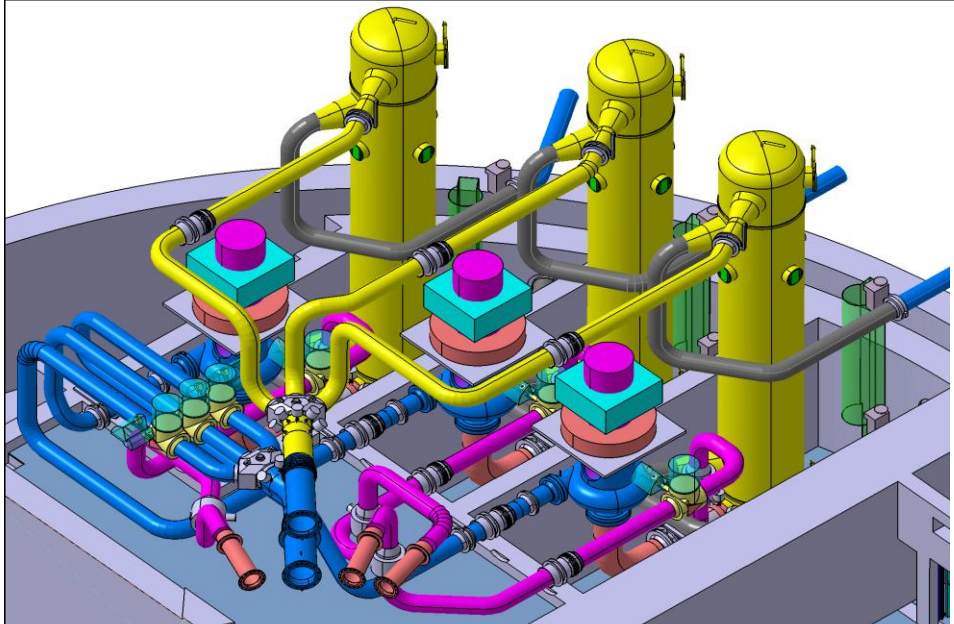


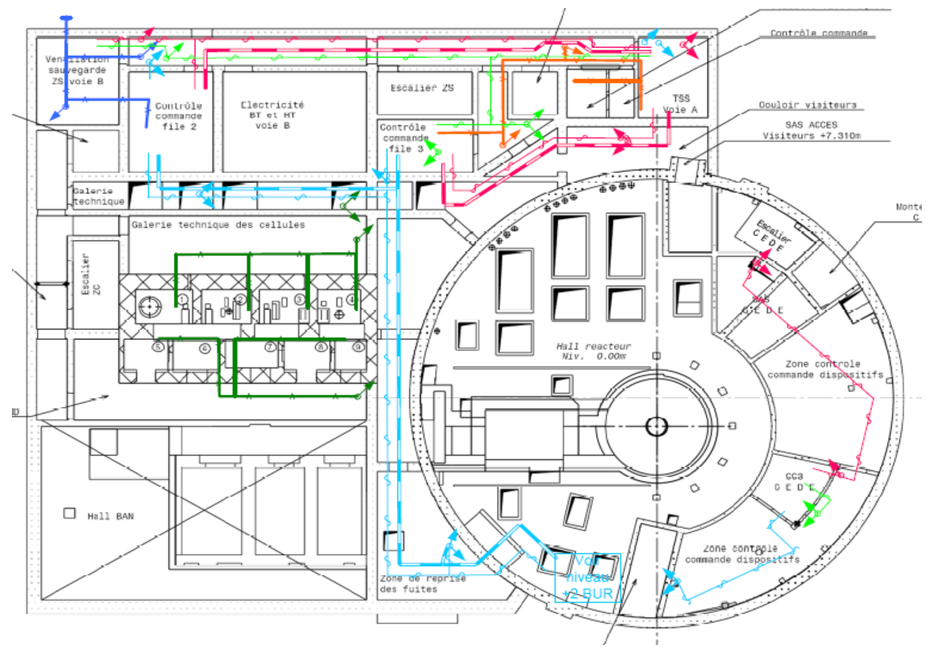
Reflector blocks

- **Closed primary circuit slightly pressurised during power operation**
- **Choice of 6061-T6 aluminium alloy for the parts under irradiation**
- **Galvanic decoupling for intermetallic contacts**
- **Early qualification of the forging, machining and welding processes**
- **Systematic replacement of Béryllium blocks for a projected dose greater than 5.10^{22} fast neutrons/cm^2**

Example: Impact on the JHR facility design

BACKUP CIRCUITS AND SYSTEMS





• Primary circuit : 3 separate lines and 1 back-up suction line upstream of each primary pump
• Back-up systems are redundant and geographically separated
• Installation of the primary lines in limited-volume shielded cubicles complies with the reactor water block requirement : to keep the core watered under primary break conditions

JHR as an International User-Facility and an International Center of Excellence

JHR Consortium: a framework to operate JHR as a User-Facility open to International collaboration

↳ JHR Consortium, economical model for investment & operation

- ✓ CEA = Owner & nuclear operator with all liabilities
- ✓ JHR Members owner of Guaranteed Access Right
  - ☞ In proportion of their financial commitment to the construction
  - ☞ With a proportional voting right in the Consortium Board
- ✓ A Member can use totally or partly his access rights
  - ☞ For implementing proprietary programs with full property of results
  - ☞ and/or for participating to the Joint International Programs open to non-members
    - – To address issues of common interest & key for operating NPPs

JHR Consortium current partnership: Research centers & Industrial companies

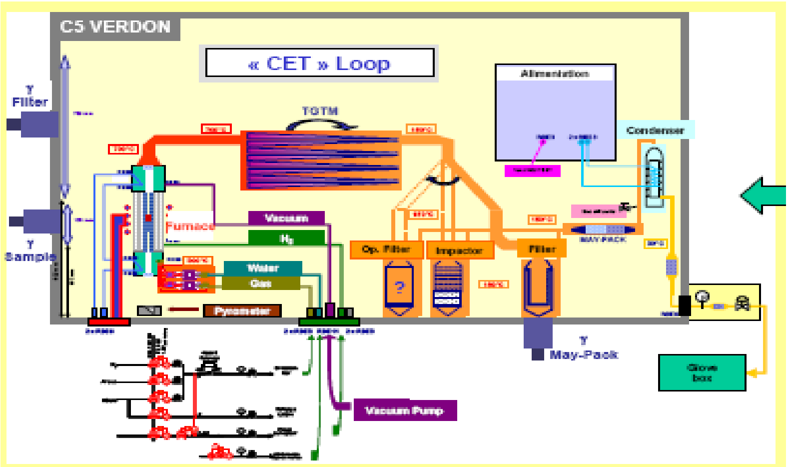
VATTENFALL — AREVA — EDF

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas — SCK•CEN Studiecentrum voor Kernenergie Centre d'Étude de l'Énergie Nucléaire — cea — VTT — ÚJV — पऊवि DAE — JAEA Japan Atomic Energy Agency

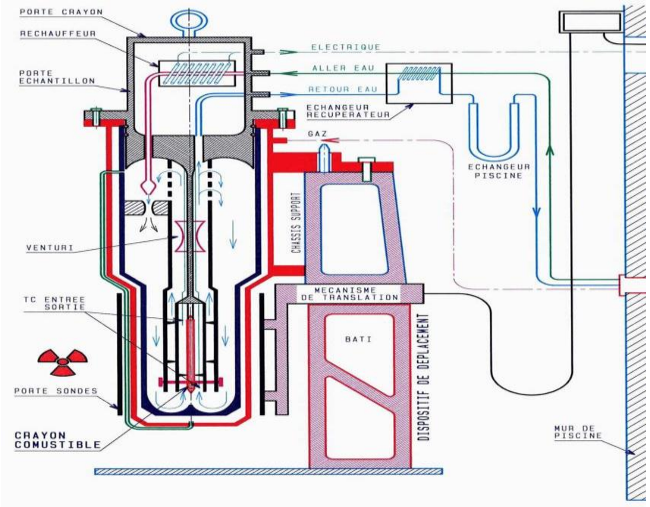
Operating Rules of JHR : an International Users Facility lead by a consortium of funding partners

Jules Horowitz International Programme (JHIP)

- Strategic Scope: To address fuel and materials issues of common interest that are key for operating plants and future NPP
- Propose a two phases project:
- Phase 1: R&D programs on CEA existing facilities (OSIRIS, LECI, LECA…) to prepare future JHR experimentations (2012-2016)



CEA Hot-Cell MERARG2



CEA Ramps Test device in OSIRIS ISABELLE

- Phase 2: R&D programs on JHR (2017-2020)

Building up the international collaboration around JHR

- A key stake for funding partners: beyond technical stakes, JHR is a collaboration platform
  - ✓ To be in touch with international scientific, industrial, safety state of art
  - ✓ To train new generations of engineers and scientist
  - ✓ To mutualise topics of common interest
  - ✓ To consolidate efforts from utilities, industries and research agency

Nuclear technologies
(instrumentation, innovation, manufacturing rules, CC)

Reactor and fuel design
(multidisciplinary approach, loops, mock-up)

Safety physics
(fast transients, LOCA, severe accidents)

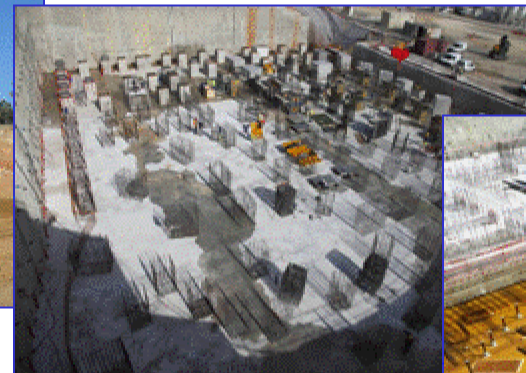
Core physics
(neutronics, thermal-hydraulics, thermo-mechanics)

Material & fuel science
(behaviour under irradiation, mechanics, corrosion)

International Secondees on JHR in 2011

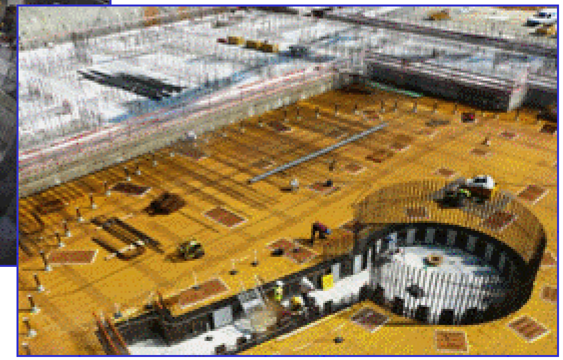
February 2008

September 2009



July 2007

July 2010



Thank you for your attention !

December 2010

March 2011

July 2011

October 2011