



EXPERIMENTAL INFRASTRUCTURE IN SUPPORT OF R&D AND LICENSING PROCESS FOR LEAD FAST REACTOR TECHNOLOGY

C. DUCU², M. CONSTANTIN¹, D. DIACONU¹, M. NITOI¹, M. APOSTOL¹

¹ Institute for Nuclear Research (RATEN ICN), Pitesti, Romania

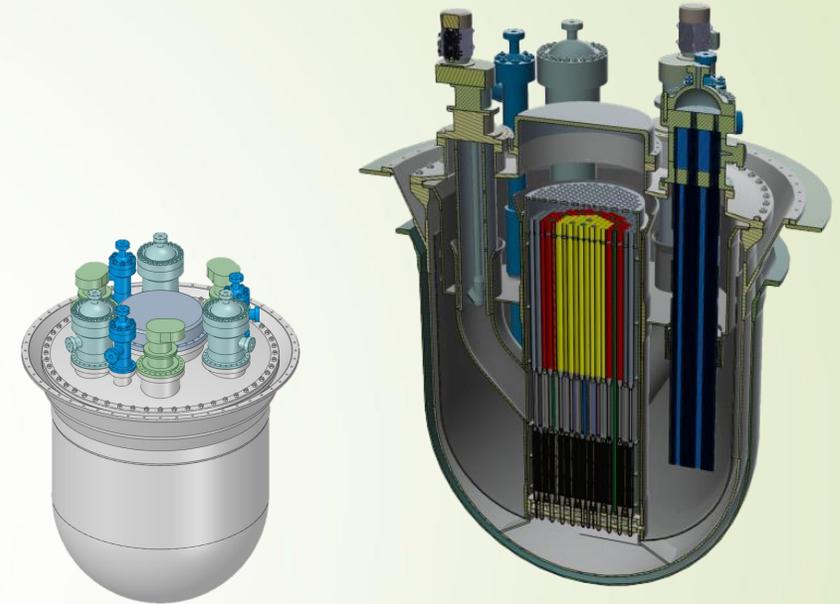
² RATEN, Mioveni, Romania

Towards a LFR SMR in EU



2025, Signing EAGLES consortium

2025, Start of pre-licensing process with CNCAN (Ro), FANC (Be), ISIN (It)



**Experimental
infrastructure**

LEANDREA

ALFRED

**LFR SMR
(EAGLES 300)**

RDI and Licensing
2030



Small scale
Demonstrator
2034

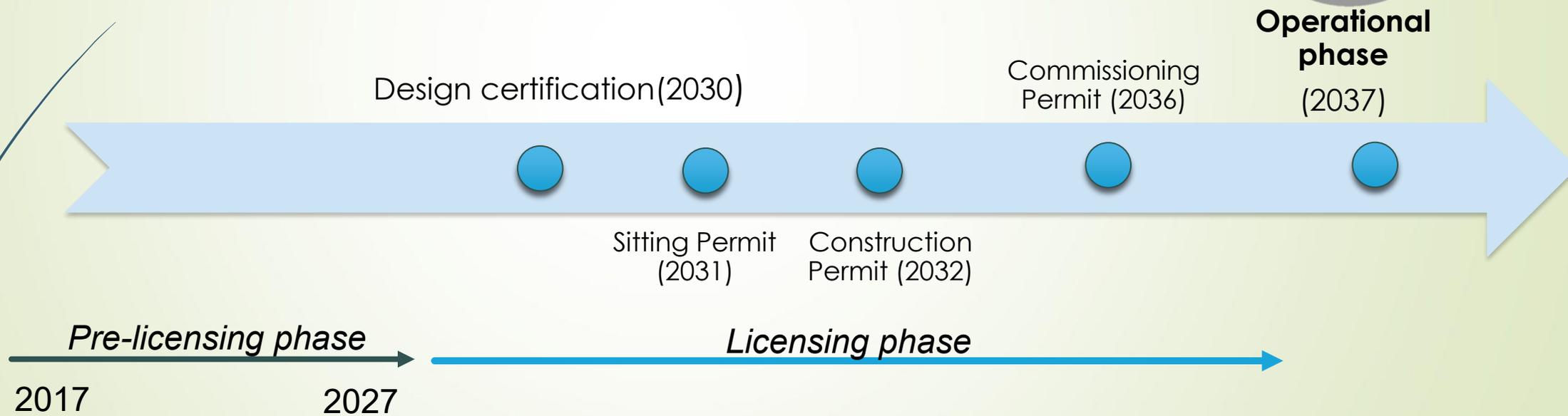
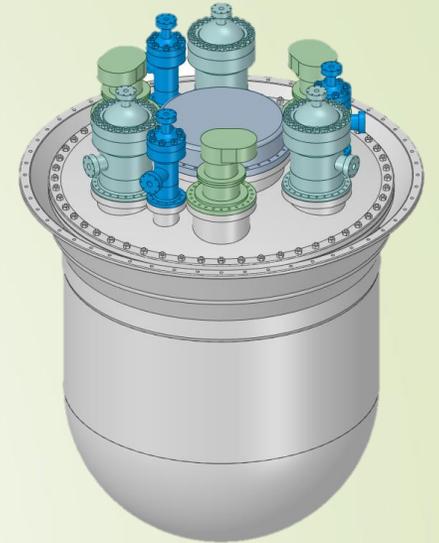


LFR power
Demonstrator
2037



Commercial
deployment
2039

ALFRED Current Roadmap



Experimental infrastructure for ALFRED

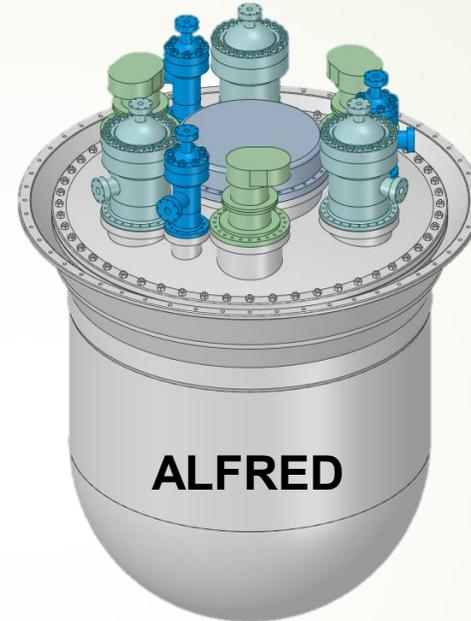
Existing RIs

Italy

- CIRCE
- NACIE
- LECOR
- LIFUS-5
- HELENA
- RACHEL
- BIDONE
- MEC. Lab
- SIRIO

Belgium (LBE)

- Facilities for MYRRHA



FALCON and ARCADIA efforts

ATHENA & ChemLab



ELF & HELENA-2



Hub



Auxiliary Building



Hands-ON



Meltin' Pot in PIEL



Investment

Project 1

2021-2025

22 M€

20 M€ from EU funds

ATHENA
ChemLab

Project 2

2025-2028

104 M€

from EU funds

ELF
HELENA-2
HandsON
Meltin'Pot

Project 3

2027-2028

1 M€

from national funds

Hub

Criteria for siting of the experimental facilities:

- (1) proximity to existing utility and communication networks
- (2) clustering of experimental installations, to promote resource sharing and operational efficiency through the use of common services and infrastructure,
- (3) utilization of existing buildings and available space within the Mioveni nuclear platform, optimizing investment and minimizing environmental impact



Objectives

- to support a comprehensive and strategically structured experimental program is being planned to support the licensing process of the ALFRED project
- to serve as a foundation for robust research and development (R&D) initiatives, targeting the resolution of critical outstanding challenges in LFR technology

ALFRED infrastructure

Carry out LFR technology-specific research (**thermo-hydraulic regimes, chemical control of oxygen and impurities**)

Investigate the behavior of **materials in corrosion and erosion** regimes

Study the **transport of chemical elements and species** in molten lead and cover gas

Ensure the **testing, demonstration and qualification** of LFR components

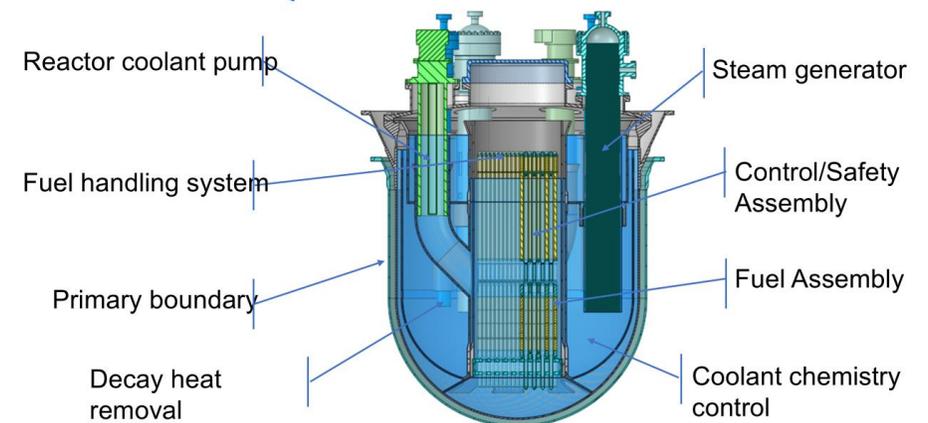
Support the **validation and verification** of computational codes/methodologies

Pre-Licensing and Licensing

Critical stage: authorization by CNCAN for construction and operation

- **Testing**
- **Demonstration**
- **Qualification**
 - Materials and processes (thermo-hydraulics, material behavior, parameter monitoring - O₂, T, flow, ...)
 - Components (HX, pumps, fuel assembly, etc.)
 - Systems (fuel/component handling systems, heat removal systems, instrumentation and control systems, etc.)
- **Verification**
- **Validation**
 - Design standards and procedures
 - Calculation codes, design codes

ALFRED Qualification needs



Testing, Demonstration, Qualification, V&V

- ▶ **Testing** is the practical act of checking how a component, system, or material behaves **under specified conditions**.
 - ▶ It answers the question: “*What actually happens when we use it?*”
 - ▶ Involves experiments, measurements, and operation in laboratories or facilities.
 - ▶ *Example: testing a fuel rod in a reactor loop to measure temperature and corrosion.*
- ▶ **Demonstration** is proving, in a **realistic environment**, that a technology or system can **work as intended**.
 - ▶ It goes beyond small-scale tests.
 - ▶ Usually done at pilot or prototype scale.
 - ▶ *Example: operating a prototype reactor module to show that it can generate electricity safely.*
- ▶ **Qualification** is the formal process of proving that a **component or material** is suitable and **authorized for a specific nuclear application**.
 - ▶ Based on standards, codes, and regulatory requirements.
 - ▶ Requires documented tests, analyses, and procedures.
 - ▶ *Example: qualifying a new type of valve to be used inside a nuclear containment system.*

Testing, Demonstration, Qualification, V&V

- ▶ **Verification is checking that a design, calculation, or system has been built correctly according to its specifications.**
 - ▶ It compares reality with the design documents.
 - ▶ Typical question: *“Did we build it right?”*
 - ▶ Example: verifying that a safety system was installed exactly as designed and wired correctly.
- ▶ **Validation is confirming that a system or method fulfills its intended purpose in real operation.**
 - ▶ It focuses on user and safety needs.
 - ▶ Typical question: *“Did we build the right thing?”*
 - ▶ Example: validating a reactor simulation code by comparing its predictions with real reactor measurements.

T,D,Q, V&V and Technology Readiness Level

Think of TRLs as the progression from idea → lab → prototype → real system.

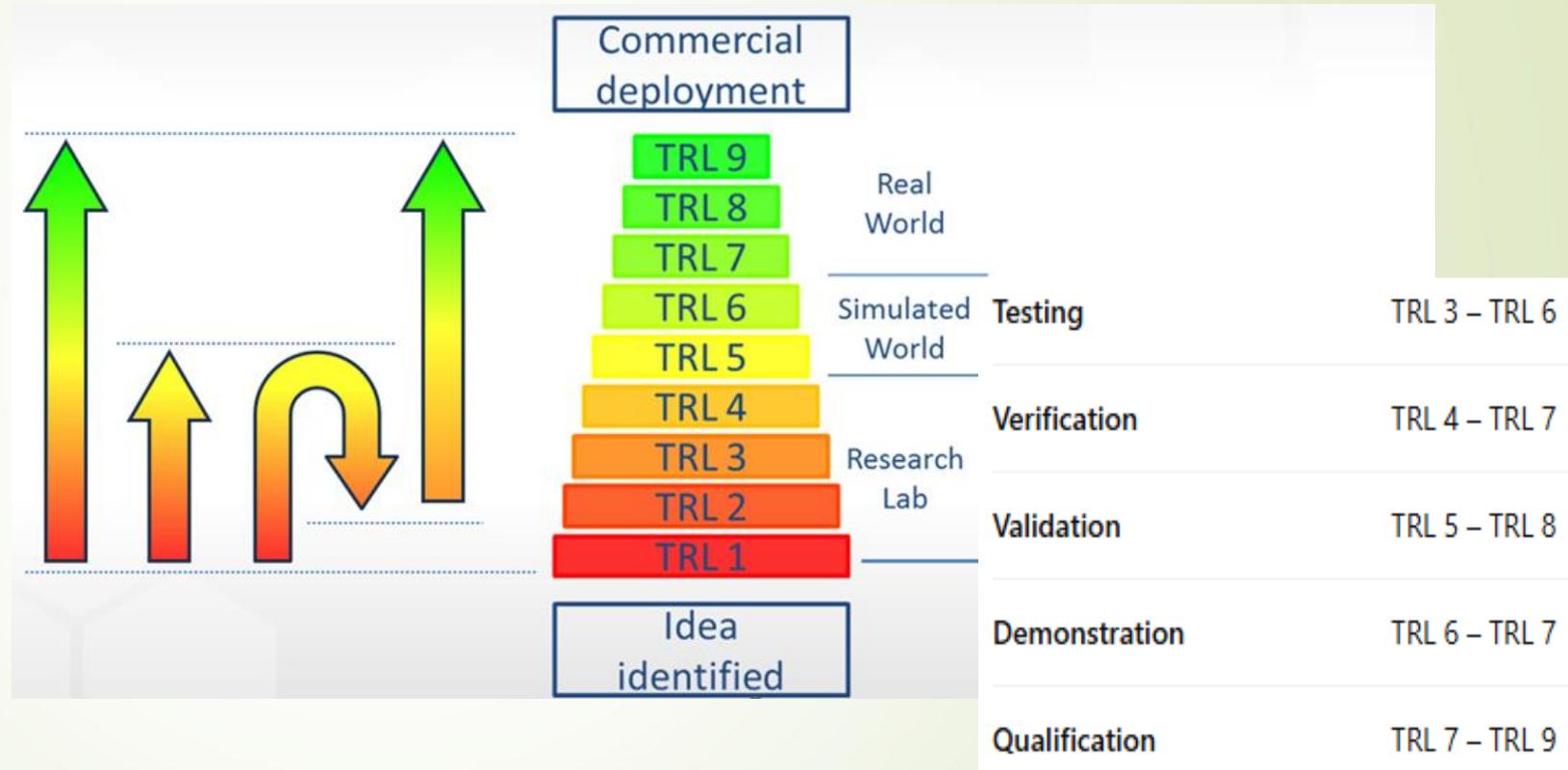
Testing → Generate experimental evidence and data

Demonstration → Show it works, Check that design and implementation meet requirements

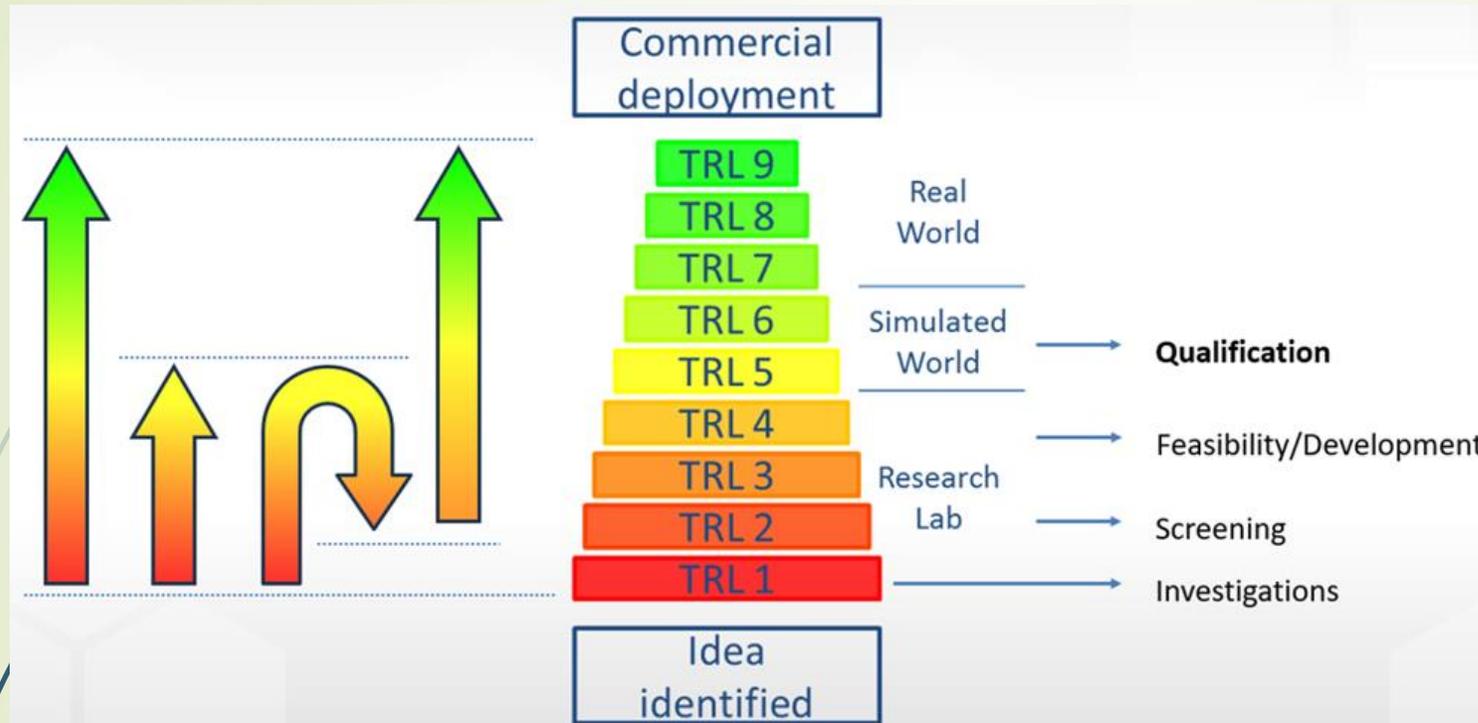
Qualification → Prove that models, methods and systems fulfill real needs/standards

Verification → Show integrated system works in relevant environment

Validation → Confirm usefulness, Achieve formal regulatory acceptance for real deployment



TRL



TRL assessment must account not only for basic proof-of-concept but also for performance in **representative environments**, **appropriate scale**, and **high-fidelity integration**. This ensures technologies are ready not just in theory, but in realistic operational settings.

Examples:

Coolant chemistry and oxygen control systems:

- current TRL~5 (validated in lead test loops, e.g., CHEOPE, HELIOS)
- needs for TRL6-7: integrated testing in **large volumes** with transient conditions; **long-duration experiments** in a reactor-like environment at operational temperatures.

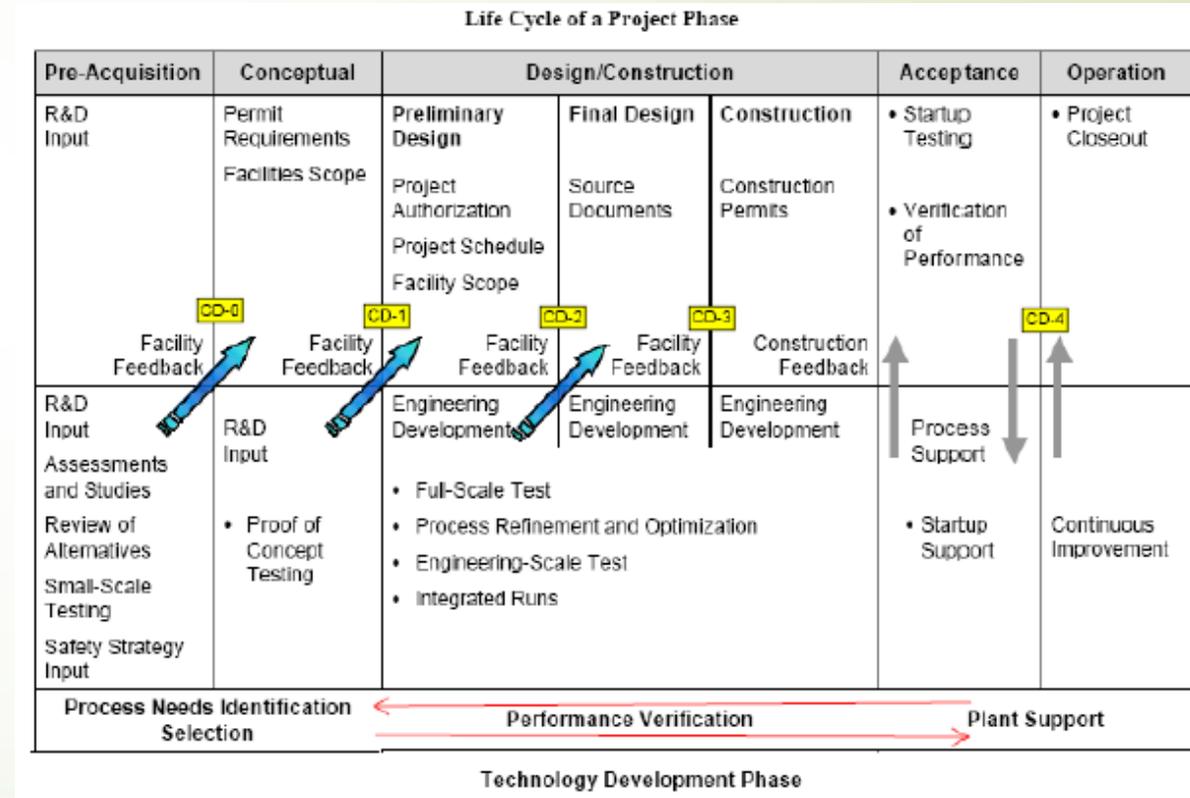
...

Refueling system:

- current TRL 1
- needs for TRL 5-6

Readiness Evaluation Methodology

- Reference for methodology: **DOE G 413.3-4A 9-15-2011, Technology Readiness Assessment Guide**
- **Three steps:**
 - **Identifying the Critical Technology Elements**
 - **Assessing the Technology Readiness Level**
 - **Developing a Technology Maturation Plan**



Source: DOE G 413.3-4A

Steps for TRA – 1. Identifying the Critical Technology Elements (CTEs)

“A technology element is “critical” if the system being acquired depends on this technology element to meet operational requirements (with acceptable development cost and schedule and with acceptable production and operation costs) and if the technology element or its application is either new or novel, or in an area that poses major technological risk during design or demonstration”.

- ▶ **Lead coolant chemistry and control:** controlling corrosion and maintaining coolant purity is a major technical challenge.
 - ▶ Oxygen control systems
 - ▶ Impurity monitoring
 - ▶ Coolant activation and polonium production
- ▶ **High-temperature structural materials:** materials must withstand high temperatures (~500°C), corrosion from lead, and irradiation damage.
 - ▶ Ferritic/martensitic steels (e.g., T91, 15-15Ti)
 - ▶ Advanced austenitic steels
 - ▶ ODS (oxide dispersion-strengthened) steels
- ▶ **Fuel design** - cladding resistant to lead corrosion and swelling; coatings
- ▶ **Primary heat exchanger and pump systems:** these must function reliably in high-temperature lead environments
 - ▶ Immersion-type pumps (electromagnetic or mechanical) and erosion
 - ▶ High-temperature heat exchangers with minimal pressure drop and corrosion
 - ▶ Natural circulation capability for passive safety
- ▶ **Instrumentation and control:** lead is opaque and dense, making visual inspections and sensor operation difficult.
- ▶ **Sealing and valve technologies:** Seals and valves must function reliably in high-temperature, chemically aggressive lead environments.
- ▶ **Refueling system:** remote refueling robotics, high burnup, opaque lead and oxygen control

Steps for TRA – 2. Assessing the Technology Readiness Level (TRL)

TRL assessment must account not only for basic proof-of-concept but also for performance in **representative environments**, **appropriate scale**, and **high-fidelity integration**. This ensures technologies are ready not just in theory, but in realistic operational settings.

Representative environment

Test materials and systems at:

- 450–500°C in pure lead coolant.
- irradiation dose levels relevant to core exposure.
- dynamic flow conditions representative of ALFRED operation.

Appropriate scale

- subsystems tested at $\geq 80\%$ scale.
- thermal-hydraulic and mechanical similarity maintained in test loops

Fidelity and Integration

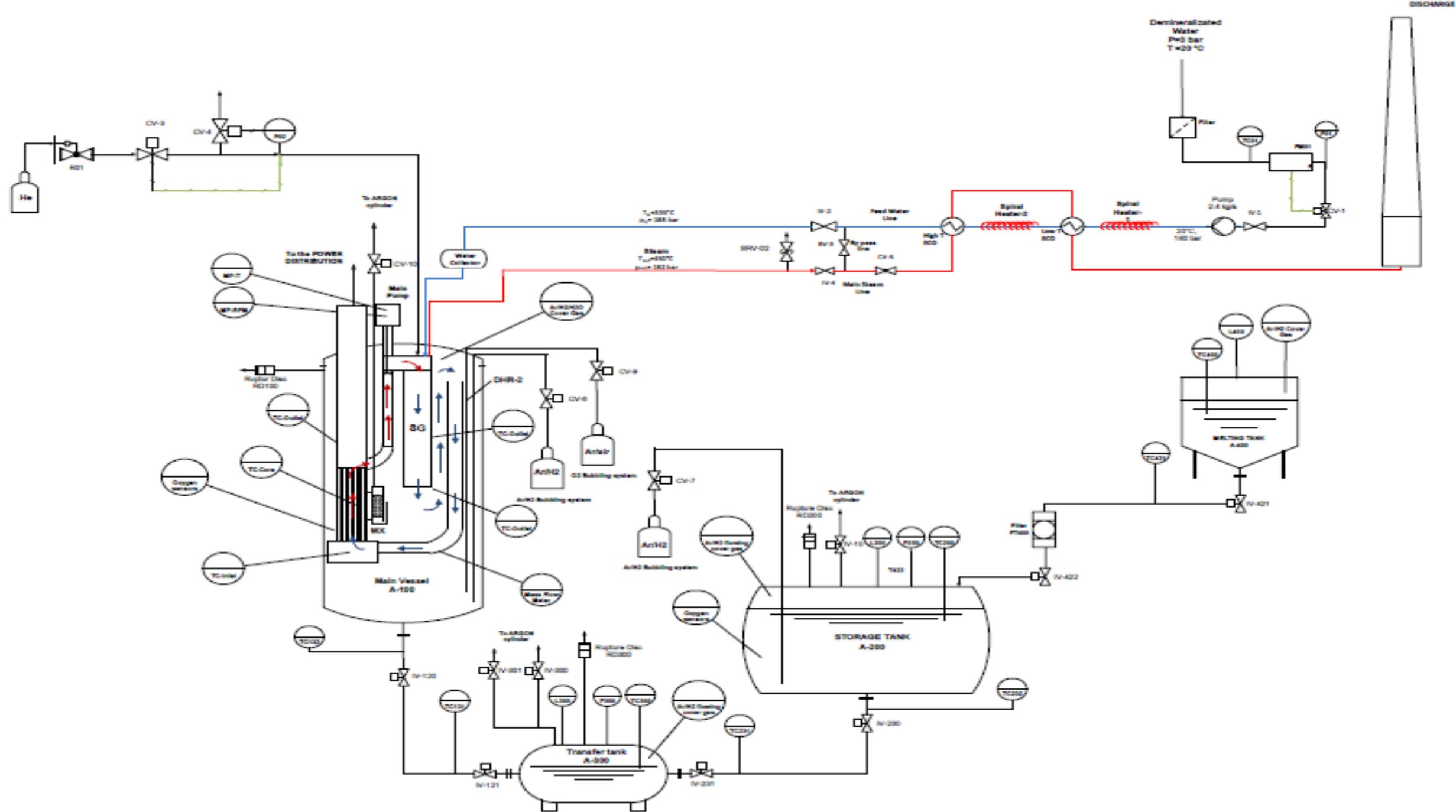
- use full-prototype materials and manufacturing techniques.
- validate coupling effects between core, HX, DHRs, and control systems.

ATHENA, Advanced Thermo-Hydraulics Experiment for Nuclear Application

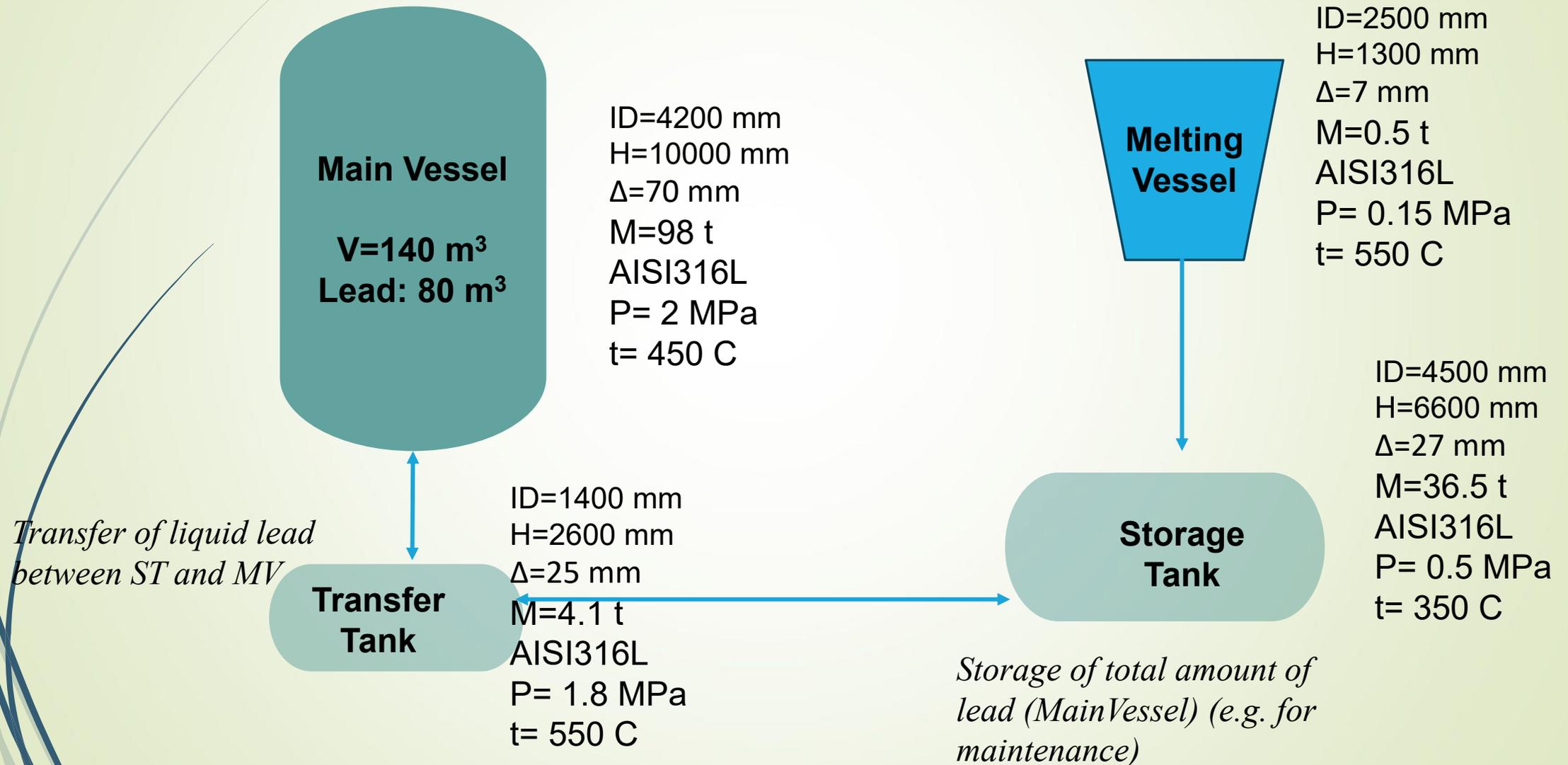
- ▶ ATHENA is an electrically heated 2.21 MW large pool (around 80 m³ molten lead) type multipurpose facility, representative scale for ALFRED, to
 - thermal hydraulic regimes in large pool volumes of lead (in forced and natural circulation)
 - investigate relevant phenomena (lead stratification, oxygen control, corrosion, and erosion) associated with pool statics, dynamics, and chemistry
 - simulate integral tests representative of normal operation
 - simulate peculiar transient integral tests relevant to safety assessment and economic operation in representative scale
 - test full scale single components (i.e. SG, DHR, RCP)
 - provide a large experimental database suitable for model development and code validation



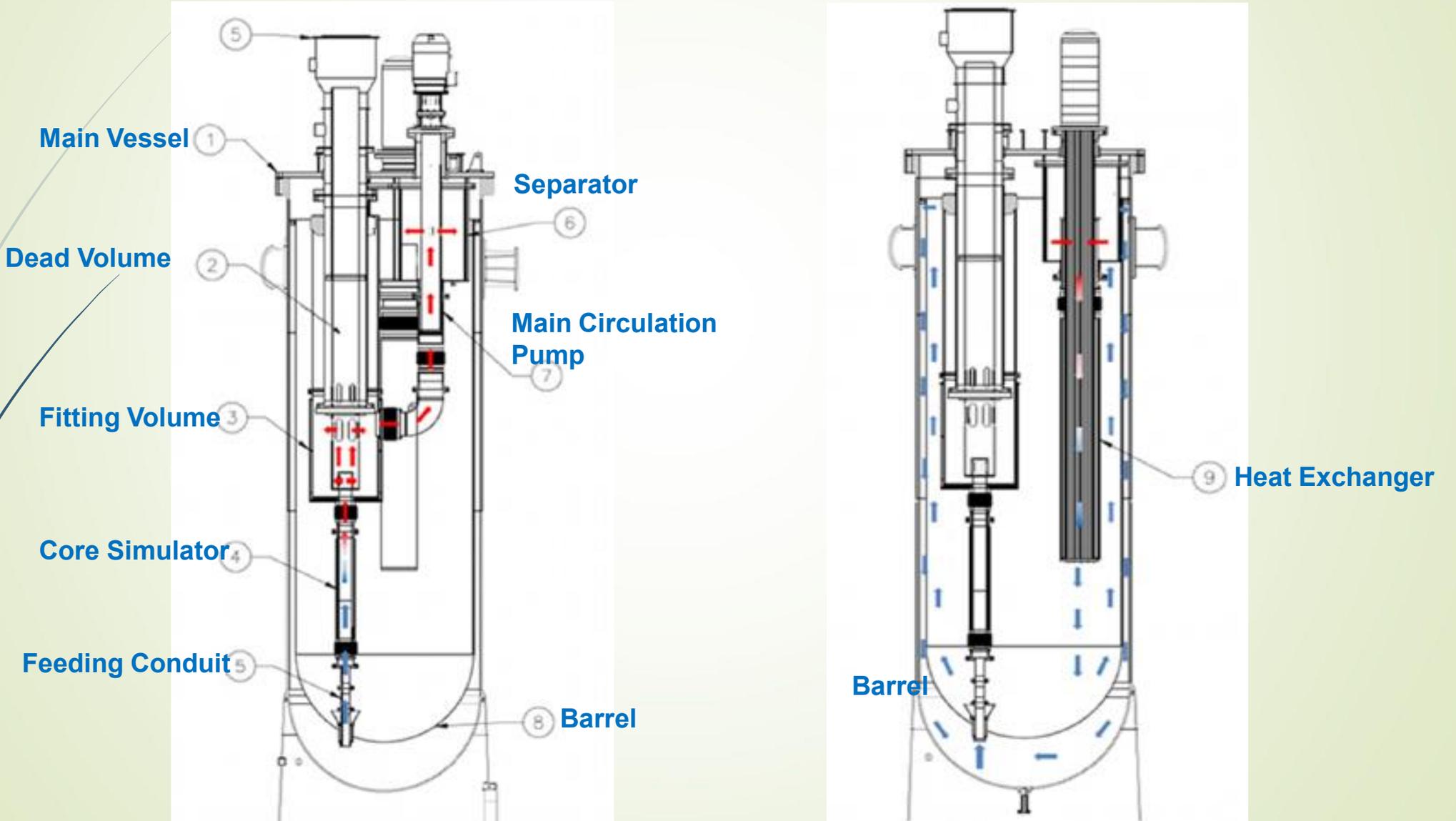
Parameter	Quantity
Total power	2.21MW
Total mass flow rate	189 kg/s
FPS inlet temperature	400 °C
FPS outlet temperature	480 °C
Rod diameter (D)	10.5 mm
Pitch (P)	13.86 mm
P/D	1.32
Hexagonal key	166 mm
Wrapper width	4 mm
Active length	600 mm
Average linear power	29 kW/m
number of pins	127
Average velocity	1.7 m/s



ANTHENA, Vessels' Characteristics

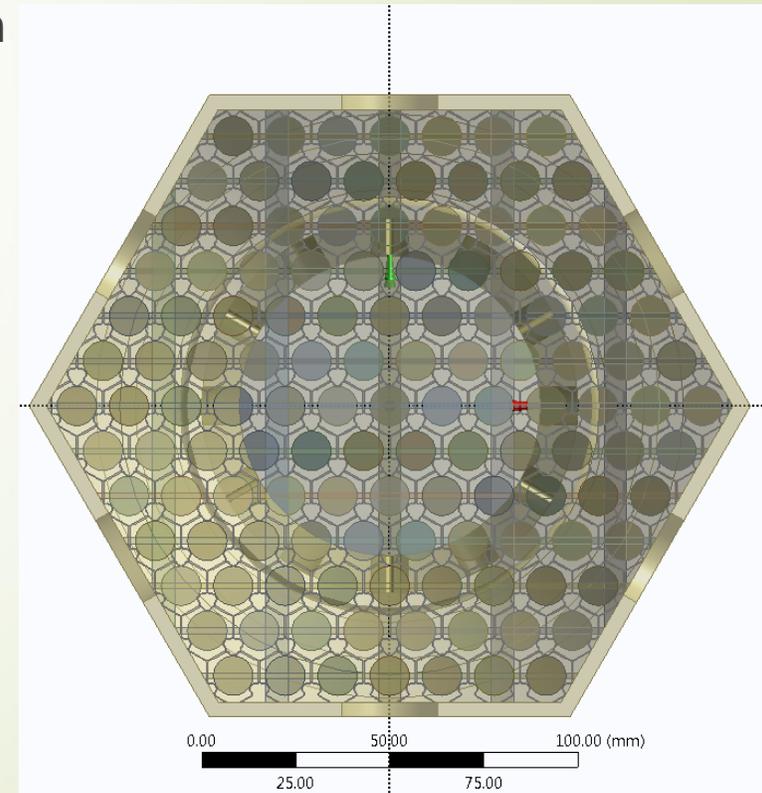


ATHENA, Flows



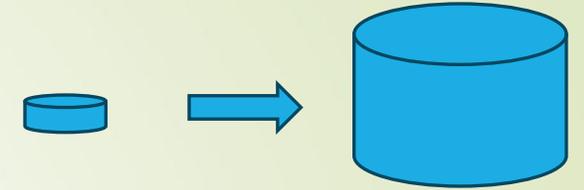
Core Simulator

- ▶ central FA supplies P_{\max} , **2.21 MW**
- ▶ includes 127 electrically heated rods
- ▶ disposed in triangular geometry with a pitch of 13.82 mm
- ▶ Rod diameter, 10.5 mm
- ▶ Rod active height, 600 mm
- ▶ average linear heat rate at full power, 29 kW/m
- ▶ Mass flow rate, 189 kg/s



Scale effects

- Simple definition: “What works at laboratory scale may behave differently at full industrial scale.”
- Scale effects are the differences between the behavior of a small-scale model and the behavior of the real, full-size system, caused by the fact **that physical laws do not scale linearly with size**
- **Some examples:**
 - Thermal-Hydraulics**
 - Heat transfer, flow patterns, and boiling behavior can be different in a small test loop than in a full reactor vessel.
 - Structural Mechanics**
 - A small model may resist loads well, but a full-size component may deform or vibrate differently.
 - Safety Systems**
 - Natural circulation cooling may work in a model but not scale up linearly to a large reactor.



To handle scale effects, engineers use:

- similarity criteria
- dimensionless numbers (Reynolds, Peclet, etc.)
- scaling analysis
- validated simulation codes
- **large-scale demonstration facilities**

ATHENA in support of ALFRED

ATHENA vs ALFRED 125

➤ Main Vessel

- Inner diameter, 1: 2.07
- Height, 1:1
- Volume ratio, 1: 4.29

➤ Main pump

- Number of pumps, 1:4
- Head, 1:1
- Mass flow rate x pump, 1:20

➤ Fuel Pin Simulator

- Thermal power, 1:80
- Number of assemblies, 1:25
- Rod diameter, 1:1
- Average linear power, 1:1
- Active length, 1:1
- Hottest FA power, 1:1

Appropriate scale

- subsystems tested at $\geq 80\%$ scale.
- thermal-hydraulic and mechanical similarity maintained in test loops

Representative environment

Test materials and systems at:

- 450–500°C in pure lead coolant.
- irradiation dose levels relevant to core exposure.
- dynamic flow conditions representative of ALFRED operation.

Fidelity and Integration

- use full-prototype materials and manufacturing techniques.
- validate coupling effects between core, HX, DHRs, and control systems.

➤ SG

- Number of SGs, 1: 4
- Power per SG, 1:20
- Feed-water mass flow rate, 1: 1
- Feed-water inlet T, 1:1
- Lead total mass flow rate x SG, 1:20
- Tubes: OD, active length, 1:1

➤ Integral section

- Height for NC, 1:1

Importance of vertical 1:1 Scaling

► Main Vessel

- Inner diameter, 1: 2.07, Height, 1:1, Volume ratio, 1: 4.29

► Z Axis and Stratification phenomena: thermal stratification refers to the formation of **distinct temperature layers** inside the large volume of liquid lead from RV. It can develop due to several coupled mechanisms:

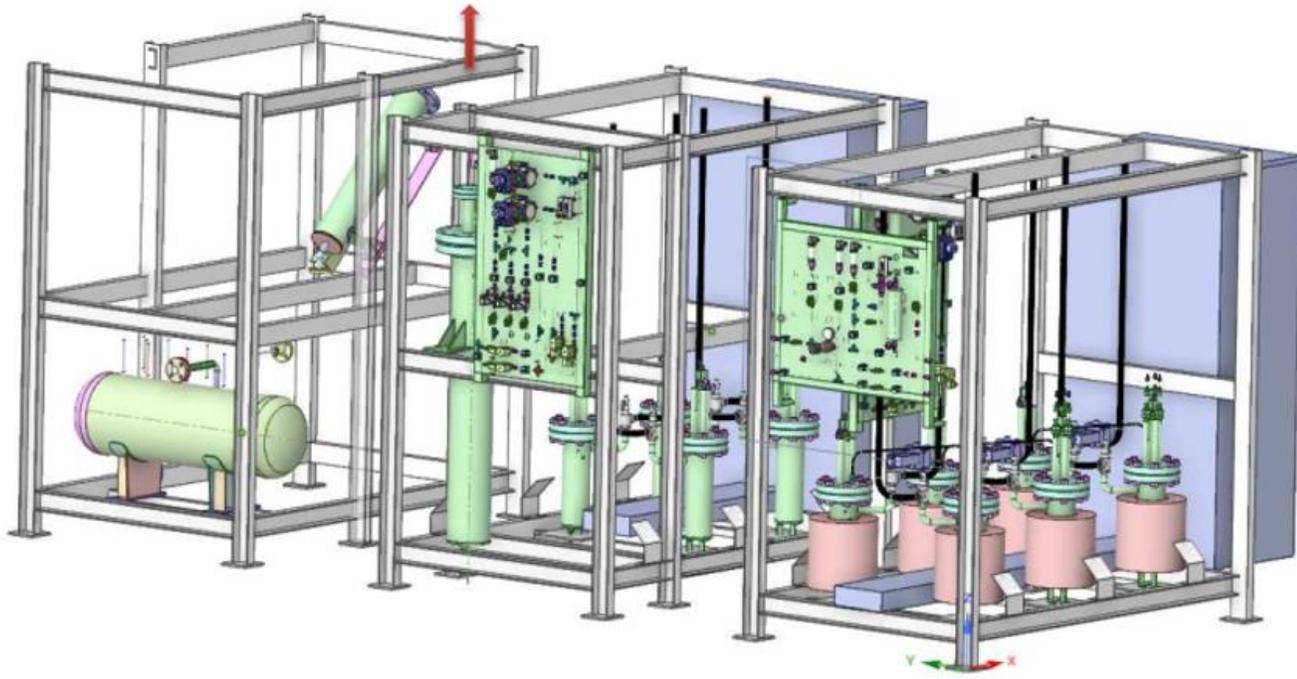
- Buoyancy-driven separation: (1) $\rho(T)$, (2) stimulated by insufficient mix (e.g. due to turbulences)
- Geometry-induced effects: (1) internal structures (barrel, plenum configurations) guide the flow, (2) geometry configuration creating stagnant zones
- Transient operating conditions: (1) Pump coast-down, (2) Transition from forced to natural circulation, (3) Rapid power changes, (4) Start-up and shutdown

► Consequences:

- Structural and mechanical effects: (1) Large temperature gradients on vessel walls, (2) Differential expansion and mechanical stress, (3) Thermal fatigue of internal components, (4) Potential distortion of internals
- Materials and chemistry aspects: (1) Temperature-dependent corrosion and dissolution rates, (2) Non-uniform oxygen control conditions, (3) Localized material degradation
- Thermal-hydraulic performance: (1) Reduced efficiency of heat exchangers, (2) Unpredictable inlet temperatures to pumps, (3) Degraded natural circulation paths, (4) Hot spots in the core outlet region
- Safety functions: (1) Reduced effectiveness of passive cooling systems, (2) Reduced efficiency of DHRs

ChemLab, Lead and Cover Gas Chemistry Laboratory

- ▶ The Chemlab laboratory includes two sections:
 - ▶ A) **Experimental section** dedicated to experimental tests on oxygen control, solubility studies of chemical elements and corrosion of structural materials in liquid lead,
 - ▶ B) **Metallographic laboratory** for the characterization of structural materials in liquid lead and the study of the amount of metals released in liquid lead.



10 Capsules for long-term corrosion tests

- ❑ Medium: static liquid lead;
- ❑ Temperature: 500 - 700°C
- ❑ Volume of Pb: 2 liter,
- ❑ Oxygen Control System: 10^{-6} ~ 10^{-8} wt. %

Small pool-type facility

- ❑ Medium: static liquid lead;
- ❑ Temperature: 525°C
- ❑ High of the vessel: 1.2 m
- ❑ Volume of Pb: 35 liter,
- ❑ Oxygen Control System: 10^{-6} ~ 10^{-8} wt. %

ATHENA and ChemLab, Aspects of the implementation process



ATHENA and ChemLab implementation status

- ✓ Building
- ✓ Primary system vessels installed
- ✓ Thermocouples on the main tanks
- ✓ Main tanks thermal insulation
- ✓ Pipes and valves
- ✓ Water and Pb pumps
- ✓ Secondary circuit
- ✓ Secondary circuit instrumentation
- ✓ Electrical connections for signal and control in the gas panels



Next actions

- ❑ Supply and installation of workstations in the control room - delivered in the pre-commissioning phase
- ❑ Insulation on flanged joints on the piping (to be completed after pre-commissioning tests)
- ❑ Completion of the compressed air distribution line (to be completed after the insulation of the process lines and equipment is completed)
- ❑ Installation of the Gas Service Station (to be completed once the process systems are ready for operation)
- ❑ **Supplying the lead**

ATHENA and ChemLab, support for Licensing

Objectives

Thermo-hydraulics

- operational and accidental regimes, natural circulation capacities
- lead stratification
- erosion of structures
- integral and local flow paths
- temperature and pressure distribution.

Chemistry and materials

- corrosion of structures
- behavior of materials and coatings
- chemistry of lead and cover gas

Safety analysis: system response to simulated accidental regimes.

Validation: validation of integral system codes.

Support for licensing

Qualification of materials, components, equipment and systems

Qualification of coatings

Demonstration of oxygen control in high volume of coolant

Demonstration of filtration capabilities

Test sections

TS #1

- Capsules for corrosion behavior of materials in molten lead, control of oxygen. Instrumented for controlling, monitoring and recording gas flow, temperature and oxygen level.
- Large capsules for studying the efficiency of O₂ getters (oxygen retention vessels); Study of sensors; Long-term corrosion study (over 8000 h) allowing the use of a large number of relevant samples in the conditions of qualification of a material.

Static experiment

- Oxygen measurements;
- Assessment of oxygen sensor reliability;
- Oxygen control;
- Static corrosion of structural materials samples (with and without coatings).

Temperature range in the test section 400 – 550 °C

Operating pressure and design pressure 0,5 bar

TS #2

- Small pool type installation: oxygen control and monitoring systems; specific instrumentation for regulating concentrations in gas mixtures, specific gas sensors for measuring concentrations of gaseous species (hydrogen sensors, oxygen sensors for inlet, hygrometer for outlet).
- *Static/dynamic experiment*
 - Study the gas bubbling method with mixtures of argon / H₂ and argon / O₂ (air) to control the oxygen concentration on a specific range or for a given value;
 - Study the method of realizing the H₂ / H₂O / argon gas for controlling the oxygen concentration on a specific range or for a given value;
 - Study the efficiency of oxygen containment containers (eg Zr, Ti, Mg and Ta) in the condition of liquid lead at a low oxygen concentration and studying the feasibility of their use for a pool type installation;
 - Test potentiometric oxygen sensors for metal in liquid phase (precision, minimum sensor temperature, response time)
 - Test and qualify the control and monitoring system for gaseous intake and exhaust phases (flow control system and gas sensors).
- *Temperature range in the test section 400 – 550 °C*
- *Operating pressure and design pressure 1,5 bar*
- *Flow range - Up to 2m/s*

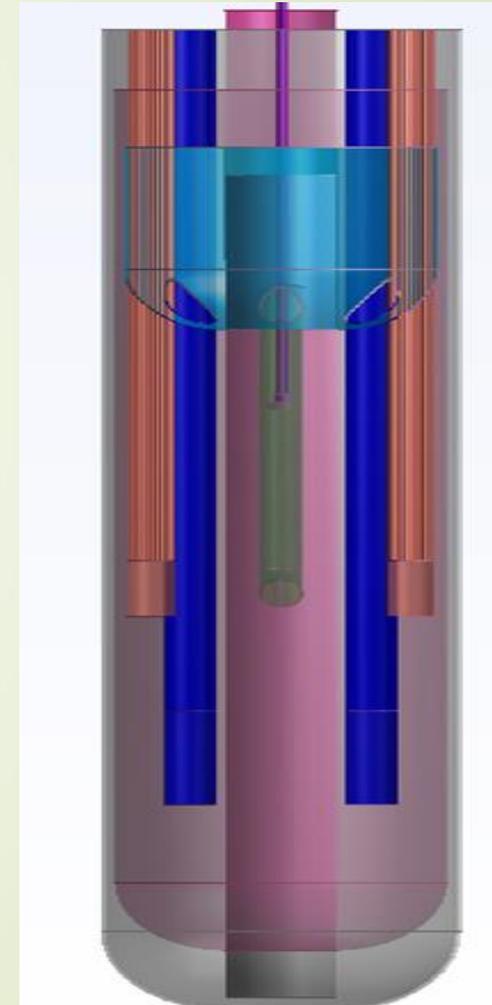
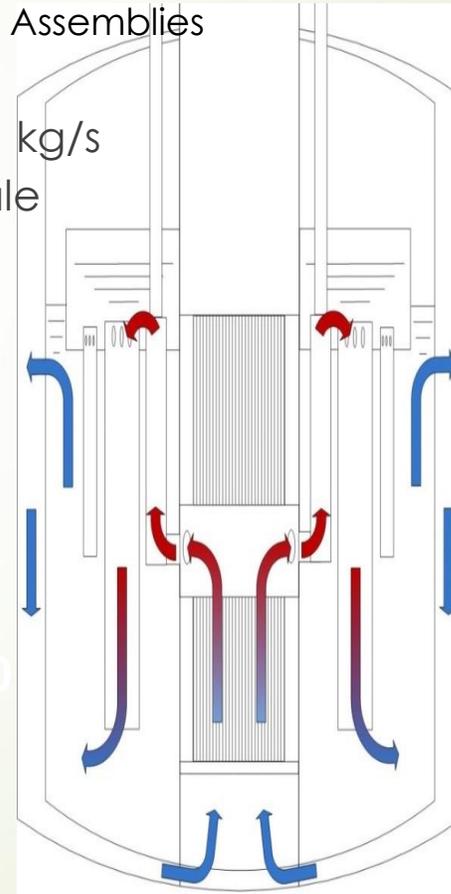
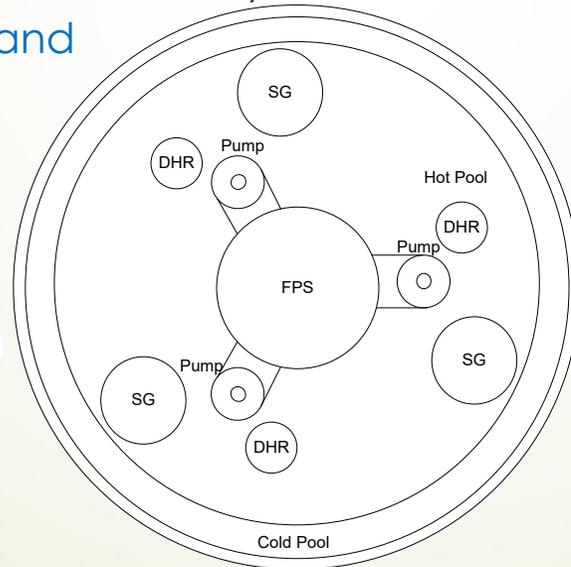
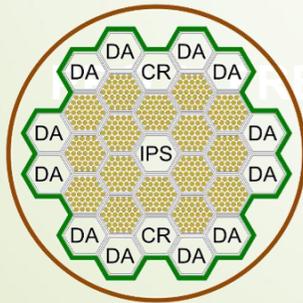
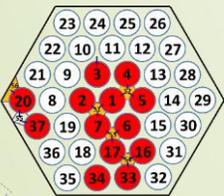
Equipment

Metallographic Laboratory

- ▶ Optical microscope
- ▶ Scanning electron microscope (SEM) coupled with energy dispersive X-ray spectroscopy (EDS),
- ▶ X-ray diffractometer (XRD) equipped to analyze both solid surfaces and powders,
- ▶ X-ray fluorescence spectrometer (XRF) calibrated for chemical elements that can be highlighted in the metal grid and capable of performing XRF and XRD analyses within a single instrument model,
- ▶ Inductively coupled plasma optical emission spectrometer (ICP-OES) for quantitative analysis of metallic elements in ppm concentrations, dissolved or solubilized in liquid lead during corrosion tests.
- ▶ Coolant chemistry measurement and control -measured parameters
 - ▶ oxygen concentration;
 - ▶ temperatures;
 - ▶ lead flow rate
 - ▶ gas flow rate;
 - ▶ concentration of dispersed impurities

ELF, Electric Long-running Facility

- ▶ Large size vessel (2.3 m diameter, 10 m in height),
- ▶ endurance and reliability tests under forced and natural circulation conditions
- Core Simulator (**10 MW**): 31 Sub-Assemblies (S/As), 16 are Fuel Assemblies
- 3 SGs, DHR System
- 3 prototypical vertical pumps operating at $\sim 520^\circ\text{C}$, $\sim 191 \text{ kg/s}$
- ▶ capable of hosting and testing single and coupled full scale components.
- P: 0.3 MPa, design T: 550°C , Pb Inventory: 450 tons
- Coolant Chemistry control and monitoring system (external loop).



ELF activities

- Endurance tests under forced and natural circulation condition to **demonstrate the reliability** and performance of the main components in the reactor cooling system
- Demonstration of the **control of physical and chemical phenomena in large pool molten lead configuration** (stratification effect, natural circulation, and other transient conditions)
- Experimental analysis** of the transition from forced to natural circulation occurring during a simulated protected loss of heat sink with loss of flow accidental scenario
- Investigating the **technological performance of the coolant chemistry control system** in the pool configuration
- Investigating the **long-term effects on coatings** and structural materials in the pool configuration

Objectives

Thermo-hydraulics:

- integral and local flow paths
- thermal stratification and stripping phenomena
- heat transfer between assemblies
- temperature field variation and stabilization in simulated accidents.

Operation and maintenance:

- demonstrate long-term operability of the LFR
- evaluation of operating procedures.

Safety analysis: - system response to simulated accidents.

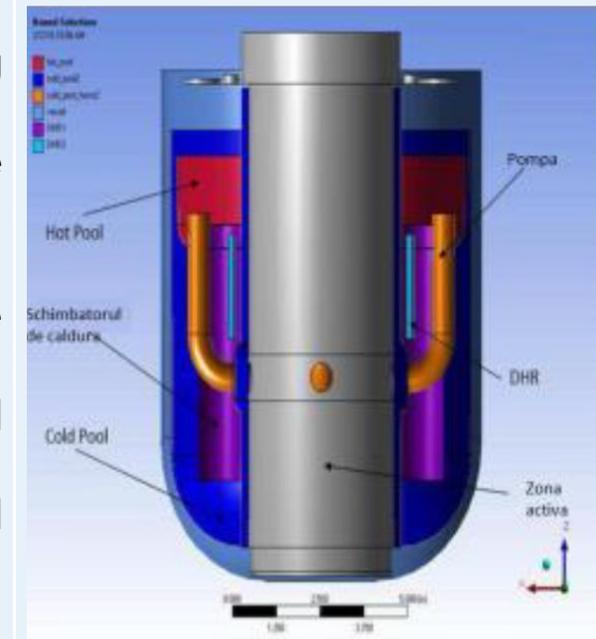
Reliability:

- component performance/failure rates;
- coolant chemistry control performance.

Validation: - validation of integral system codes.

Support for licensing

Qualification of the reactor cooling system design, Performance, reliability and robustness, Long-term evaluation of components (pump, steam generator, chemical cooling systems).



HELENA-2

A loop working under both FC and NC regimes, to test components and equipment in relevant conditions for ALFRED (thermal hydraulics + corrosion).

Thermal-hydraulic characterization of the ALFRED hottest Fuel Assembly (FA), with regards to:

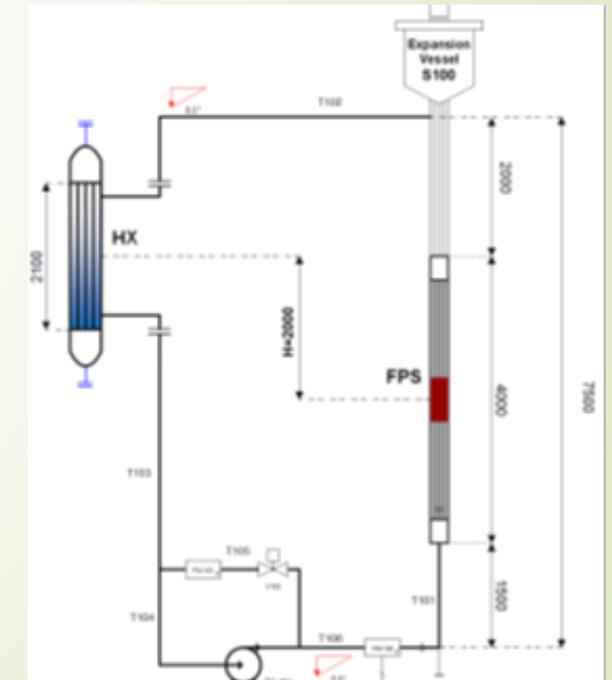
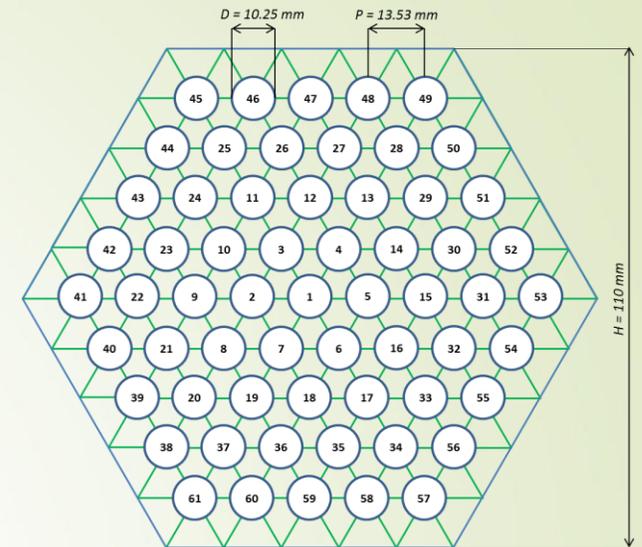
- measurement of the clad temperature;
- measurement of the sub-channel temperature;
- evaluation of the Heat Transfer Coefficient (HTC);
- identification of the hot spot and peak temperature location;
- evaluation of the temperature profile along the heated length;
- experiments in FC e NC regimes;
- flow induced vibration characterization.

Temperatures: max.600 °C

Speeds: max. 2 m / s

O₂ content: 10⁻⁸÷10⁻⁹ % wt

erosion/corrosion and valve testing



HELENA-2 activities, support for Licensing

Objectives

Thermo-hydraulics

- temperature profile along the comb pin
- maximum sheath temperature
- subchannel temperature-local/integral pressure drops
- pin cooling under NC conditions

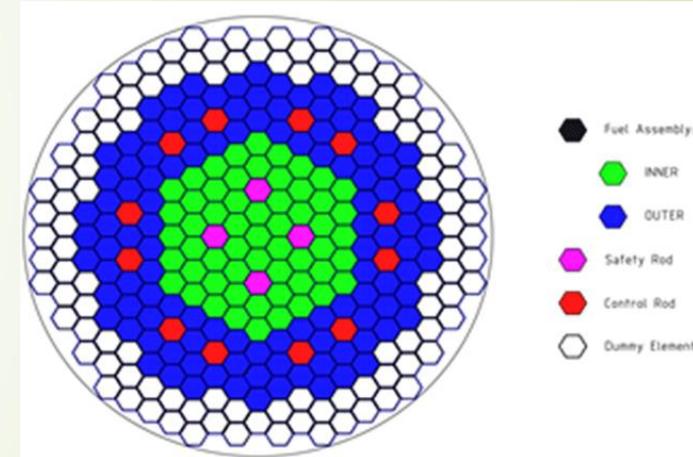
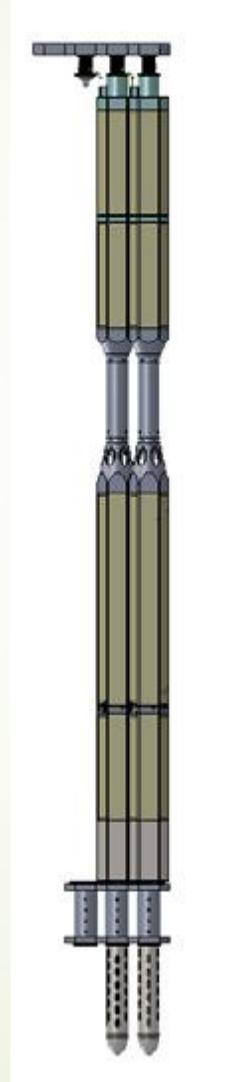
Fluid-structure interaction: beam vibration frequencies and displacements

Validation: validation of the thermo-hydraulic codes of the subassembly

Support for licensing

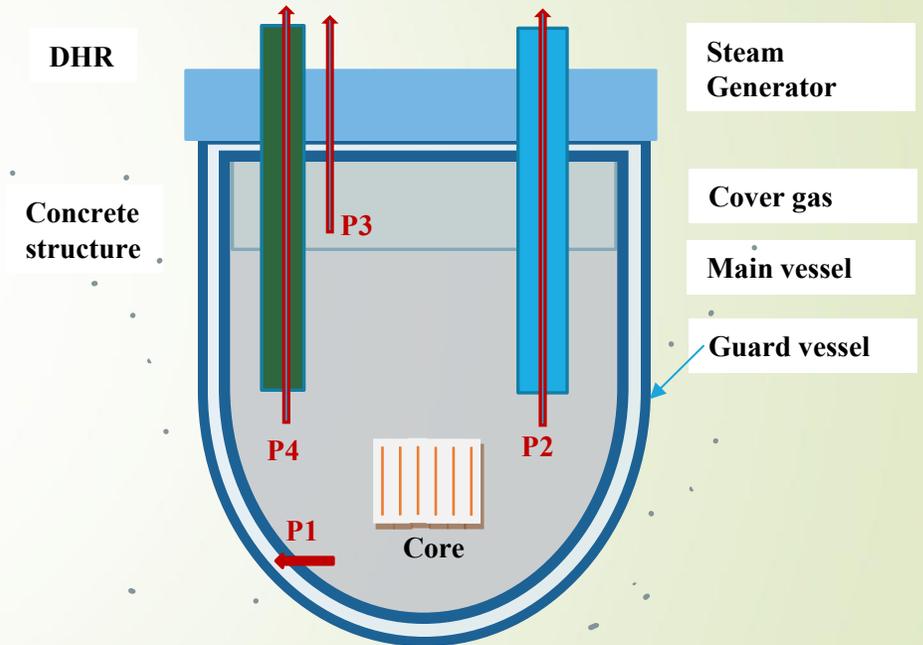
Qualification of:

- fuel assemblies,
- control rods.
- shutdown devices.



SA and Melting Pot Features

- **LOCA is very improbable** in LFR system due to the low operating pressures, and the pool configuration with double structure of vessels
- **SGTR introduces some concerns** and needs for investigations; the entrance of the high-pressure steam in the primary circuits may produce pressure waves and bubbles movement
- a special attention for **coolant flow blockage**, generated mainly by corrosion and erosion of the materials, producing hot spots and possible release via cover gas system and containment atmosphere
- Other paths to be considered
 - accidental opening of top vessel penetrations,
 - rupture of the tubes of the steam generator,
 - rupture of the DHR,
 - failure of the main vessel
- similar concerns like in WCR remain for the SA accidents at SFP



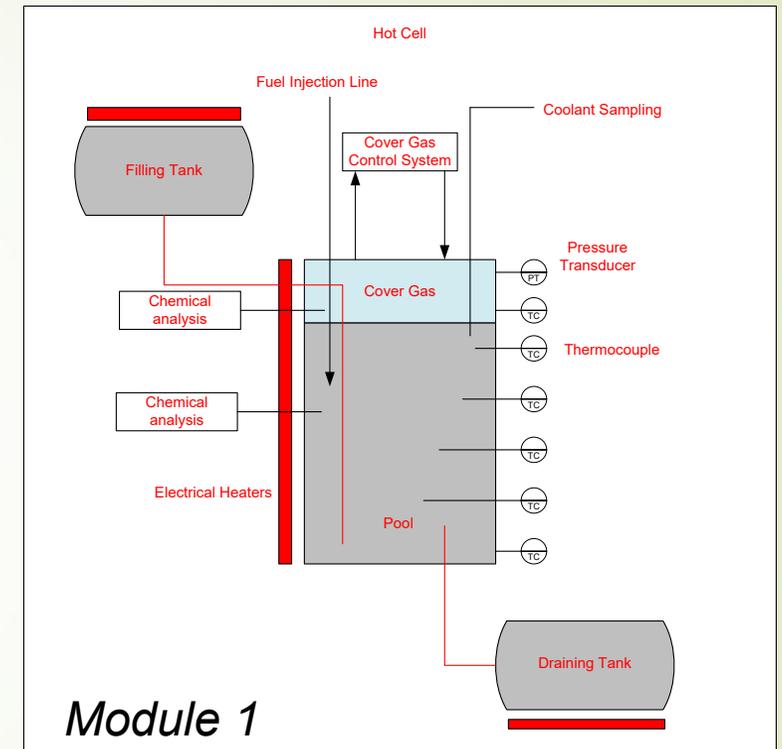
SA and Meltin'Pot Features

Meltin'Pot facility consists of 4 independently operated modules:

- Module 1 - **fuel-coolant interaction**
- Module 2 - **fuel dispersion/relocation**
- Module 3 - **fission product retention/dispersion**
- Module 4 - **polonium retention/dispersion**

Designed to be housed inside dedicated hot cells in the PIEL of RATEN ICN

- V~5-15 l of pure lead, T: 400-750°C, cover gas (argon) system.
- a system to control the oxygen concentration in the lead between 10^{-7} - 10^{-8} %w.
- dedicated systems for the injection of fuel pellets inside the main vessel device and to keep them in fixed positions
- small size due to the contamination of the lead (needs to replace it after each experiment), but enough large to accommodate the device for the injection of irradiated MOX pellets.
- two operational tanks (one for filling, one for the storage of the contaminated lead)



Advanced investigation equipment

EDS; X-ray spectroscope; Backscattered electron emission and secondary imaging SEM, equipped with cathodoluminescence detector; Thermal diffusivity scanning microscope; High temperature X-ray diffractometer; Thermal conductivity microscope; Differential scanning calorimeter; Differential thermal analyzer.

Meltin'Pot, support for Licensing

Objectives

Thermo-hydraulics

- fuel dispersion and relocation

Chemistry:

- fuel-coolant interaction
- retention of fission products in lead and/or migration in the cover gas
- retention of activation products (e.g. Po) in lead
- water/steam-lead chemical interaction

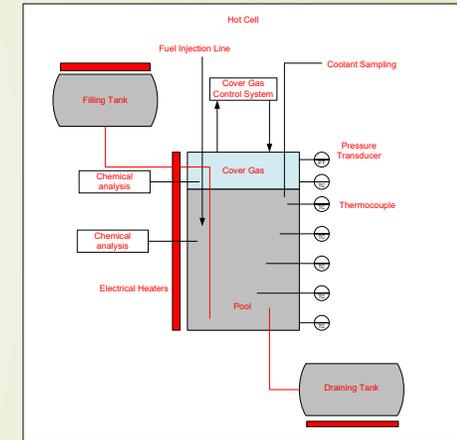
Validation:- validation of chemistry models

Support for licensing

Demonstration of fuel-coolant interaction

Demonstration of fuel dispersion in the coolant

Demonstration of retention of fission and activation products by the coolant

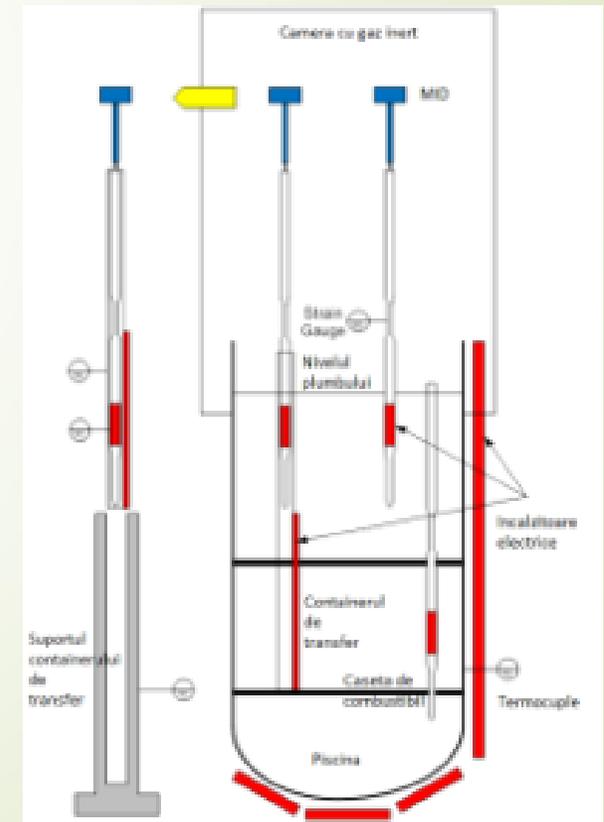
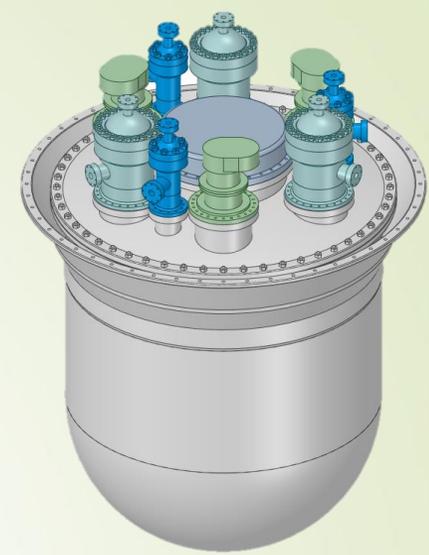


HANDS-ON

- Validation of fuel handling procedure and equipment
- Reliability and robustness of the design solutions adopted for the fuel handling system (loading/unloading control)
- Functionality and reliability of the fuel transfer system with associated transfer container
- Large scale testing and technological assessment of the fuel assemblies' maneuverability, in air (stage 1) and in molten lead (stage 2)

Vessel hosting a full-scale simulator of a sector of the ALFRED core (comprising fuel, control and shield assemblies as well as all the surrounding support and restraint structures), to represent the handling target

A mockup of the handling machine with all the related transfer elements that are required to reproduce the exact conditions that will be experienced by the operators.



Meltin'Pot, support for Licensing

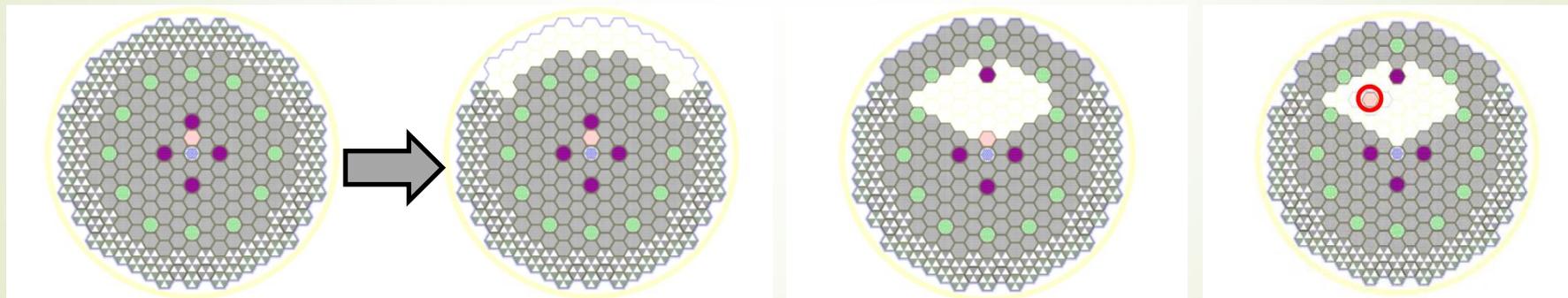
Objectives

Operation and maintenance: demonstration of fuel handling procedures.

Reliability: component performance/failure rates.

Support for licensing

Qualification of fuel handling system and procedures



Experimental programme

- ▶ Licensing experimental programme, in development
- ▶ Some EU support by Euratom projects: LESTO project supporting operation of ATHENA and ChemLab for specific experiments
 - ▶ steady-state experimental and numerical analysis of the ATHENA facility (in forced flow and natural convection),
 - ▶ experimental investigation of **PLOFA (Protected Loss of Flow Accident) in the ATHENA facility**,
 - ▶ validation of the numerical approaches for simulating transients in the ATHENA pool; post-test analysis of the ATHENA transients
- ▶ For ELF, HELENA2, HandsON, Meltin'Pot the experimental programme is in the conceptual phase and the 1st year of operation will be supported by Project 2 (already secured funds).
 - ▶ a stepwise approach: the experiments in Meltin'Pot will start by using fresh fuel (uranium oxide and MOX) and, in a second stage, irradiated fuel, at different burn-up levels (from 10 MWd/kg to 100 MWd/kg).
 - ▶ the different phenomena will be investigated at different temperatures (at least 5) relevant for the ALFRED demonstrator in the range 400 -750°C.
 - ▶ the fuel fragmentation and the resulted configurations of fragments are planned to elucidate the re-criticality issue.
 - ▶ more accurate experimental data on the retention in pure lead under representative temperature and oxygen concentration are crucial for the construction of realistic simulation computer codes

Concluding remarks

- ▶ R&D activities are necessary for the completion of the project, for supporting the licensing process, as well as for the construction of the nuclear systems.
- ▶ Key aspects in the development of LFR are structured in:
 - ▶ Studies/analyses/characterization corresponding to the component materials and coolant chemistry;
 - ▶ Investigations regarding the integrity of the core, components moving in molten lead, instrumentation, maintenance and repair activities, as well as in-service inspection;
 - ▶ Functionality of steam generators, heat exchangers and experimental campaigns dedicated to demonstrating their safety and reliability in operation;
 - ▶ Thermohydraulic of liquid metal systems (processes/phenomena) mainly in pool-type configurations;
 - ▶ Reliability of pumps for HLM;
 - ▶ Advanced fuels and irradiation tests;
 - ▶ Validation and verification of computational codes.

Thank you for your attention!