FAST REACTORS ACTIVITIES IN ROMANIA

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Outline

- National Nuclear Program
- National efforts
  - RATEN R&D program
  - Infrastructure development
- International Collaborations
  - EAGLES Consortium
  - Research projects

Nuclear power in Romania

Cernavoda NPP - two units in operation, covering approx. 18% of Romania's total energy production.

The Romanian Energy Strategy -long-term commitment to nuclear energy
National Strategy for the Development of the Nuclear Field in Romania is aiming for: Security of energy; Sustainable development; Competitiveness as strategic objectives.

Reactor	Type	Construction Start	First Criticality	Operating Status
Cernavoda-1	CANDU-6	1980	16th of April 1996	in operation - refurbishment planned
Cemavoda-2	CANDU-6	1980	6th of May 2007	in operation
Cemavoda-3,4	CANDU-6	1980	-	under preservation, plans for resuming construction
Cemavoda-5	CANDU-6	1980	-	no plans for resuming construction; the existing structures will be used for supporting activities of the other units.

Reconsolidation of the nuclear

❑ **refurbishment of Cernavoda Unit 1 reactor**;

Scenario "Enhanced Safety": Extending the life of Unit 1 for an additional cycle of up to 30 years; Compliance with safety requirements, with an increased safety margin;

The optimal balance between the operational performance of the plant, the financial performance, the risks during the refurbishment and after it.

- Candu Energy - contract (July 2022) to conduct design and engineering services for Unit 1 refurbishment
- Engineering, procurement and construction contract for refurbishment of Cernavoda U1 -a consortium of Korea Hydro & Nuclear Power, AtkinsRealis's Candu Energy, Canadian Commercial Corporation and Ansaldo Nucleare.
- September, 4 - The refurbishment of Cernavodă Unit 1 has started with the construction of an intermediate radioactive waste repository.

Unit 1 –re-operational in 2029

❑ **construction and commissioning of Cernavoda Units 3 and 4**;

- Unit 3&4 design = Reference Design (Cernavoda Unit 2)+ Design Improvements (CANDU latest technology development; CANDU Operating Experience; Design changes resulting from evaluation of Reference Design against latest WENRA recommendations, IAEA NS-R-1 Safety of Nuclear Power Plants: Design; Design changes resulted from Fukushima event.
- November 2024 -The engineering, procurement and construction management contract for the completion of Cernavoda U3 and 4 has been signed with the FCSA Joint Venture including Fluor, AtkinsRéalis, Ansaldo Nucleare and Sargent & Lundy Energie.

Unit 3 to be commissioned in 2030, Unit 4 to be commissioned in 2031.

Plans -cont

❑**implement the NUSCALE SMR project;**

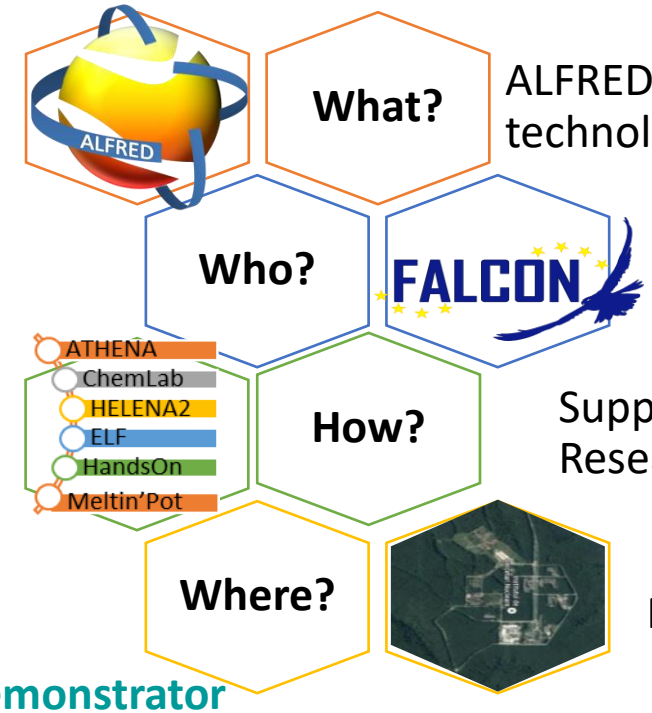
- The first NuScale power module is expected to be built in Romania by 2027
- The full 6-module plant is estimated to be complete by 2028
- **January 2023** -first stage of the FEED study started -a series of initial engineering and design activities and studies, technical analyzes of the location, the estimation of the specific project schedule and costs
- Second stage of Engineering and Design Studies for the development of SMR in Doicești (front-end engineering and design studies and activities, technical analyzes of the site, as well as licensing and authorization activities)
- **May 2023 -** SN Nuclearelectrica SA and the Politehnica University of Bucharest launched the first NuScale Energy Exploration Center, which houses the control room simulator for the VOYGRTM NuScale small modular reactor plant.

❑**Advanced Lead Fast Reactor European Demonstrator (ALFRED).**

ALFRED project - Innovative solution for nuclear energy

Deployment of ALFRED

- prove the advantages of LFR as a technology fulfilling the expectations for Gen-IV nuclear energy systems
- support in the long-term the safe and sustainable operation of future LFR plants



ALFRED is the ETDR for the LFR technology

Supported through a Distributed Research Infrastructure

Mioveni, Romania

Advanced Lead Fast Reactor European Demonstrator

- a design with increased safety and sustainability;
- a key facility for testing and qualifying in a relevant environment new structural materials and nuclear fuels, as well as innovative components and systems;
- an opportunity to improve the knowledge, competences and skills in a comprehensive and well-structured framework, on all operational aspects of LFR technology.

LFR in Romania

ALFRED -included as a key element of innovation in the Governmental Programme; National RDI Strategy; National Strategy for Romania Sustainable Development 2030

- 2011 Government Decision for hosting LFR Demonstrator
- 2013 FALCON Consortium Agreement
- 2014 "ALFRED Construction in Romania" Governmental Memorandum
- 2015 Smart Specialization Strategy of the South Muntenia Region
- 2016 National RDI Strategy
- 2016 Support of scientific community
- 2017 Roadmap of Major Research Infrastructure
- 2017 Support of nuclear industry
- 2018 Romanian Position Paper
- PRO-ALFRED 2019-2020
- ATHENA+CHEMLAB 2020-2025
- POCIDIF 2025-2030

RATEN ICN - representative organization for Romania for the development of the R&D activities and for the construction of the ALFRED demonstrator in Romania

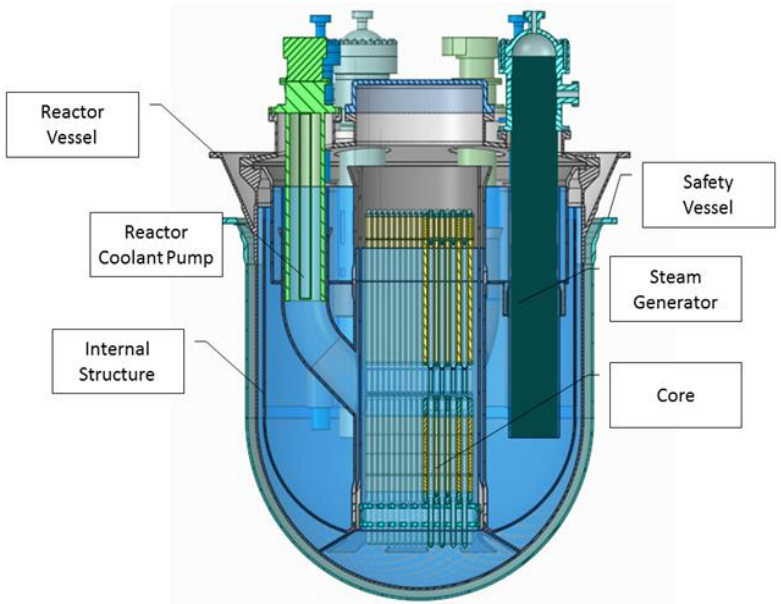
Design

Parameter	Value
Reactor type	Lead cooled fast reactor
Primary system configuration	Pool type
Power conversion system	Land-line
Reactor vessel dimensions	
RV inner diameter	8.3 m
RV wall thickness	0.13 m
RV Height	10.0 m
SG dimensions	
SG total Height	10.41 m
SG Diameter (flange)	1.75 m
Fuel and core	
Fuel type	MOX
FA configuration	Hexagonal, closed
Fuel pin bundle	Hexagonal, grid-supported
Primary coolant	
Type	Lead
Pressure (cover gas)	0.1 MPa
Inventory	3640 tons
Secondary coolant	
Type	Water

- leveraging on advantages of using lead as coolant,
- pool configuration,
- very compact design,
- SGs directly installed inside the RV with a great reduction of the complexity of the primary system,
- no primary pipes to be considered in a LOCA,
- High retention of FPs in the lead in case of core degradation, thus reducing the source term,
- High boiling T of Pb and low vapor pressure – great safety margins.

-passive decay heat removal
-two independent and redundant shutdown systems (diverse actuation principles)

- control rods, bellow the core, passively inserted by buoyancy for SCRAM
- safety roads (only for SCRAM), above the core, inserted by pneumatic actuation, forced insertion by tungsten ballast

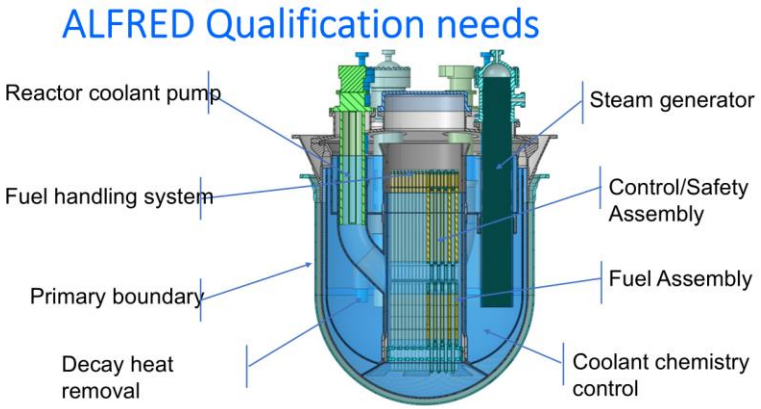


Advanced Lead-cooled Fast Reactor European Demonstrator

- Strengthens the implementation of DiD concept by two key enforcements:
  - additional lines of protection based on the inherent responses and on the passive actuation of engineered provisions;
  - broader margins between the operating and accident conditions, and the failure limits of the means defining the lines of protection.
- Heavily leveraging on the intrinsic safety features, offered by the use of molten lead as coolant, and the design choices, ALFRED will serve to address the lack of operational experience and to manage the licensing challenges.
- Safety approach of ALFRED is consolidated by:
  - use of inherent safety characteristics;
  - use of passive safety systems;
  - minimisation of the reliance on the operator interventions.

- **NATIONAL R&D PROGRAM**

NEEDS



- **Critical stage**: authorization by CNCAN
- The development and deployment of LFRs relies on the qualification of innovative solutions to ensure their safety, reliability, and compliance with regulatory requirements.

- **Testing**
- **Demonstration**
- **Qualification**
  - Materials, 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)

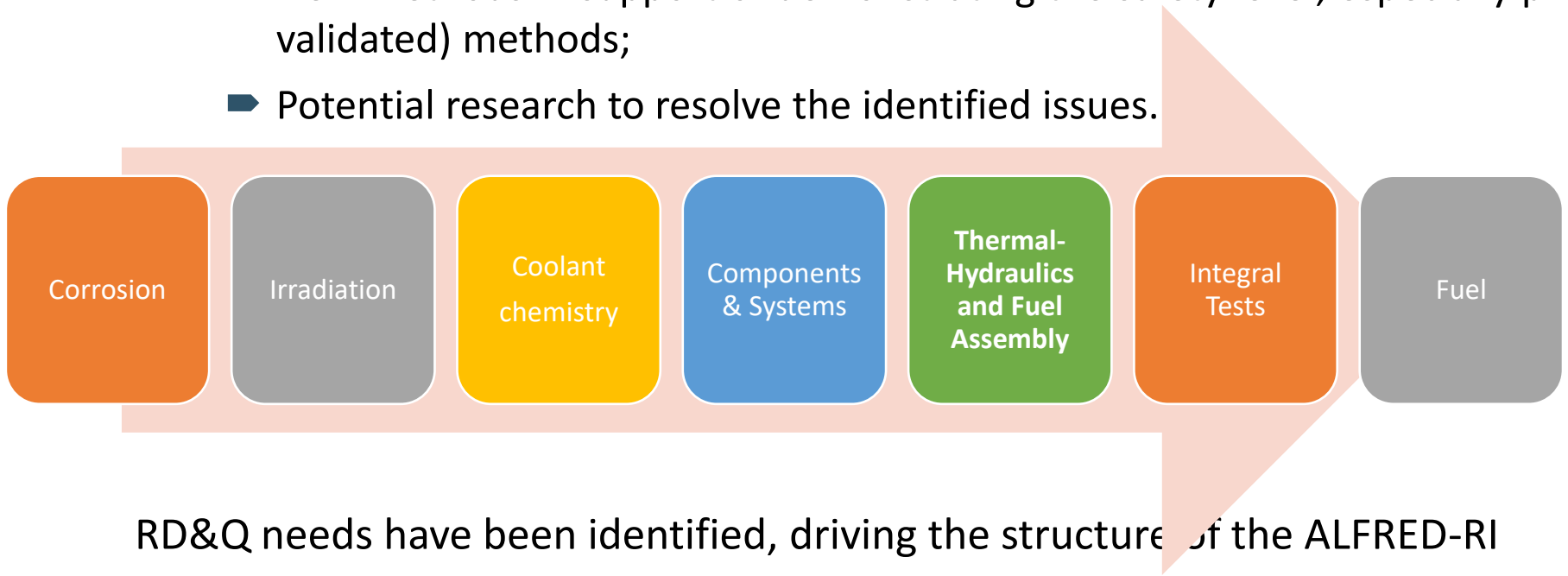
- **Verification**
- **Validation**
  - Design standards and procedures
  - Calculation codes, design codes

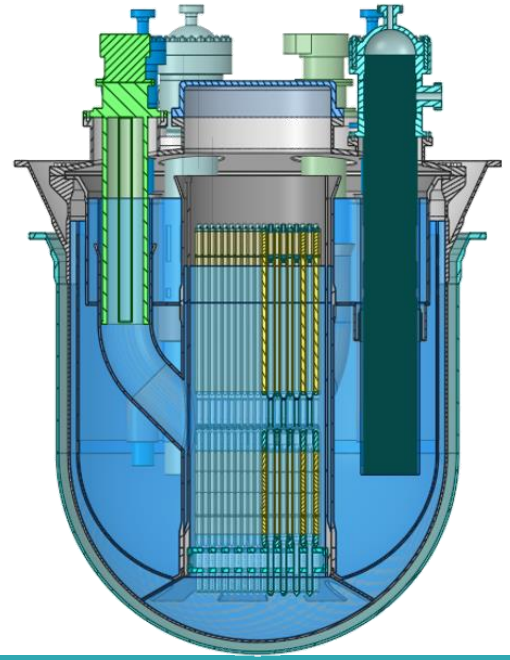
R&D Definition

Opportunities - Innovation in design approach

The design will be reviewed and evaluated regarding its suitability for obtaining the construction and operating license, after the site-specific factors will be taken into account.

- The review of the design aims to identify:
  - Innovative features of the project or SSCs;
  - New methods in support of demonstrating the safety level, especially previously unused (non-validated) methods;
  - Potential research to resolve the identified issues.





RD&Q needs have been identified, driving the structure of the ALFRED-RI

Research Agenda

- Experimental effort, planned for the licensing process of ALFRED, focused on demonstration of full control of the phenomena, qualification activities, validation and verification of computer codes, testing of materials, components and equipment.
- Key aspects in the development of LFR that require further investigation and that were included in Romanian LFR Research-Development-Innovation Agenda :
  - Studies/ analyses/ characterization corresponding to the behaviour of component materials and the coolant chemistry;
  - Investigations regarding the component movement in molten lead (e.g., control and safety rods), the instrumentation;
  - The functionality of steam generators, heat exchangers, etc. -experimental campaigns dedicated to demonstrating their safety and operational reliability;
  - Thermohydraulics of liquid metal systems especially in pool-type configurations.

Advanced Nuclear Reactors and Fuel Cycles R&D Programme

- activities dedicated to fast reactors, focused on LFR technology;
- coordinated by RATEN ICN;
- financed by the Ministry of Energy .

R&D projects devoted to LFR technology development being focused on:

- Nuclear *Reactors Physics* & & Thermohydraulics;
- *Safety Evaluations* for Advanced Reactors;
- *Modelling and simulations* of operational regimes in experimental installations;
- *Infrastructure Development* for Characterization, Testing and Qualification of Materials and Components for Gen IV Reactors;
- Investigation of *materials behaviour and technologies development* for Advanced Nuclear Systems;
- Methodologies for evaluating and *monitoring the operating behaviour* of LFR structures;
- Preparational activities for Advanced and Modular Reactors *Siting and Licensing*;
- Investigation of *scenarios for integration* of innovative reactors in the national energy program, to ensure long-term sustainability;.

- **Infrastructure development**

ALFRED infrastructure role

- *to support ALFRED deployment*; all experimental facilities will contribute to building the knowledge base required for the finalization of the reactor design and preparing the licensing.
- *to support further advancement of the LFR technology*: after the deployment of ALFRED, the reactor itself will serve as additional facility in the infrastructure, contributing to develop up to deployment any further innovative solution allowing the enhancement of the safety and sustainability performances of the commercial units.

ATHENA - Large lead pool, devoted to large-scale testing of the ALFRED main components in different thermohydraulic regimes, and investigating the relevant phenomena (lead stratification, oxygen control, corrosion, and erosion) associated with pool statics, dynamics, and chemistry.

CHEMLAB - Laboratory for lead and cover gas chemistry and materials science

-*the experimental laboratory* to investigate the oxygen control, the solubility of chemical elements, and the corrosion of structural materials;

-*the structural analysis laboratory* to study the interaction between lead and structural materials.

HELENA-2 - Loop type facility to test components and equipment in relevant thermal-hydraulic conditions (forced and natural circulation); Corrosion experiments in lead in dynamic conditions

ELF - Large-scale pool-type facility to test the endurance and reliability of components and systems

HandsON - Pool-type experimental facility, to demonstrate the feasibility of handling of fuel assemblies

MELTIN'POT - behaviour of the fuel in the event of an accident.

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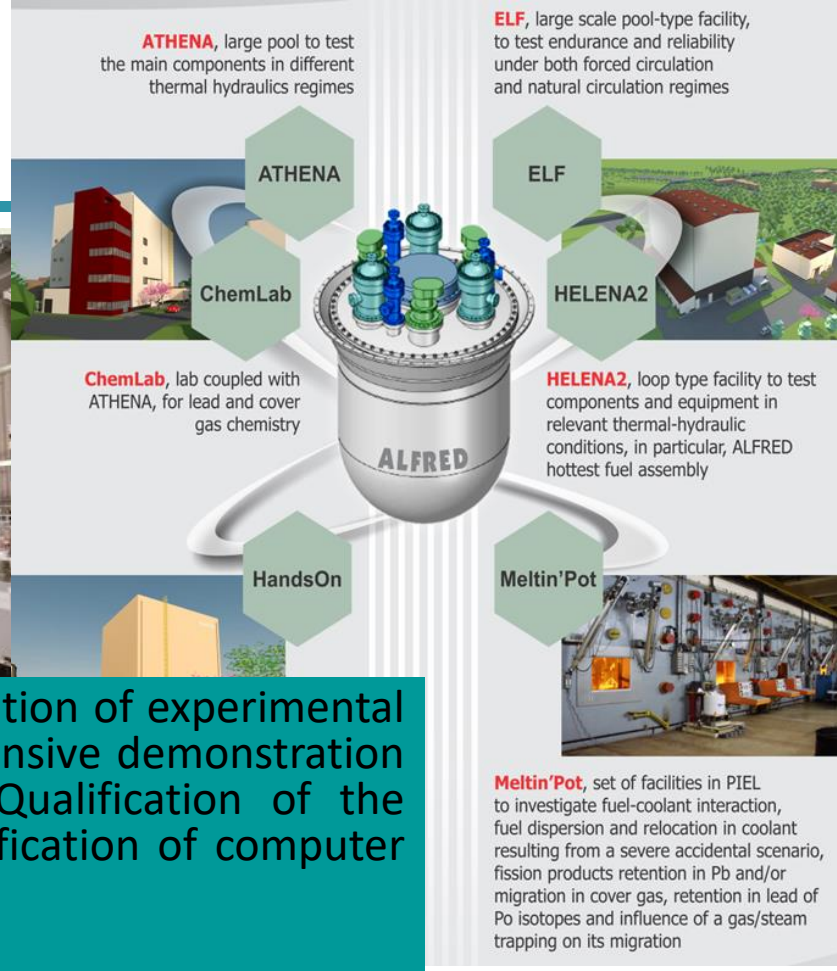
ALFRED infrastructure

Activity is oriented towards the implementation of experimental facilities at Mioveni site, to support an extensive demonstration and authorization program for ALFRED; Qualification of the materials, components; Validation and verification of computer codes



- **International Collaborations**

European research projects - involvement

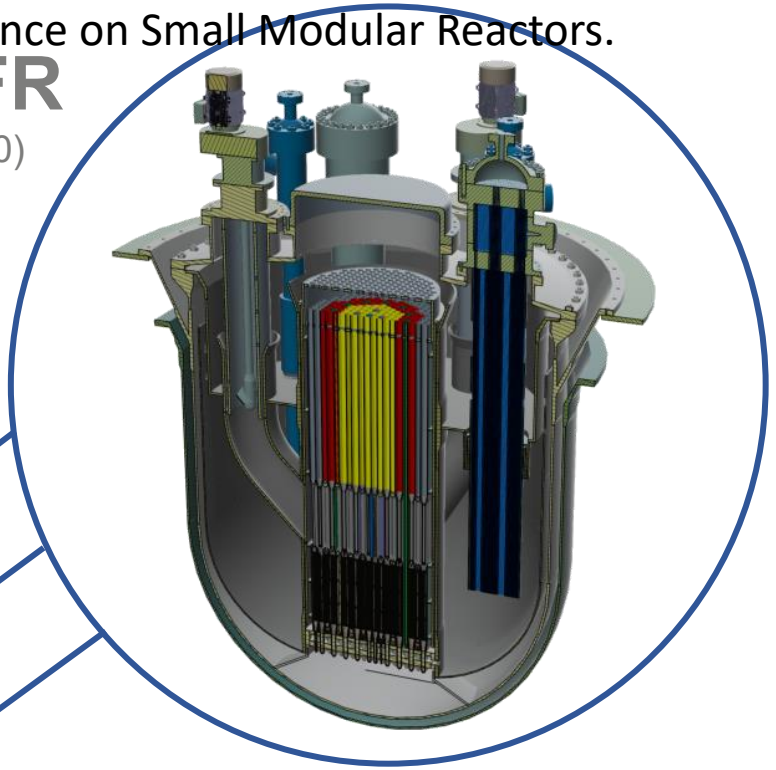
- **GEMMA** (GEneration IV Materials Maturity) (2017-2021)
- **PIACE** (Passive Isolation Condenser) (2019-2022)
- **PASCAL** (Proof of Augmented Safety Conditions in Advanced Liquid-Metal-Cooled Systems), 2020-2024
- **PATRICIA** (Partitioning and Transmuter Research Initiative in a Collaborative Innovation Action), 2020-2024
- **ANSELMUS** (Advanced Nuclear Safety Evaluation of Liquid Metal Using Systems) 2022-2026
- **INNUMAT** (Innovative Structural Materials For Fission And Fusion) 2022-2026
- **HARMONISE** (Towards Harmonisation In Licensing Of Future Nuclear Power Technologies In Europe) 2022-2025
- **FREDMANS** (Fuel Recycle and Experimentally Demonstrated Manufacturing of Advanced Nuclear Solutions for Safety) 2022-2026
- **ECC SMART** (Joint European Canadian Chinese development of Small Modular Reactor Technology) 2022-2024
- **ECOSENS** (Economic and Societal Considerations for the Future of Nuclear Energy in Society) (2022 – 2025)
- **CONNECT NM** (Coordination of the European Research Community on Nuclear Materials for Energy Innovation) 2024-2029
- **LESTO** (LEad fast reactor Safety design and Tools) 2024-2027

International collaborations

Activities to support the MoU between ANSALDO Nucleare, ENEA, RATEN, SCK.CEN - continued, with the objective of creating a partnership for the development of commercial SMR LFR. The EU-SMR-LFR project was selected among the 9 projects that are considered for the working groups of the European Industrial Alliance on Small Modular Reactors.

EU-SMR-LFR

(re-branding EAGLE-300)



European Industrial Alliance on SMALL MODULAR REACTORS

- Competitive economics
- Proven passive safety features
- Sustainable closed fuel cycle
- High temperature heat
- Commercial fleet deployment by 2040

Reference design

Simplified, robust, modular

Candidate sites

Mol-Belgium and Pitesti-Romania

Shared roadmap

Jointly owned IP

ansaldo nucleare FALCON

ENEA FALCON
Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

RATEN FALCON
REGIA AUTONOMĂ TEHNOLOGII pentru ENERGIA NUCLEARĂ

sck cen
Belgian Nuclear Research Centre

- Eagles Consortium - ANSALDO, ENEA, RATEN and SCK.CEN -Collaboration agreement for accelerating the development of LFR technology – June 25, 2025
- EAGLES partners have signed with the IAEA on September 15, 2025, the Practical Arrangements establishing a framework for non-exclusive cooperation in the field of nuclear reactor safety and its interface with nuclear security.

- PA will support a joint pre-licensing pilot process (pilot for NHSI regulatory track) dedicated to the two complementary precursors of the commercial LFR SMR: LEANDREA, an irradiation facility for the qualification of materials and fuel intended to be built in Belgium, and ALFRED, a technology demonstrator planned to be built in Romania.
- IAEA extrabudgetary project will actively involve the Romanian and Belgian regulatory authorities, CNCAN and FANC/Bel V, as well as the Italian regulatory authority as an observer.

Expected Results

- An agreed, robust safety approach for the implementation of DiD in the concept designs of the reactors in the EU-SMR-LFR technology road map;
- An agreed, comprehensive fuel qualification programme for ALFRED;
- An agreed comprehensive R&D road map, systematically addressing the essential areas to be investigated;
- An agreed, robust safety approach and methodologies for DSA and PSA application in the safety demonstrations;
- A positive final opinion of the regulatory authorities on the conceptual designs.

Objectives -Year 1

- Introduction of the reactor concepts to FANC/Bel V and CNCAN
- Presenting the selected design options
- Agreement with FANC/Bel V and CNCAN on the standards to be used in the designs
- Agreement with the regulatory authorities on the safety approaches and use of DSA and PSA safety for demonstration
- Delivery ot the first R&D&Q road map to the regulatory authorities
- Definition of the fuel qualification programme for ALFRED.

Preparatory Phase

- Goal: Support the development of both precursors and SMR-LFR designs in line with international standards and national requirements
- Work within the consortium
  - Establish jointly the internal consortium objectives for pre-licensing;
  - Review the reactors concept designs and decide on design options;
  - Review the safety approaches and align on a common approach.
- Work with FANC/Bel V, CNCAN and IAEA
  - Set up a joint pre-licensing pilot process with FANC/Bel V and CNCAN, trough an IAEA extra-budgetary project (pilot for NHSI regulatory track)
  - Define the set of standards and regulations based on which the designs will be evaluated
  - Format and content of the pre-licensing deliverables and responsible organizations;
  - Definition of the R&D Road Map on the essential areas to be investigated for SMR-LFR technology and responsible organizations

IAEA TC Project -Strengthening the National Capabilities to License Advanced Nuclear Systems

Period: 01.01.2024 – 30.12.2027

Counterpart institutions

-National Commission for Nuclear Activities Control (CNCAN)

-Technologies for Nuclear Energy State Owned Company (RATEN)

- Romania - host country for NuScale SMR and ALFRED
- Limited staff with in-depth knowledge in NuScale and ALFRED licensing topics
- Need to enhance the competences in safety aspects of new technologies, along with a deeper investigation of ways to demonstrate without doubts the high safety level of the new advanced nuclear installations.
- **Goal**: improve the national capabilities in all the safety assessment and safety demonstration related aspects needed for licensing of advanced nuclear systems (NuScale SMR and ALFRED) in Romania
- **Implementation:** through workshops, training courses, fellowships, scientific visits, and expert missions

Take-away messages

- ALFRED Project is conceived as a comprehensive demonstration program for the LFR technology, in which the ALFRED reactor will be supported by a distributed research infrastructure covering the research, development and qualification programme
- The on-going national efforts are devoted to: enlarging the experimental infrastructure, preparational activities for licensing the design, intensive research studies regarding the technology, and contributions to development of commercial SMR LFR reactors.
- A robust pre-licensing involvement aims to provide a means for identification of key areas and topics for which the final confirmation of the associated safety claims will have to be provided by experimental activities, thereby substantiating the ALFRED Safety Demonstration Programme.
- International Collaborations - key condition to success

Thank you for your attention!