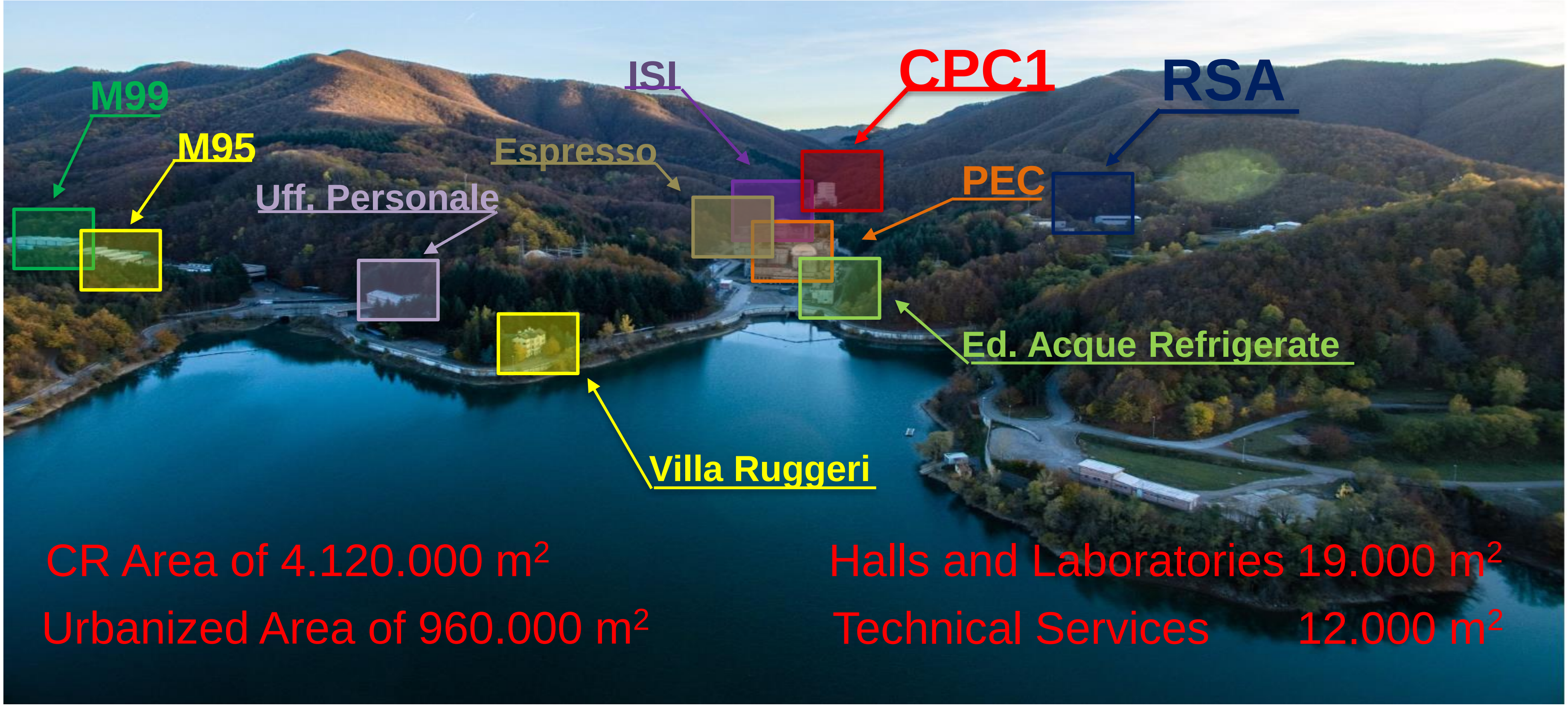
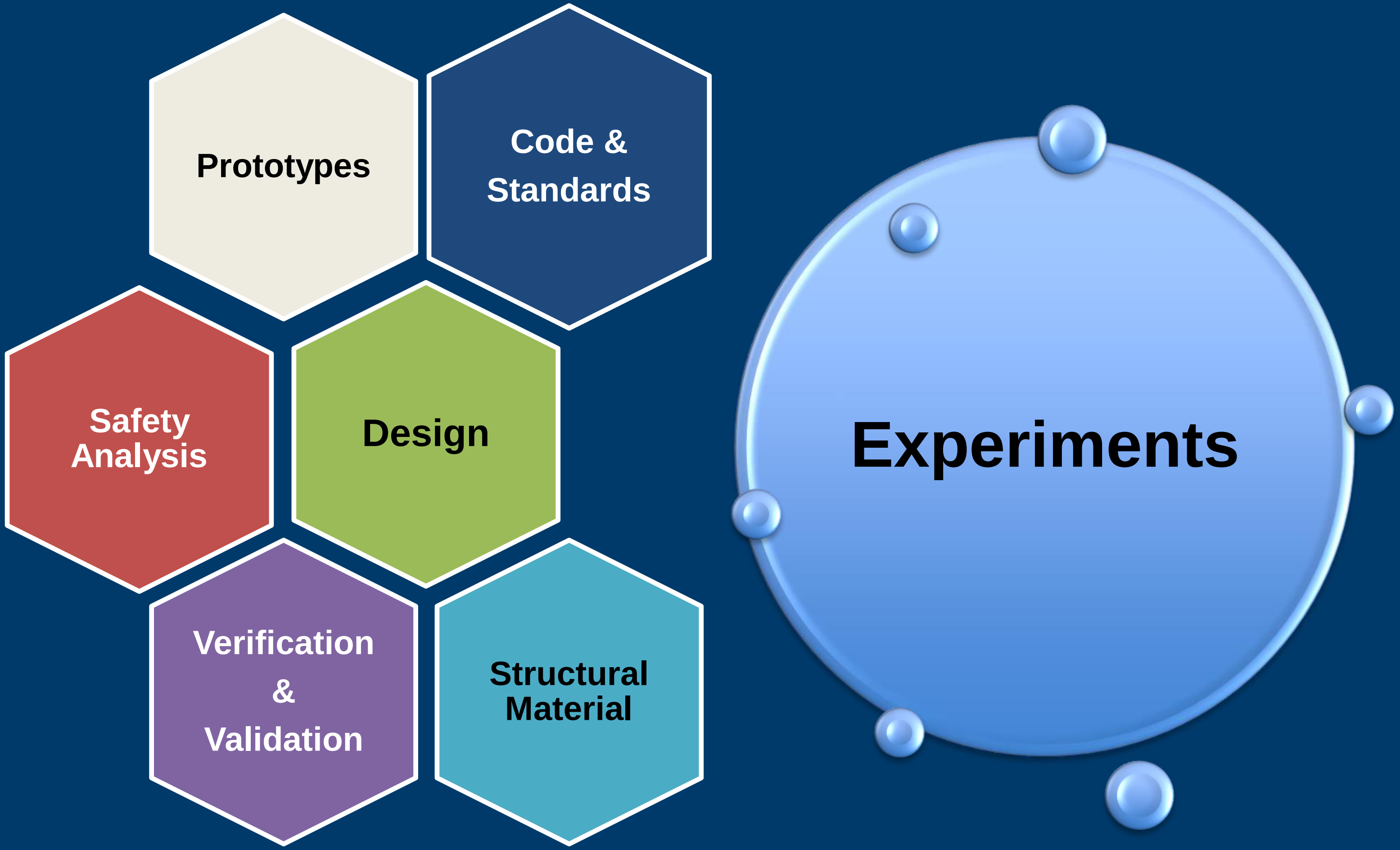
# ENEA Brasimone Research Center


ENEA

Mariano TARANTINO – Nuclear Department

# ENEA Brasimone Research Center




Prototypes
Code & Standards
Safety Analysis
Design
Verification & Validation
Structural Material
Experiments

# Fission

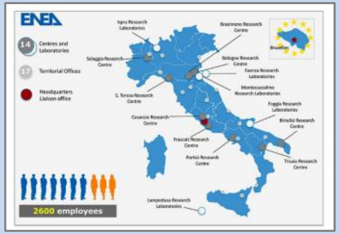
# Italy-ENEA: R&D in Nuclear Technologies

Italy

- Italy plays a leading role in nuclear research and development
- Italy is acknowledged as a reference in:
  - **core design**, **passive safety systems**, **component prototyping** and **technological demonstration**.
- Several spin-offs of this leadership: contracts, collaborations and consultancies from all around the world.

ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development

Since its very foundation, ENEA performs R&D on nuclear fission and plays an important role in Italy.



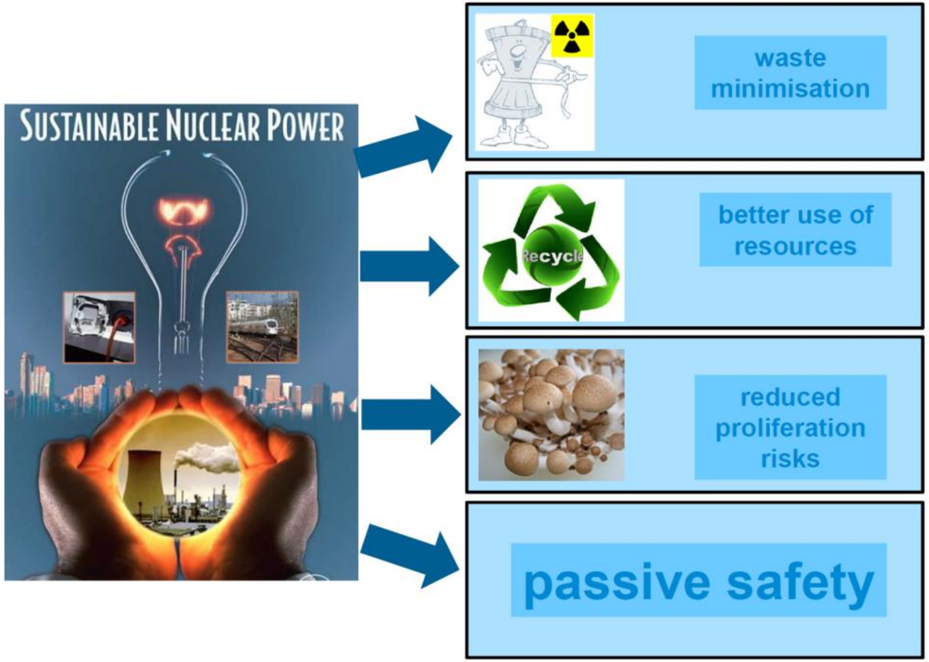
# LFR to solve "open issues"

- Nuclear Energy
  good but not good enough

- Improvement Safety

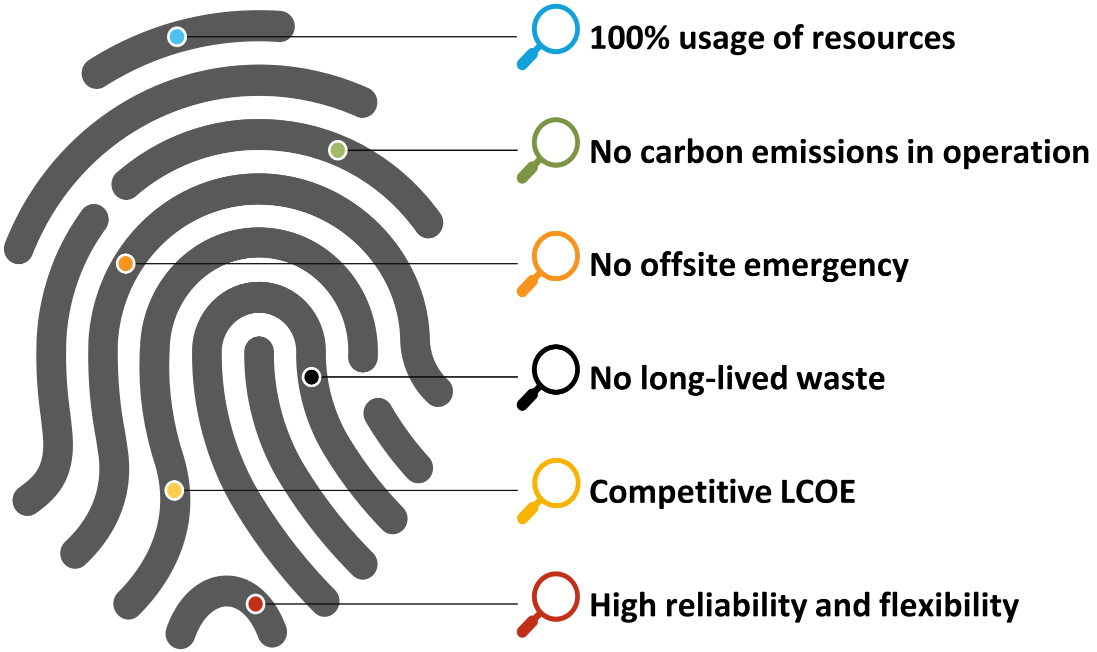
- Waste
  - Too much of it
  - Too long lived

- Economy
  Once through strata
  uses less than 0,5% of the fuel



# The «ideal» Nuclear Power Plant

Fission Nuclear Power Plants of a new type are being developed for a short-term deployment (beyond 2030) to replace the current fleet and better integrate future hybrid energy systems: smaller, more flexible, economically competitive, able to produce more than purely electricity.

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# Closing the fuel cycle

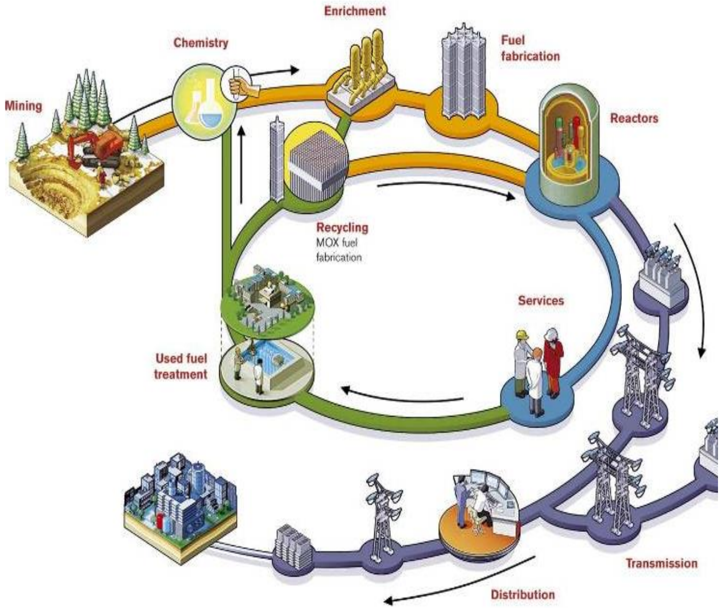
The fission process used in nuclear reactors produces a **number of isotopes that can be toxic to human lives and the environment**.

Since the start of the large scale deployment of nuclear energy, **disposal** of the long lived isotopes has been an issue that has had a priority in most nuclear countries.

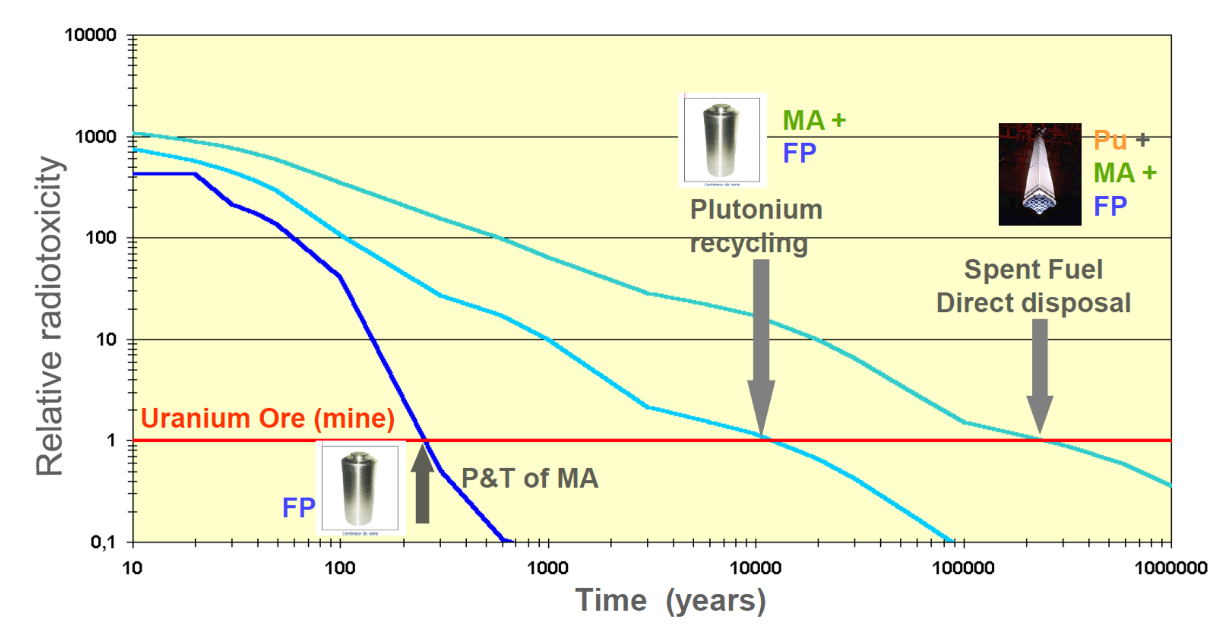
**The P&T objectives can be summarized as:**

- Minimization of waste mass sent to a repository,
- Reduction of the potential source of radiotoxicity
- Reduction of the heat load in the repository

**Fast neutron spectrum reactors are the most adapted technology and offer flexible options for implementation.**



# Closing the fuel cycle




**Recycle of all actinides in spent LWR fuel in fast reactors provides a significant reduction in the time required for radiotoxicity to decrease to that of the original natural uranium ore used for the LWR fuel (i.e., man-made impact is eliminated). From 250,000 years down to about 400 years with 0.1% actinide loss to wastes**

# Lead-cooled Fast Reactor

## Lead has unique properties for developing a fast reactor

| Atomic mass | Absorption cross-section | Boiling Point (°C) | Chemical Reactivity (w/Air and Water) | Risk of Hydrogen formation | Heat transfer properties | Retention of fission products | Density (Kg/m$^3$) @400°C | Density (kg/m$^3$) @400°C | Melting Point (°C) | Opacity | Compatibility with structural materials |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **207** | **Low** | **1737** | **Inert** | **No** | **Good** | **High** | **10580** | 10580 | 327 | Yes | Corrosive |
| Fast neutron spectrum<br><br>Closure of the fuel cycle | Large fuel pin lattice<br><br>Low core pressure loss | Primary system at low pressure | No intermediate loop<br><br>Possible use of low-cost water or air loops for DHR | Reduced risk of plant damage | Reduced risk of fuel cladding overheating | Reduced source term during postulated accidents | No risk of core compaction<br><br>Core supported by lead | But it also has properties that have discouraged some designers | | | |

*Designers* has identified technical solutions to minimize the impact of the unfavorable characteristics of lead and in some cases has also drawn design advantages.

# Toward LFR

*A comprehensive R&D program is necessary because of:*

- **The use of a new coolant and associated technology, properties, neutronic characteristics, and compatibility with structural materials of the primary system and of the core.**

- **Innovations which require validation programs of new components and systems (the SG and its integration inside the reactor vessel, the extended stem fuel element, the dip coolers of the safety-related DHR system, pump, OCS, …)**

- **The use of advanced fuels (*at least in a further stage*).**

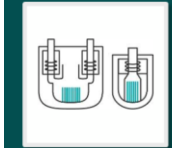
*International Collaborations are set-up and continually strengthen*

# LFR …..supported by Europe (and ENEA)

| Ref. | Acronym | Coordinator | Total Budget | EC Contribution |
|---|---|---|---|---|
| 1 | TECLA | ENEA | 6.061.890,0 € | 2.499.906,0 € |
| 2 | EUROTRANS | KIT | 42.926.414,0 € | 23.000.000,0 € |
| 3 | VELLA | ENEA | 2.147.000,0 € | 2.000.000,0 € |
| 4 | ELSY | ANSALDO | 6.884.590,0 € | 2.949.645,0 € |
| 5 | SEARCH | SCK-CEN | 5.719.903,3 € | 2.977.524,0 € |
| 6 | MATTER | ENEA | 12.180.253,2 € | 5.993.919,0 € |
| 7 | HELIMNET | CNR | 718.348,0 € | 499.984,0 € |
| 8 | GETMAT | KIT | 13.959.123,0 € | 7.500.000,0 € |
| 9 | ADRIANA | UJV | 1.429.911,2 € | 992.650,0 € |
| 10 | ARCADIA | RATEN | 3.543.864,0 € | 3.543.864,0 € |
| 11 | CHANDA | CIEMAT | 9.237.814,6 € | 5.400.000,0 € |
| 12 | ESNII + | CEA | 10.362.135,4 € | 6.455.000,0 € |
| 13 | MAXSIMA | SCK-CEN | 10.087.542,0 € | 5.500.000,0 € |
| 14 | SILER | ENEA | 4.450.851,9 € | 2.926.133,4 € |
| 15 | SARGEN-IV | IRSN | 1.293.111,8 € | 999.128,0 € |
| 16 | FREYA | SCK-CEN | 5.060.978,8 € | 2.799.992,0 € |
| 17 | THINS | KIT | 10.592.854,8 € | 5.941.810,8 € |
| 18 | LEADER | ANSALDO | 5.699.396,4 € | 2.994.088,0 € |
| 19 | CDT | SCK-CEN | 4.029.789,0 € | 2.000.000,0 € |
| 20 | GEMMA | ENEA | 6.625.379,4 € | 3.999.182,0 € |
| 21 | INSPYRE | CEA | 9.368.684,1 € | 3.998.478,8 € |
| 22 | SESAME | ENEA | 6.643.280,0 € | 5.200.000,0 € |
| 23 | MYRTE | SCK-CEN | 11.994.610,0 € | 8.995.962,0 € |
| 24 | PATRICIA | SCK-CEN | 8.415.315,6 € | 6.499.979,5 € |
| 25 | PASCAL | ENEA | 4.610.189,1 € | 3.799.238,0 € |
| 26 | HARMONISE | LEI | 2.843.500,0 € | 2.499.999,8 € |
| 26 | LESTO | ENEA | 4.734.755,5 € | 3.998.638,3 € |
| | | | **211.621.485,1 €** | **125.965.122,5 €** |

| | TRL | TRL Function | Generic Definition | Phase |
|---|---|---|---|---|
| achieved | 1 | Technology Down-Selection | •Basic principles definition | Screening |
| achieved | 2 | | •Technology concepts and applications definition | |
| Ongoing | 3 | | •Demonstration of critical function<br>•Proof of concept | Pre-qualification |
| Ongoing | 4 | Final Process Selections & integration | •Lab-scale component validation | |
| Ongoing | 5 | | •Component validation in a relevant environment | Qualification |
| Further Development | 6 | Full-scale integrated testing | •System/subsystem model or prototype demonstration in relevant environment | |
| Further Development | 7 | | •System prototype demonstration in prototypic environment | Demo |
| Further Development | 8 | Full-scale demo | •Actual system completed and qualified through test and demonstration | |
| Further Development | 9 | | •Actual system proven through successful operations | |

# ENEA & newcleo



**REACTOR DESIGN:**

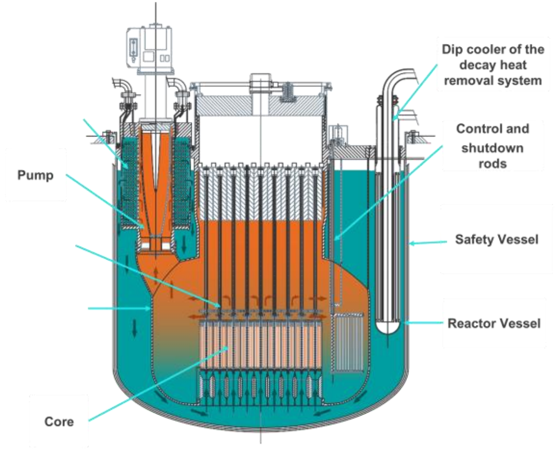
**Small Modular Lead-cooled Fast Reactors**

*new*cleo is working to design, build, and operate Advanced Modular Reactors exploiting fission

**FUEL MANUFACTURING:**

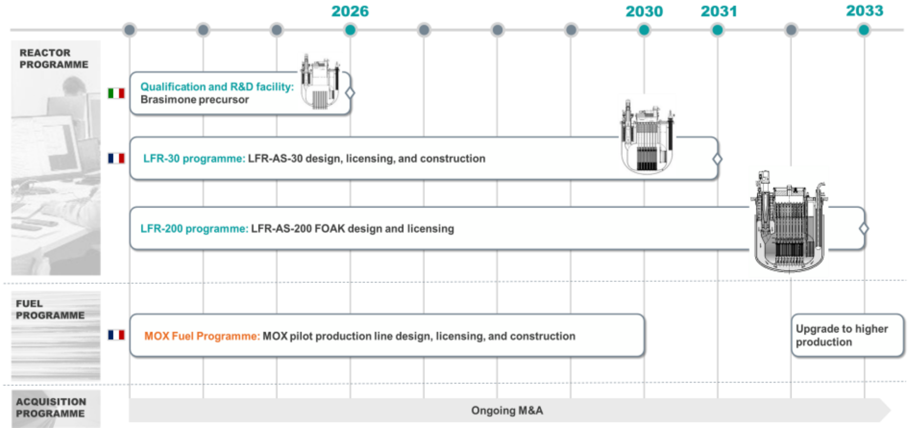
**Mixed Uranium Plutonium Oxide**

MOX and Fast Reactors allow the fuel cycle closure, using what today goes to *waste* as fuel

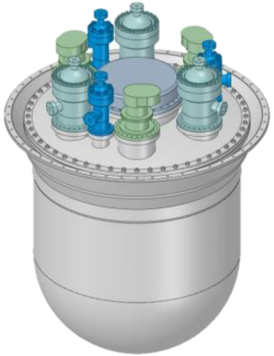



| | |
|---|---|
| **CAPSULES** operational since December 2023 | Several tanks filled with O2-controlled lead and Argon, and with immersed specimens: corrosion of structural materials in molten lead |
| **CORE** **200 kW** operational in March 2024 | New loop-type test facility for corrosion/erosion testing of structural materials in molten lead |
| **OTHELLO** **2 MW** conceptual design in progress | New thermal-hydraulics loop test facility: components performance testing, validation experiments |
| **PRECURSOR** **10 MW** pending definition of detailed objectives and scope | New pool-type large-scale test facility: broad-scope investigations on LFR system transient behaviour, component testing/qualification, etc. |
| **MANUT** pending definition of detailed objectives and scope | Mechanical-type test facility: fuel handling systems and mechanisms (including rotating plugs) in air |
| **CHEM-LAB** | Chemical laboratory to support lead technology related investigations |
| **NACIE-LHT** procurement in progress | Test section at existing ENEA NACIE loop facility: lead cross flow heat transfer |
| **CIRCE-SGTR** **with UniPi** pending definition of detailed objectives and scope | One or more test sections at existing ENEA-CIRCE: thermal-hydraulics and fluid-structure-interaction phenomena involved in Steam Generator Tube Rupture (SGTR) scenarios in LFR |
| **CIRCE-XXX** pending confirmation of availability | Campaigns at existing ENEA CIRCE: endurance tests on axial flow pump bushings, control rods insertion/handling, components insertion/extraction, circulation transients |
| **DIP COOLER** **at PoliTo** detailed design in progress | New test facility mimicking dip cooler based Decay Heat Removal system: performance and start-up issues |
| **ATHENA-XXX** **at RATEN-ICN** pending confirmation of availability | Campaigns at existing pool-type ATHENA test facility with new test sections to be designed: thermal-hydraulics, lead chemistry control in large pools, SGTR tests with full-length tubes |
| **MATERIALS LAB** **Environmental Park Turin** pending confirmation of availability | Material laboratory, mechanical testing on structural materials |

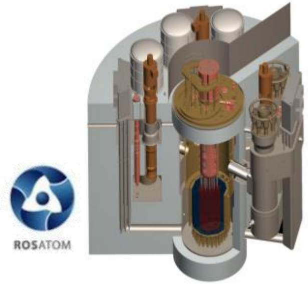
## roadmap to achieve tangible development goals



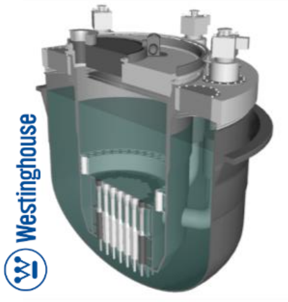
# International Framework



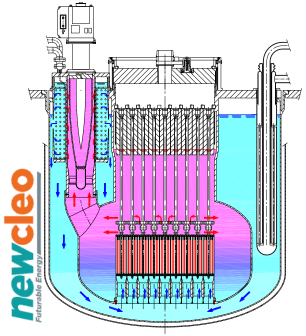
ALFRED
120 MWe, Romania - Italy
Under design




BREST-OD-300
300 MWe, Russia
Under construction

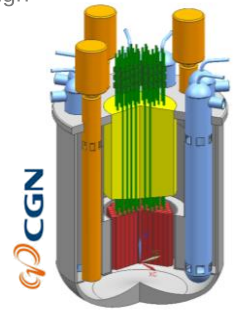



Westinghouse LFR
450 MWe, USA
Under design

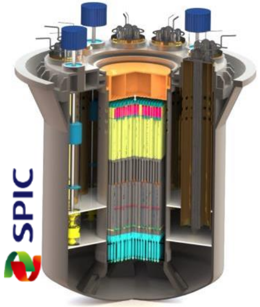



NewCleo AS-200
200 MWe, UK-ITALY
Under design

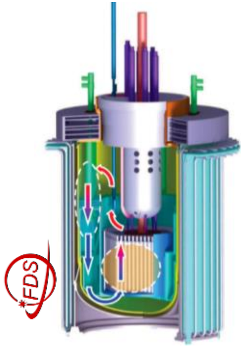

LeadCold SEALER
1-10 MWe, Sweden
Under design




CLFR-300 and CLFR-10
300/10 MWe, China
Under design




BLESS
100 MWe, China
Under design




CLEAR-1
10 MWth, China
Under design


Micro-Uranus
60 MWth, Korea
Under design

# EAGLES-300: Enlarging the collaboration at European level

**Italy**

- Investing in LFR research since the 2000s.
- Discontinued national research program in 2018.
- But continued to support industrial research and Euratom projects.
- Now showing renewed interest in nuclear technologies.
- Very open to international collaboration.

**Romania**

- RATEN-ICN center involved in European projects on LFR since about 2010.
- Declared interest in hosting the first LFR demonstrator (ALFRED) in 2011.
- Joined the FALCON consortium led by Ansaldo Nucleare in 2013.
- Eembedded ALFRED and the associated research infrastructure in multiple national strategy documents.
- Financing the largest and most powerful experimental lead infrastructure in Europe (ATHENA).
- Allocated an additional €100 million over the next 4-5 years.

**Belgium**

- Traditionally focused on ADS to LBE solutions.
- In 2022, an analysis of SMR solutions was launched, concluding that LFR is the technology that best meets national targets.
- Allocated an investment of 100 M€ over 4 years.
- SCK CEN is in charge of the research and demonstration activities.
- Experience in licensing process with FANC/Bel-V.
- Managing a fleet of experimental HLM-based infrastructures (including a subcritical reactor).

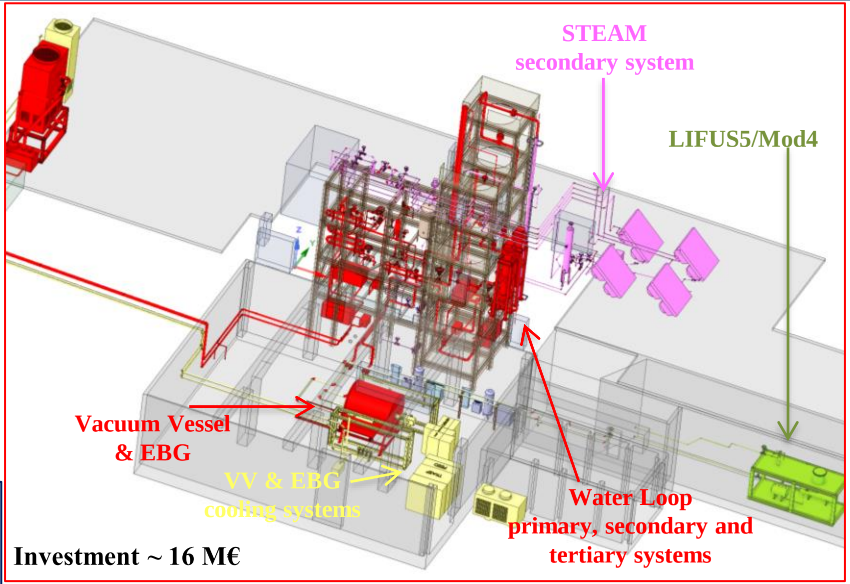
# Fusion

# W-HYDRA Platform – in construction

- **W-HYDRA** *(Water cooled lithium lead-thermal-HYDRAulic)* **platform includes***:*
  - **WL** (*Water Loop*): WCLL Test Bed and a related water facility (Medium/Large Scale Water Facility)
  - **STEAM** (*STEAM generator test facility*)
  - **LIFUS5/Mod4** (*the 4° version of lead-LIthium FUSion 5 facility*) → integral test facility experiment of PbLi/water reaction scenarios

**W-HYDRA** is a large experimental infrastructure (3.1 MW heating power, 18.5 MPa pressure, 25m in height)

- Strategic for the development of the TBM, the Breeding Blanket and the Balance of Plant of the ITER and DEMO reactors
- Unique in the international panorama, it will be able to support the design, technology and licensing of ITER's Water Cooled Lithium Lead TBS
- Flexible: it can be used for testing activities related to the Fusion field and beyond, thanks to the availability of an 800kW Electron Beam Gun and of a 25 $m^3$vacuum chamber




**Investment ~ 16 M€**

**W-HYDRA platform under construction – planned at C.R. Brasimone by 2025**

**Experimental activities scheduled are:**

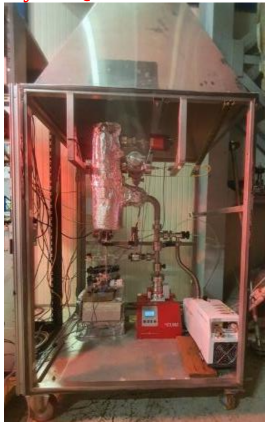
- ✓ WCLL BB First Wall mock-up in **WL with EBG**
- ✓ WCLL BB Manifold mock-up in **WL**
- ✓ WCLL BB SG pulsed operation in **STEAM**
- ✓ WCLL BB "in-box-LOCA" in **WL+LIFUS5/Mod4**

# PbLi-Tritium extraction technologies

IELLLO facility

TRIEX-II facility

HyPerQuarCh II device



PAV internals – Nb tubes

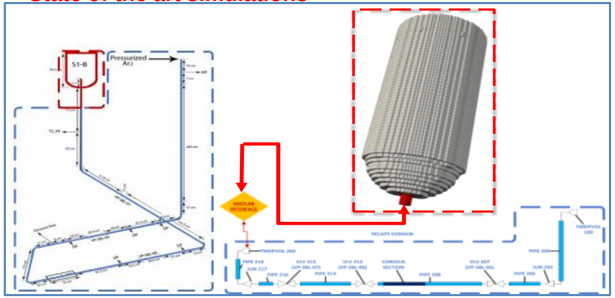
GLC Mock-UP

- TRIEX-II facility – H isotopes extraction from PbLi – Testing of Gas Liquid Contactor (**GLC**) and Permeator Against Vacuum (**PAV**)
- HyPerQuarCh II device – Studies of H isotopes solubilities in PbLi
- HPS sensor – for monitoring/measuring the H isotope concentration in PbLi and tested/calibrated in stagnant conditions (HyPerQuarCh II) and fluent conditions (TRIEX-II) – developed @ ENEA
- Testing of industrial and prototypical instrumentations in PbLi (IELLLO)
- Supporting the PbLi loop design, testing the components, operating procedures and the industrial and prototypical instrumentations in PbLi (IELLLO)

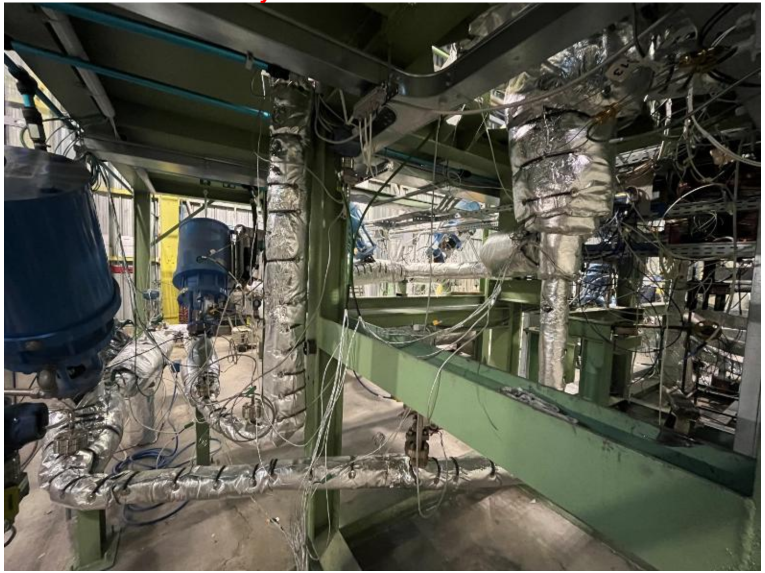
# PbLi-water interaction & Code Development

- Separate Effect Test Facility **LIFUS5/Mod3** aimed at generating the experimental database for codes' development and validation during PbLi and water interaction (chemical reaction process, first pressure peak)
- State of the art computational capabilities in simulating complex multi-fluid/multi-phase accident scenario

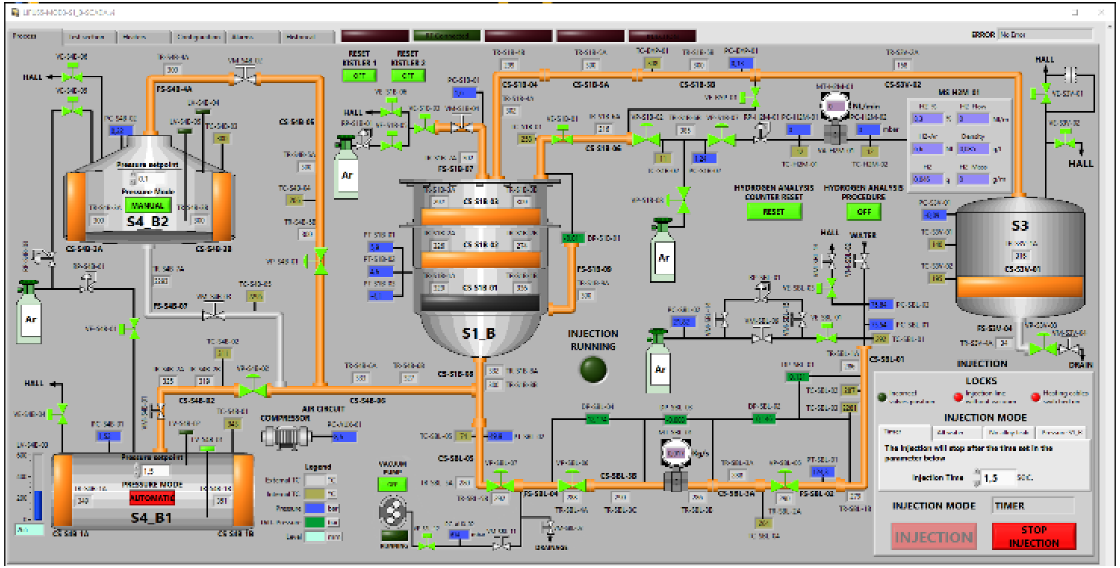
State of the art simulations



LIFUS5/Mod3 facility

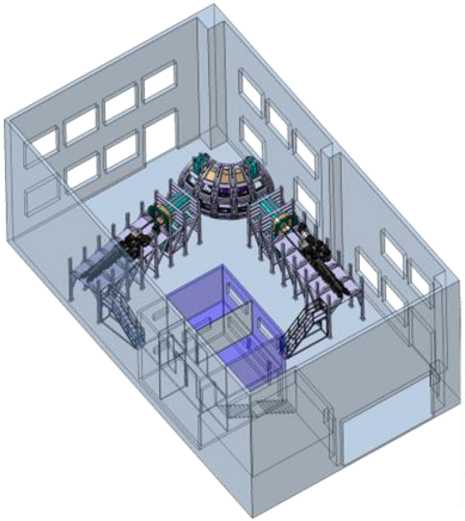


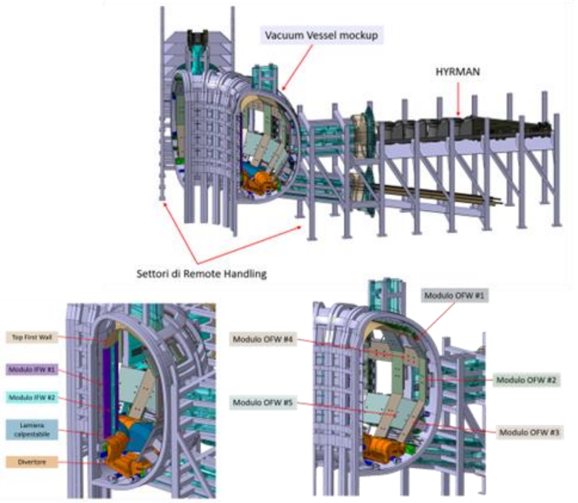
LIFUS5/Mod3 synoptic



# DTT RH Training Facility

- The REMote HAndling Test FACILITY (REMHAT) will be manufactured by ENEA and installed at Centro Servizi Metrologici e Tecnologici Avanzati (CeSMA) – University of Naples Federico II.
- The project include the supply of:
  - Refurbishment of the building
  - Procurement and installation of Vacuum Vessel Mock-up (110°)
  - Procurement of n. 3 CMM (**CASSETTE MULTIFUNCTIONAL MOVER** ) for the assembly and replacement of Divertor Cassett
  - Procurement of n. 2 HYRMAN (**HYPER-REDUNDANT MANIPULATORS**)
  - Control System






The REMHAT facility is part of the proposal for "*Rafforzamento e creazione di Infrastrutture di Ricerca*" ("Strengthening and creation of Research Infrastructures ") financed in 2022 to ENEA by the Italian National Resilience Recovery Plan (PNRR), the DTTU (Divertor Tokamak Test facility Upgrade) project has been established.

# SNR

# ENEA collaborations on Surface Nuclear Reactors

## Partners

Agenzia Spaziale Italiana

Ministero dell'Ambiente e della Sicurezza Energetica

framatome Space

## Activities

**SELENE**

Moon Energy Hub design

SELENE Sistema Energetico Lunare con l'Energia Nucleare

**Space It Up**

Enabling Techs for human exploration

**Piano Ricerca Nucleare**

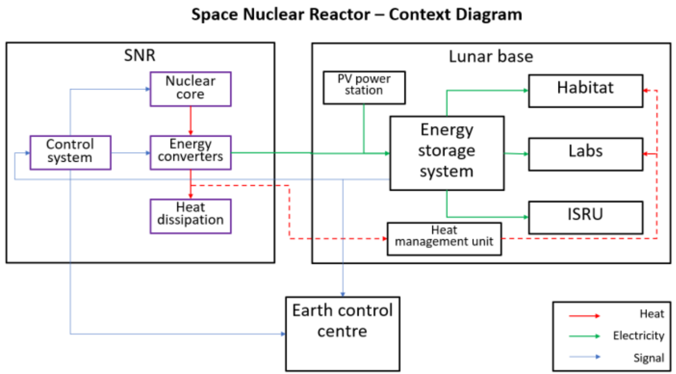
Analytical/Exp. activities of critical techs

# ENEA – ASI: Feasibility study

Framework agreement between ENEA and the Italian Space Agency (ASI) which aimed to discuss the feasibility of a Space Nuclear Reactor (**SNR**) for the Moon:

Objectives

- Analyse context and opportunities
- Define reference scenario
- Identify key system requirements
- Select specific technologies
    - Nuclear core
    - Heat transfer
    - Energy conversion
    - Heat dissipation
- Assess feasibility through option engineering

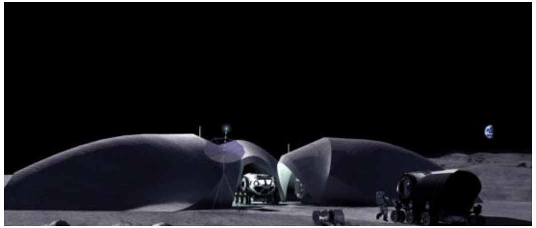



Reliability:
- Minimum power always available
- Failure rate & dose limits
- Resistance to loads
- Remote maintenance

Operation:
- Nominal power output: 350 $kW_e$
- Automated control
- Operating life: 10 years

Flexibility:
- Load following capability
- Sub-system level modularity
- Design scale-up flexibility

Deployment:
- Payload compliant with launchers
- Automated commissioning
- Ready to launch by 2035

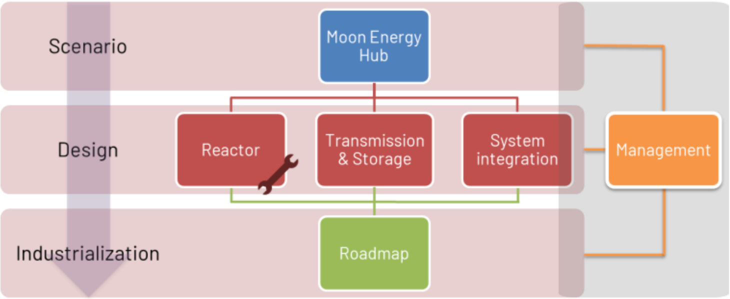


# The SELENE project

SELENE
Sistema Energetico Lunare con l'Energia Nucleare

## Objectives

Project co-funded by ASI with a focus on the concept of a Moon Energy Hub, responsible for the production, storage, and transmission of electrical/thermal energy through nuclear reactors (SNR).




Experiment

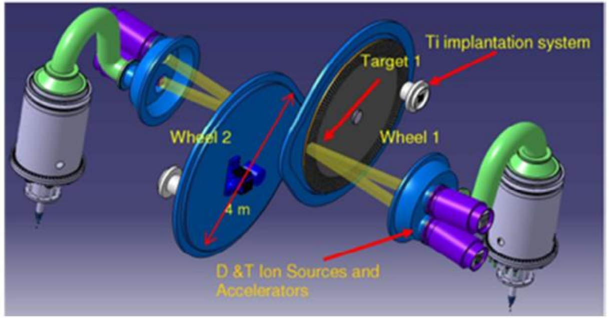
## Team


SELENE duration spans June 2024-27

# Innovative Technologies

# SORGENTINA-RF

**Project goal**: Increase the Technology Readiness Level (TRL) of an experimental plant for the production of radiopharmaceuticals using fast fusion neutrons




Total project cost: € 4’664’014.45

- € 3’498’010.84 **Regione Emilia Romagna**
- € 1’166’033.61 **ENEA**

Project outlook:

- Waste-minimized production of radiopharmaceuticals
- Low-cost production of parent solutions for radiopharmaceuticals
- Development of new technologies in collaboration with industry

ENEA

# EXADRONE

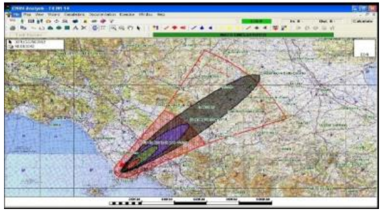
- **Laboratorio Automazione e Controllo:** Investi quasi 500 k€ complessivamente, permette di realizzare, testare e validare attrezzature innovative.

- **Accademia di Volo:** attrezzature e campo di volo disponibili. Nullaosta ENAC.

- **Monitoraggio Ambientale**. Progettato e realizzato LIDAR con laser e spettrometro ultracompatto come payload del drone per analisi acque (laghi, fiumi, mare). (Supporto PA)

- **Monitoraggio Ambientale**. Progettato e realizzato sensore nucleare come payload del drone per monitoraggio ambienti contaminati e applicazioni CBRN.

- **Progetto SAVE**: mediante **Laboratorio Automazione e Controllo** vinto bando di gara MIUR per la prototipazione e futura industrializzazione di una lampada a LED per sanificazione COVID-19.



- METAPROJECTS in partnership con ENEA.

# LINC-ER

Progetto **LINC-ER: Laboratorio per la caratterizzazione di Irradiatori Neutronici Compatti in Emilia Romagna** *(La nuova infrastruttura serve a caratterizzare un Neutron Brush intraoperatorio)*

- Budget di progetto → **500 k€** *(opere civili e attrezzature)*


**Generatori di Neutroni** (Compact High Flux D-D Neutron Generator) commissionato da THERANOSTICENTRE Srl e prodotto da BERKION TECHNOLOGY LLC (USA) completato.

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