The safe management of spent fuel and radioactive waste management in the small inventory Member States, Brussels 22 October 2024

Overview of JRC role and activities in radioactive waste management, infrastructure and training

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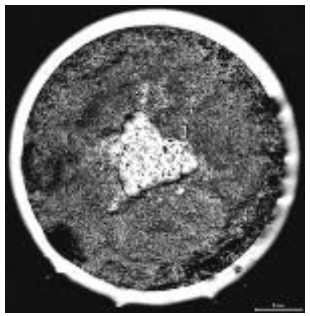
Outline

- Introduction and context
- Nuclear research infrastructure and experimental scope
- Access and training capacities
- Support to stakeholders
- Perspectives

Spent LWR fuel



Spent fast reactor fuel

European Commission

Directorate G: Nuclear Safety and Security

Implementing the EURATOM Research & Training Programme

Radioactive Waste Management

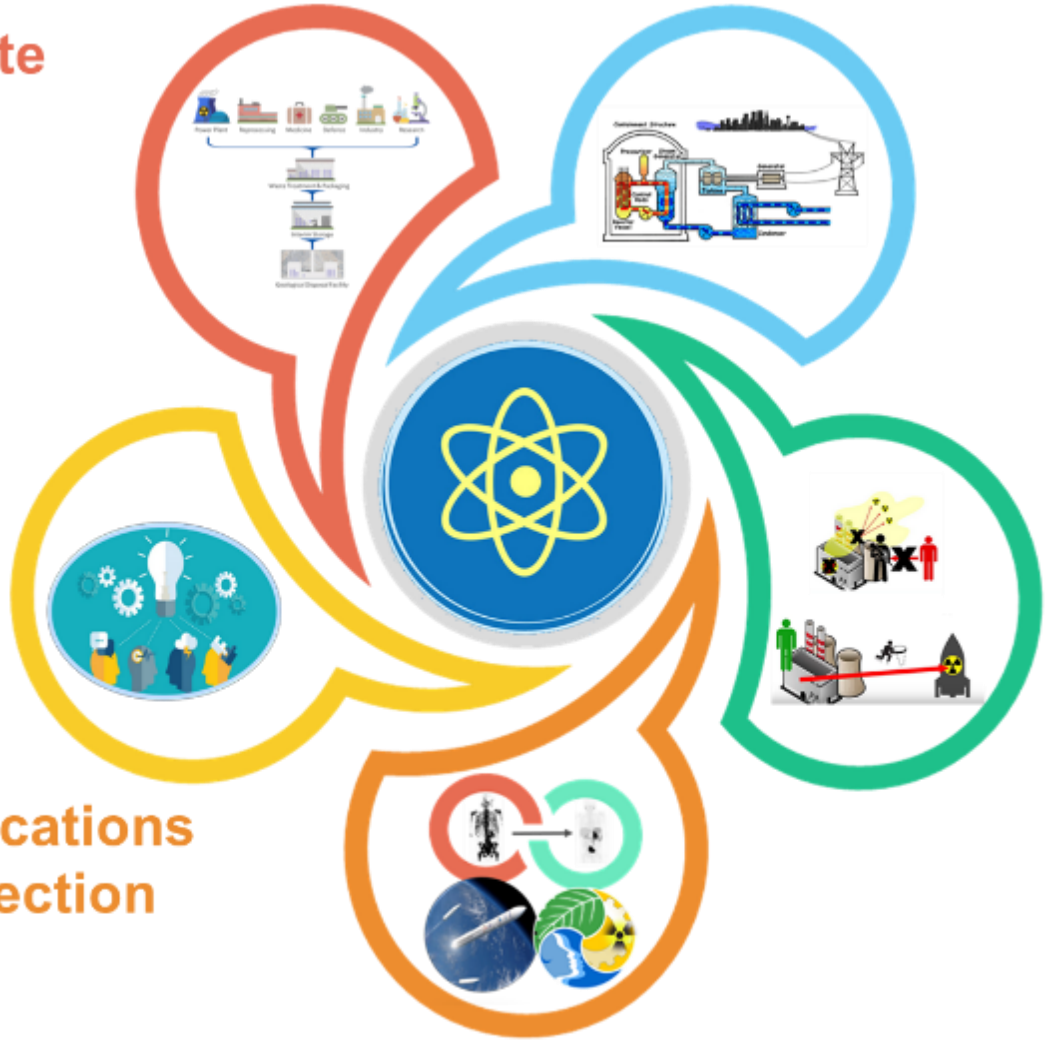
Deep Geological Disposal
Extended Interim Storage
New Waste Forms (ATF, SMR)
Regulatory framework
E&T, KM, Open Access

Nuclear Knowledge & Competence

Maintain Competence (E&T)
Human Resources Observatory
Support JRC Open Access
Reference Data & Standardization
Innovation & Technology
from Research to Industry

Non-power Applications & Radiation Protection

Medicine, Environment, Space
EU beating Cancer
Standardization
Accelerators
Open access, E&T



Nuclear Safety of Nuclear Power Plants

Nuclear reactor safety
Update of safety regulations
LTO, SMR, Gen-IV
Innovative materials
Fuel development and testing
Infrastructures: JHR, HFR and Open Access
Emergency Preparedness

Nuclear Safeguards and Security

EU Safeguards obligations
EU nuclear non-proliferation
Synergies with Security Union & Defense
International Partnership
E&T, KM

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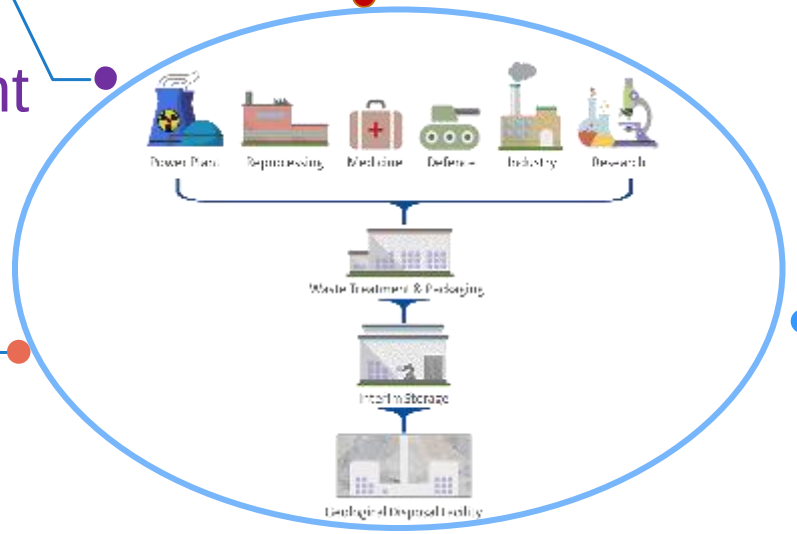
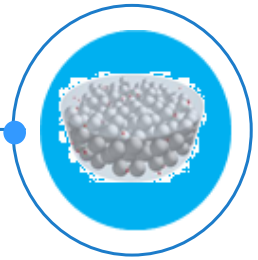
Radioactive waste management and geological disposal

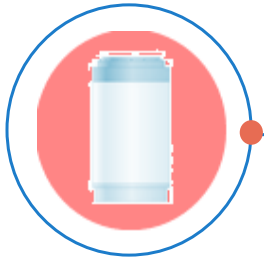
✓ Regulatory framework
✓ Policy support
✓ Back-end of fuel cycle

✓ Knowledge management and dissemination
✓Training and education
✓Open Access





✓ New waste forms (ATF, SMR)
✓ Closed fuel cycle
✓ Innovative analysis tools



✓ Extended interim storage

✓Geological Disposal

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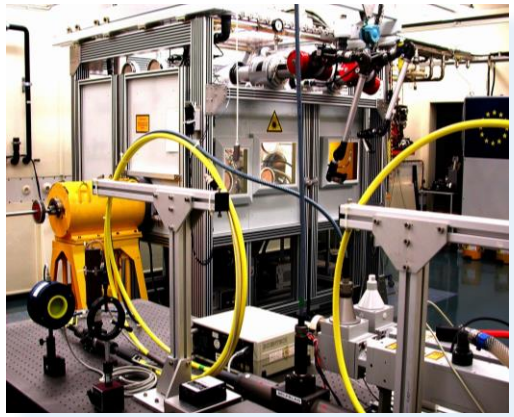
Nuclear R&D at JRC

experimental tools and facilities to work safely with radioactive substances

Hot cells for irradiated fuel studies

Transmission electron microscopy



Thermophysics & thermodynamics: Laserflash

Water corrosion loop AMALIA (cold lab)

Accelerators for nuclear data

Minor Actinide laboratory

Large geometry secondary ion mass spectrometry (SIMS)

Advanced Safeguards Measurement, Monitoring and Modelling Lab (AS3ML)

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Spent fuel (SF) safety studies at JRC

assess SF/wasteform properties and ability to fulfil its expected function over long-term

Pools, handling, transport, storage, retrieval, disposal

SF characterization, NDA

Accident conditions:
corrosion, loss of cooling; damaged SF, corium, debris properties

Mechanical load resistance: impact, bending tests

Extended interim storage

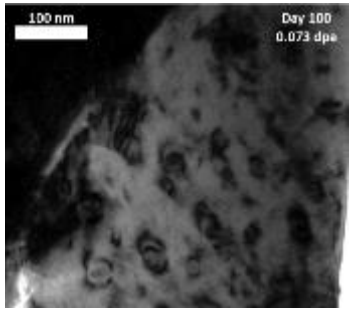
radionuclides containment, rod retrievability *(≥100 y?)*
Potential spent fuel rod mechanical degradation during storage

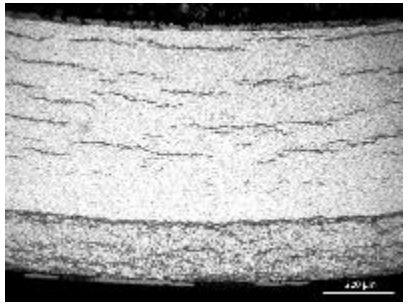
- cladding (hydrides)
- fuel (decay damage, He accumulation)

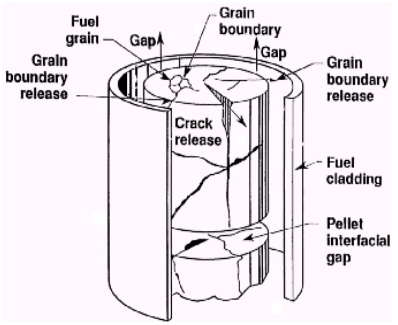
Geologic Disposal

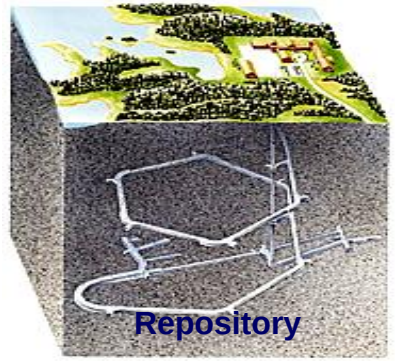
reduce uncertainties on release of long-lived radionuclides over an *open-ended disposal timescale*

Radionuclides “Source Term”, “Instant Release”.
Matrix corrosion: effects of spent fuel properties and local environment









Convey experimental data into models and codes (predictions)

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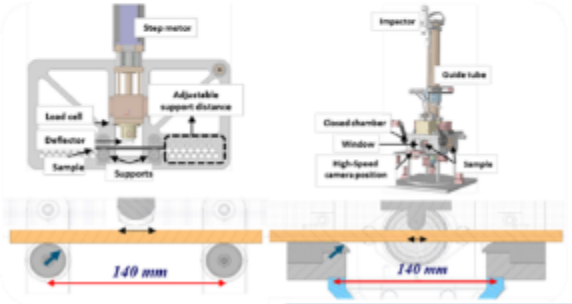
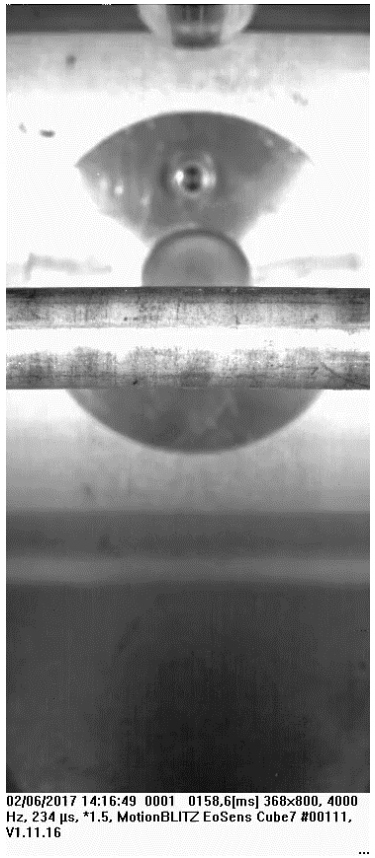
Spent fuel mechanical testing

Safety analysis of spent nuclear fuel rods under accidental loading conditions



Setup for bending, ring compression and impact tests



Main Results

- Same order of magnitude for bending or impact test on the released fuel mass
- Heavy fragments, ~ 0.5% aerosol & fine particulates
- No significant differences for cladding type
- Increase of released mass with burn up

Data contributing to establish regulatory and licensing guidelines which affect spent nuclear fuel transportation, extended interim storage and retrieval thereafter.

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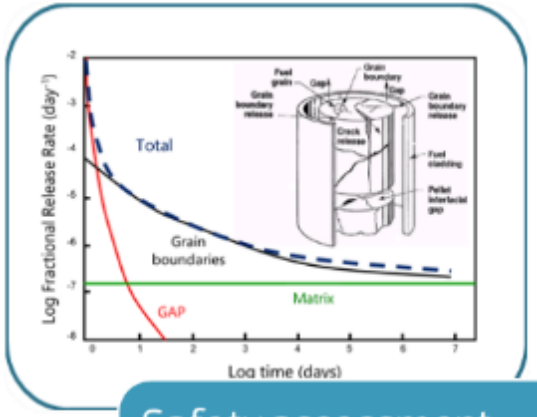
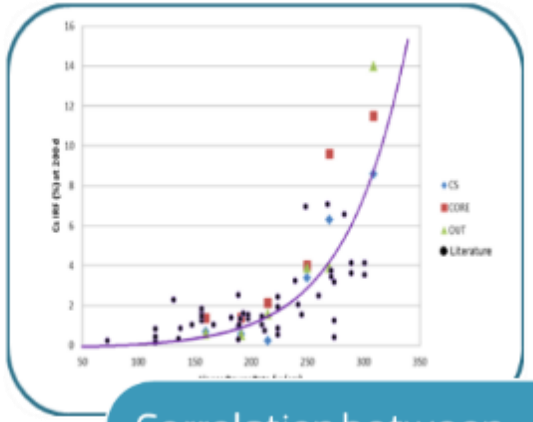
Spent fuel stability under conditions relevant for geological disposal



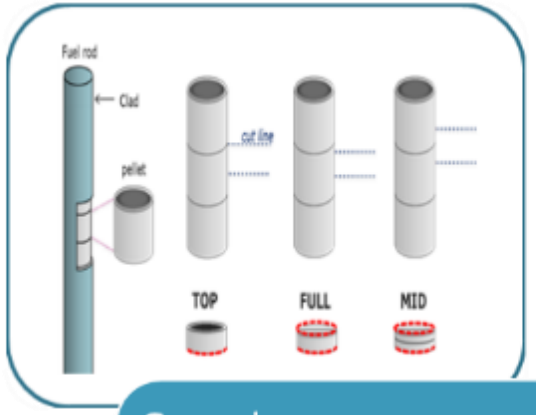
Safety assessment

- Reduce uncertainties
- Extend experimental database
- Improve Modelling



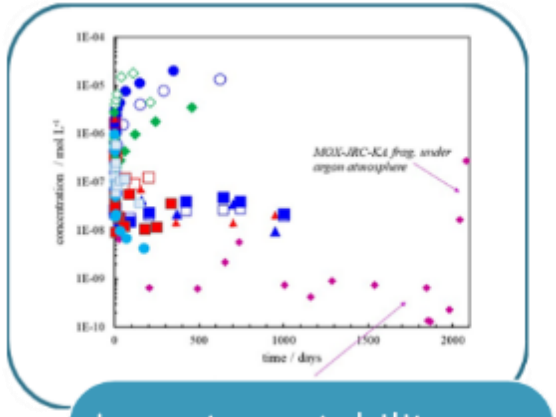
Correlation between IRF and irradiation history

- Linear Power Rating as the main factor affecting IRF
- Driving force for the relocation of some Rn to the void spaces



Sample representativeness

- Radial effect: HBU protective effect
- Positive dishing effect on IRF
- Longitudinal effect: local irradiation differences



Long-term stability

- Long-term matrix dissolution studies under strong reducing conditions
- High stability of SNF. Inhibition of matrix dissolution. Reduction to U(IV)

Reducing uncertainties on the short-, mid- and long-term aqueous release of radionuclides is a key contributor in safety assessment of the waste repositories.

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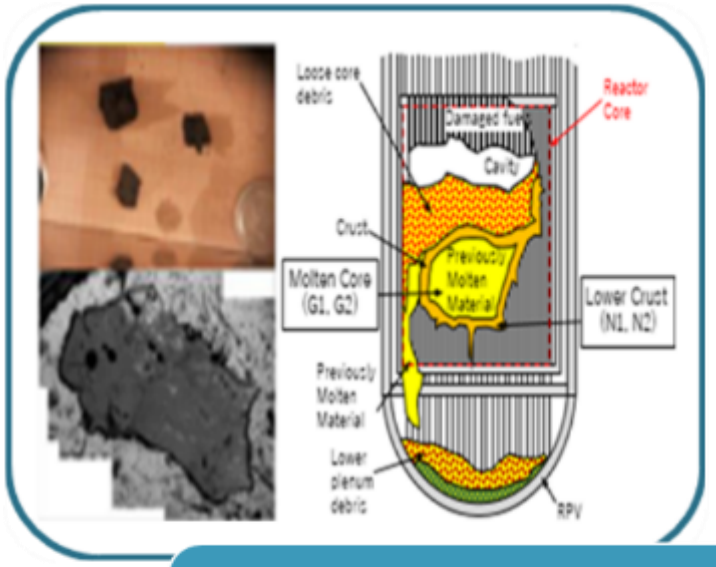
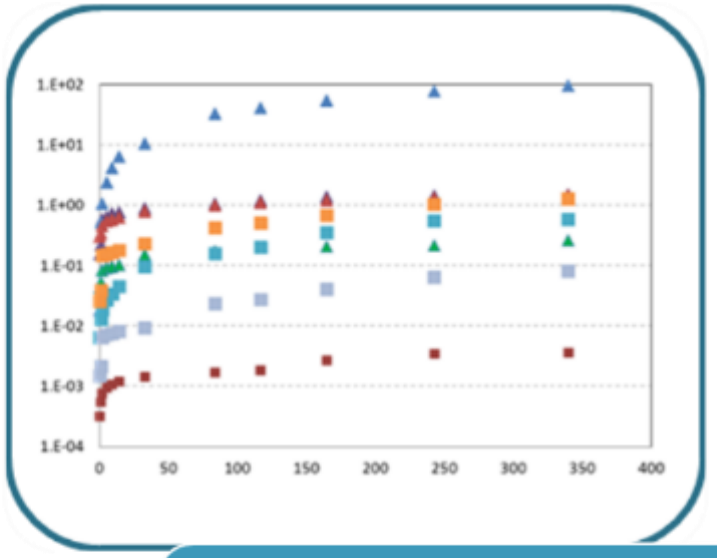
Severe accident waste management

stability of corium and degraded fuel



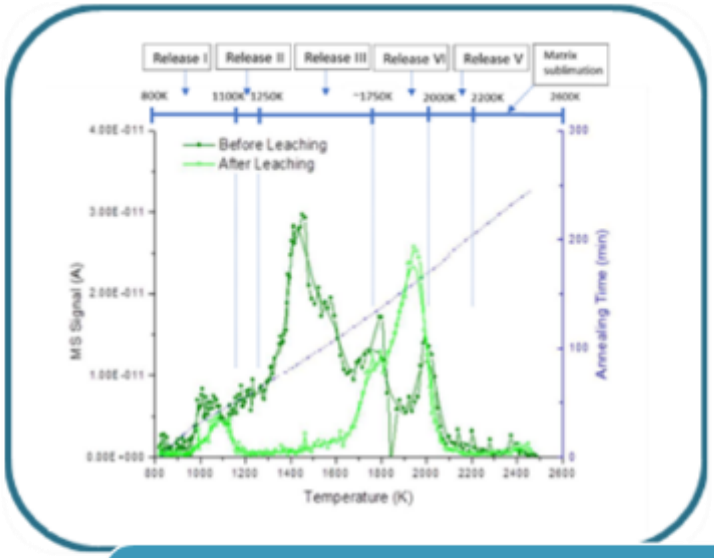
Post-accidental scenarios

- Understanding aqueous solubility of corium and damaged fuel
- JRC-Karlsruhe unique inventory: TMI, Chernobyl and Phebus samples



Corium aqueous stability

- First ever made leaching experiments with genuine TMI corium samples
- Analogies with SNF
- Experimental data base too limited



Modelling

- New modeling approaches are being investigated
- Coupling with KEMS to interpret Rn source term

Quantification of the water/corium interaction in terms of radionuclides release in cooling media supports the definition of realistic post-accidental management strategies

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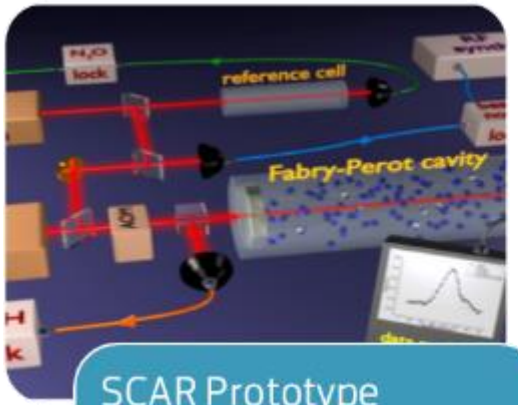
Innovative Analytical Methods

Saturated Cavity Absorption Ring-down (SCAR) spectroscopy for C-14 determination

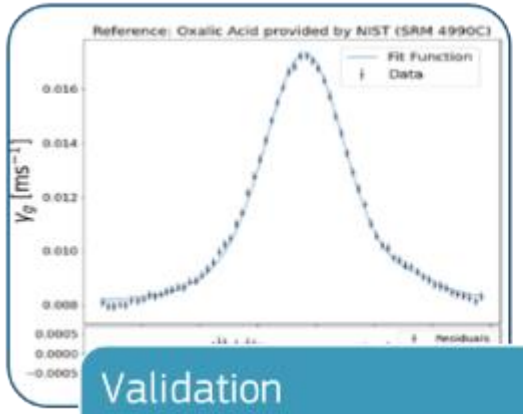


SCAR Prototype

- Granted Exploratory Research Project 2018
- Collaboration with INO-CNR (Florence)
- DTM radionuclides

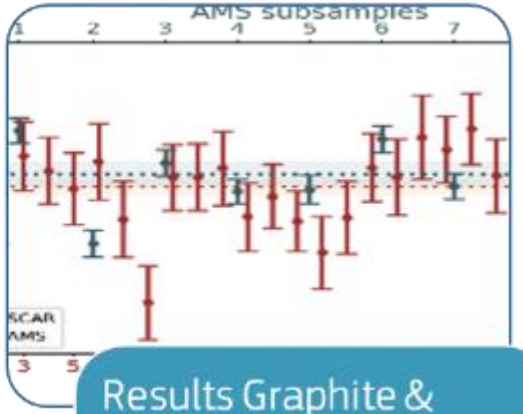
SCAR Experimental Setup

- Experimental setup commissioned for C-14 determination
- Coupled to a **carbon extraction system** operating in a radiation controlled environment



Validation

- Method validation against reference standard materials



Results Graphite & Concrete

- SCAR and AMS have comparable results.
- SCAR has a much larger dynamic range, making it more applicable to the nuclear field than AMS

The precise and accurate determination of the radionuclide inventory in radioactive waste streams is a key aspect in defining efficient nuclear waste management options

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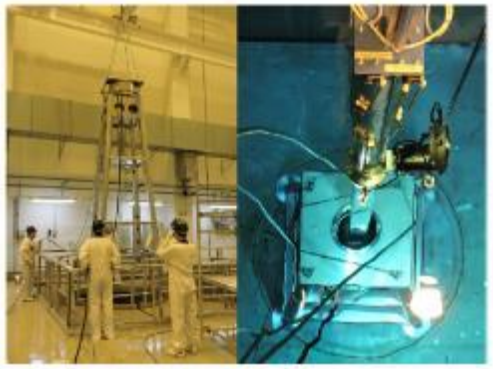
Verification of input data by neutron measurements

Neutron-based Non-Destructive Analysis of SF assemblies

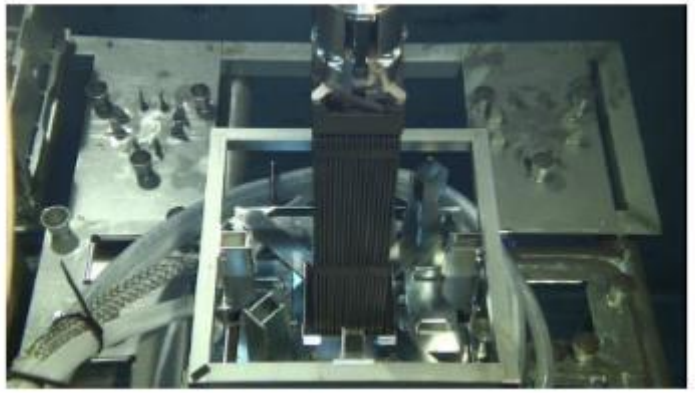
Nuclear safeguards: DOE (NGSI), IAEA, EURATOM

- Total neutron emission rate (Fork) : routine inspections
- Passive Neutron Albedo Reactivity (PNAR) : Finland
- Differential Die Away Self-Interrogation (DDSI) : Sweden

PNAR and DDSI also sensitive to neutron multiplication



PNAR: Tupasela et al., NIMA 986 (2021) 164707



DDSI: Trahan et al., NIMA 955 (2020) 1643329

Calibration standards for radioactive waste management and decommissioning

Aimed material to release	Calibration Standard	Phantom ("non"-active)
Metal	**M1:** Co-60 and Ag-110m contaminated steel tubes	**M2**: Steel Petanque balls
Concrete	**C1**: gravel	**C2:** low-activity gravel
Light materials	**L1:** Clay spheres	**L2:** Plastic balls

Certified reference materials
EURM-800 and EURM-801

^{60}Co in steel disks

Available from our catalogue
https://crm.jrc.ec.europa.eu/

Reference material

^{60}Co and ^{108m}Ag in steel tubes

Available on special request

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Open Access to JRC nuclear research infrastructure

- Based on the Charter of Access to RIs of DG RTD; **open to EU Member States** and associated countries.
- B**rings together** researchers and infrastructure.
- Enables broader **use of unique nuclear facilities.**
- Pushes forward scientific knowledge.
- **Fosters exchanges and integration** of research efforts among Member States.
- Important **training and education** tool.
- It allows addressing **current and emerging needs** in the nuclear science & technology domain.

Karlsruhe: actinide materials

Geel: nuclear metrology

Petten: reactor components

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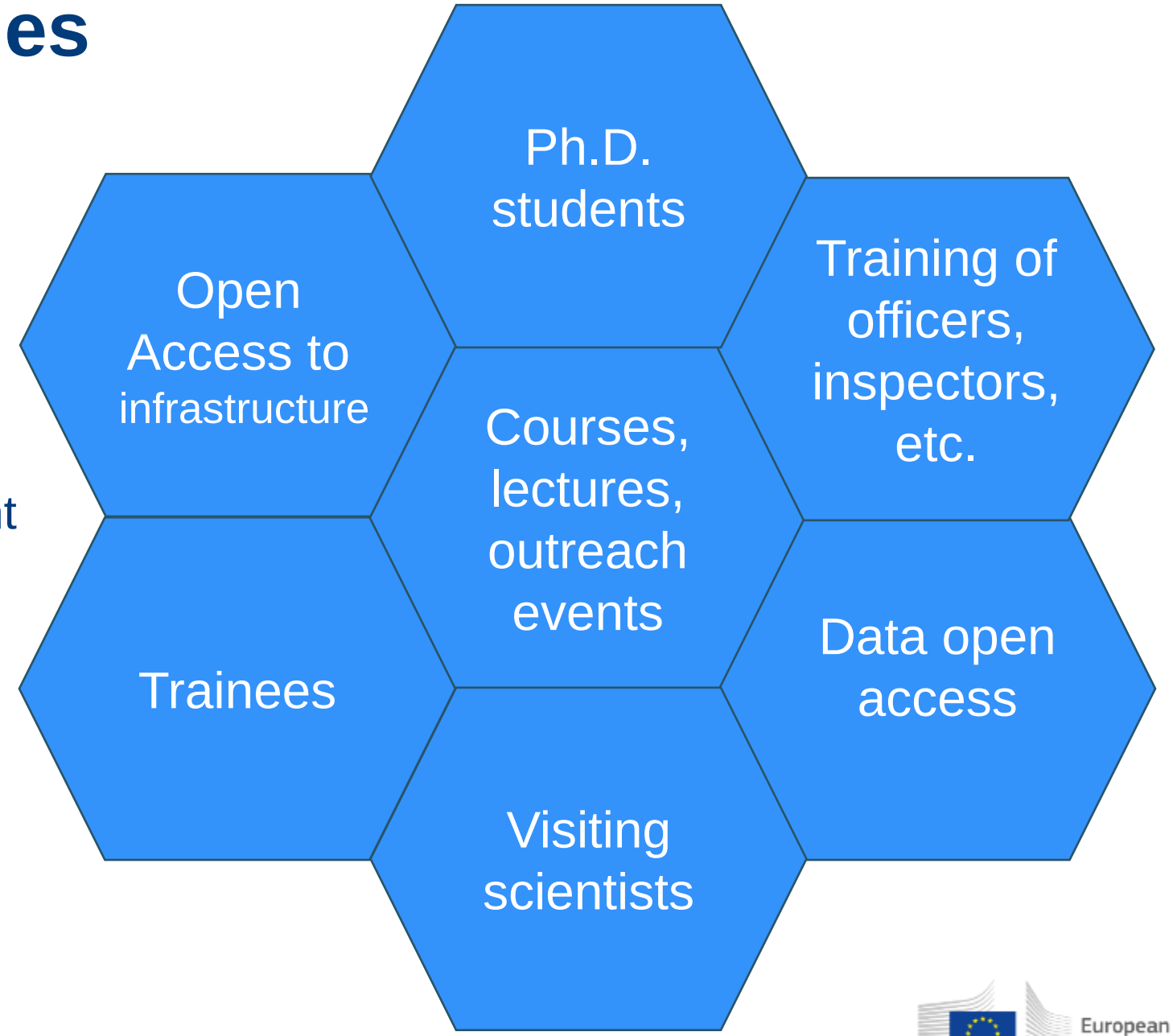
Training capacities

Training & Education,
mobility,
knowledge management,
outreach

related to waste management
and decommissioning
research activities



Monitor the situation of Human Resources
in the European Nuclear sector (EHRO-N)

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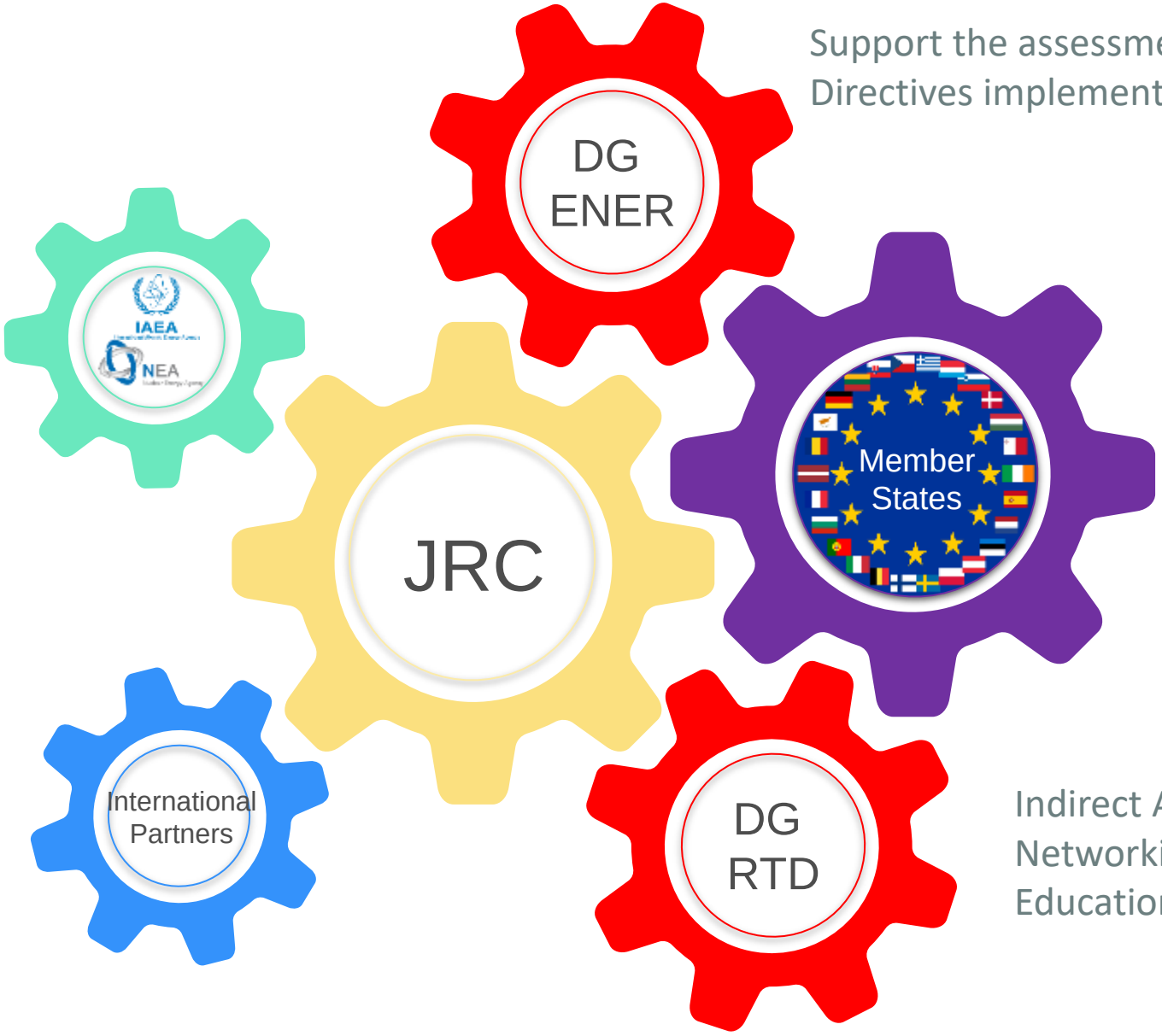
Interactions with stakeholders



Support the assessment of nuclear Directives implementation

Working groups
Technical Reports
Programme Assessment
Joint Convention Review

R&D
Open Access
Competitiveness
Education & Training

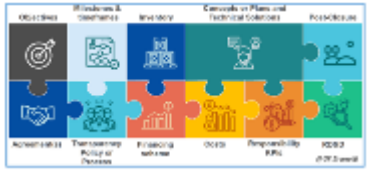
Severe accidents
Spent Fuel Storage
Gen-IV

Indirect Actions, R&D
Networking
Education & Training

European Commission

JRC roles and contributions

Policy support



Council Directives 2011/70/EURATOM on nuclear waste
2006/117/EURATOM on shipments of radioactive waste and spent fuel

Euratom Treaty obligations (e.g. investments notifications)

IAEA Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management

JRC Direct Actions

The JRC Work Programme

implements

the Direct Actions of the Euratom Research and Training programme

supports

political priorities and Work Programme initiatives of the European Commission

Contribution to Indirect Actions

Joint PROGRAMME on Radioactive Waste Management

eurad
European Joint Programme on Radioactive Waste Management

Pre-disposal management of radioactive waste

PREDIS

European Industrial Alliance on SMRs

European Industrial Alliance on SMALL MODULAR REACTORS

IAEA International Atomic Energy Agency

Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (**ARTEMIS**)

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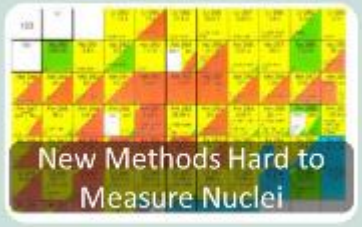
Research outlook

Improve capability to determine SF inventory



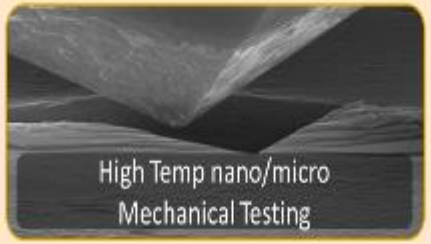
Consolidate mechanistic understanding of SF release processes in the long term post-closure

Waste disposal of emerging SMR and ATF

Post-Accident Waste Management Strategies

Alignment to Member States R&D priorities as set in relevant Joint Programming/*fora*

Extended Interim SF Storage Handling & Transport



Alternative Waste Forms & Legacies

The continuity of JRC contributions depends on the availability of adequate resources in the Euratom Research and Training programme

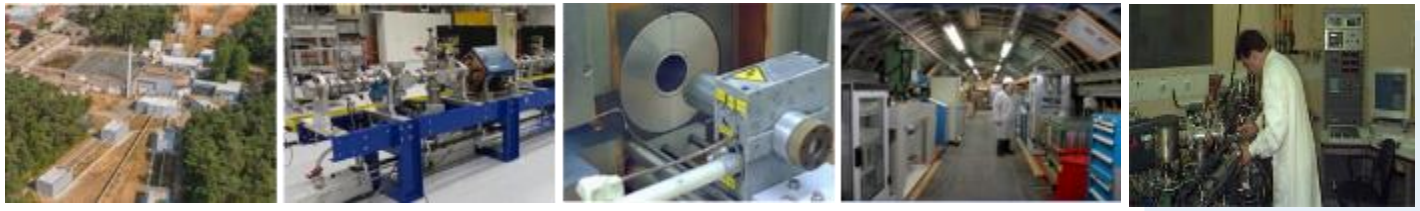
Summary and perspectives

- multi-disciplinary expertise available in JRC for R&D and policy support
  - infrastructure suited for spent fuel and radioactive materials testing
  - adapted/newly developed measuring devices and experimental set-ups
  - renovation of experimental tools is key for maintaining state of the art
- the data/knowledge is shared with partners, published/disseminated
- address questions by regulators, authorities
- reduce uncertainties for safety assessment of the geologic repository

→ **The knowledge and expertise is used to support EU policies**

Partner access to JRC nuclear research infrastructure:

- **sharing/integration of facilities and capabilities**
- **joint projects**
- **students, researchers training**
- **know-how transfer**



The continuity of JRC contributions depends on the availability of adequate resources in the Euratom Research and Training programme

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