Nuclear Research at the JRC-Institute for Transuranium Elements, Karlsruhe

Prof. Dr. Thomas FANGHÄNEL
Director
The JRC in the European Commission

7 Research Institutes in 5 EU countries

As a Directorate-General of the European Commission, The JRC provides customer-driven scientific and technical support to Community policy making.

As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union.
**Nuclear waste management and Environmental Impact:**
- Spent fuel characterisation
- Partitioning, transmutation, conditioning
- Radioactivity in the environment

**Nuclear safety:**
- Safety of nuclear installations
- Nuclear fuel safety
- Advanced nuclear energy systems

**Nuclear security:**
- Nuclear safeguards, non-proliferation
- Combating illicit trafficking
- Open source information

**Key cross-cutting activities:**
- Actinide sciences
- Education & training
- Networking
- Medical Applications

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**Specific programme “JRC direct actions”**
- 2007-2013: 1,751 M€

**EURATOM programme “JRC direct actions”**
- 2007-2011: 517 M€

**FP7 indirect actions**
Reference Centre for policy makers, stakeholders and citizens in the nuclear field

- Basic Actinide Sciences
- Safety of nuclear reactors
- Safety of the nuclear fuel cycle
- Nuclear safeguards and security
- „EURATOM School“

Underpinning Science: atomistic and molecular process understanding of fundamental phenomena

Exploratory/Discovery Research
### Nuclear and Actinides Science

#### Transuranium Elements

<table>
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<tr>
<th>Element</th>
<th>Symbol</th>
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#### Lanthanides

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#### Superactinides

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*10th Anniversary OSL, June 14th, Karlsruhe*
The Institute for Transuranium Elements

The mission of ITU is to provide the scientific foundation for the protection of the European citizen against risks associated with the handling and storage of highly radioactive material.

ITU’s prime objectives are
• to serve as a reference centre for basic actinide research,
• to contribute to an effective safety and safeguards system for the nuclear fuel cycle, and
• to study technological and medical applications of transuranium elements.

ISO 14001:2004 standard for environmental management
OHSAS 18001 (Occupational Health and Safety Standard)
EFQM Excellence Model as basis for an integrated business processes implementation
ISO 17025 Accredited Laboratory

Founded in 1963
The Institute for Transuranium Elements in numbers

INSTITUTIONAL PROGRAMME

Staff ~ 300 (+ externals)
More than 24 nationalities

Institutional Budget about 40 M€
Competitive activities
6-8 M€, about 15% of budget
• **24 hot cells** with capacities up to **1 Mio Curies** and some **400 glove boxes** in **30 alpha-laboratories**.

• **Minor Actinide Lab** for preparing **irradiation targets** containing amounts of **actinides for transmutation experiments**

• **ARTINA category 10-100 Clean Lab** for safeguards and nuclear forensic applications

• **Destructive and non-destructive analyses**
  – Advanced mass spectrometers, laboratory robots, ...

• **Basic materials science investigations**
  – Materials studies down to 1 K and up to 8000 K and 60 GPa
  – Photo-electron spectroscopy,
  – Crystallographic investigations,
  – Solid-state studies (X-ray diffraction, electrical resistance and optical properties) on highly radioactive samples,
  – Mössbauer spectroscopy at normal and elevated pressures
  – High-resolution electron microscopes,
  – Shielded microprobes, ....
Facilities and unique equipment

New facilities 2008-2010

• "EURACT-NMR – European Radioactive Nuclear Magnetic Resonance"
  (workshop in Karlsruhe 27-29 January, 2010)
• New Transmission Electron Microscope (TEM)
• Raman spectrometer

• Instrumentation: Surface Science Spectroscopies (XPS)
• Large Geometry SIMS laboratory
ITU’s core competences

Basic actinides science and applications

Safety of the nuclear fuel cycle

Safeguards and nuclear forensics

Education, Training and user facilities/networking
The actinides are among the most complex of the long-lived elements, and in the solid state, they display some of the most unusual behaviours of any series in the periodic table.
**Alpha-Immunotherapy**

- Production of radionuclides
- Radiolabelling of biomolecules
- Radiobiology and pre-clinical studies
- Production of radionuclides and setup of adapted reprocessing
- Further diversification of applications
- Radiobiology for Th-226 and U230
- In vivo studies

**Principle of Alpha-Immunotherapy**

![Diagram of monoclonal antibody with radionuclides](image)

- **Y-90** (β, several 1000 µm)
- **Bi-213** (α, 80 µm)

Labelling and targeting of an alpha-emitting radio-immunoconjugate.
Alpa-ImmunoTherapy: Clinical and pre-clinical Studies

Alternative alpha-emitters and chelates
Increase pre-clinical and clinical studies
diversify applications

Malignant melanoma (Phase I), + pre-clinical (Sydney)

Gastric, bladder, ovarian cancer (Munich)

Breast Cancer (Baltimore)

ITU α-emitting isotopes

Brain tumours (Phase I)
Prostate cancer (Basel)

Multiple myeloma (Nantes)

Infectious diseases
HIV Phase I (New York)

CT image of patient #4 after injection of 17.4 mCi $^{213}$Bi–DOTA–SubstanceP
ITU’s core competences

Basic actinides science and applications

Safety of the nuclear fuel cycle

Safeguards and nuclear forensics

Education, Training and user facilities/networking
A European vision of nuclear energy development

- **Current Reactors**
  - First Reactors
  - Dismantling & clean-up

- **Advanced Reactors**
  - Produces 31% of Europe’s electricity

- **Future Systems**
  - New build in Finland and France (EPR), other countries...
  - Start of industrial deployment in 2040-2050

What R&D to support this vision?
Safety of the nuclear fuel cycle

- Reprocessing plant
- High Level Waste
- Uranium Storage
- Depleted Uranium
- Enrichment
- Natural Uranium
- Fuel Fabrication
- Fissile and Fertile
- Reactor
- SNF storage
- SNF final disposal
- Repository
- Spent fuel storage
- Nuclear reactor
- U mining
Safety of the nuclear fuel cycle

Safety of Advanced Nuclear Fuels:
• advanced sustainable fuels
• EURATOM contribution to Gen IV
• International Forum (GIF).

SNE-TP

Safety of Conventional Nuclear Fuels
• in-pile behaviour of nuclear fuel at extended burn-up
• Code and Modeling: Transuranus

Nuclear Waste Disposal
• studies on unirradiated wasteforms
• advanced characterisation methods
• corrosion studies on irradiated fuels
• conditioning matrices for minor actinides

Alternative Fuel Cycles
• advanced aqueous partitioning
• pyro-reprocessing technologies
• head-end conversion processes

ITU FUTURIX pellets
Multi-barrier concept
Retrievability, Reducing conditions
Source-term
Fuel corrosion

Nuclear Waste Disposal

Waste Radiotoxicity

Ingestion radiotoxicity (Sv per ton spent fuel)

- actinides
- Total
- ref. 7.83 t U in equilibrium with P&T
- with P&T
- 130,000 y
- 1000 y [99% Pu, 98% MA removal]
- 500 y [99.5% Pu, 99% MA removal]
- results based on ICRP72

Time (y)
ITU’s core competences

Basic actinides science and applications

Safety of the nuclear fuel cycle

Safeguards and nuclear forensics

Education, Training and user facilities/networking
Non-Proliferation is a policy objective of the EU, ITU provides scientific/technical support to Member States, Euratom and IAEA

Traditional Safeguards

- Nuclear material accountancy (owner)
- Independent verification (Euratom, IAEA,...)

Strengthened Safeguards

- Absence of undeclared activities (Add. Protocol)

Illicit trafficking and nuclear forensics

- Detection
- Source attribution

Radiological Dispersal Event (RDE)
Traditional Safeguards

OSL Sellafield (1999+)
Robotised glovebox for sample preparation and alpha spectrometry
Diluted spent fuel and product samples

LSS La Hague (2000+)
Hot cells for handling and analysing dissolved spent fuel
Undiluted spent fuel and product samples
Illicit Trafficking (all types) incidents 1993-2007

(source: IAEA)
ITU’s core competences

Basic actinides science and applications

Safety of the nuclear fuel cycle

Safeguards and nuclear forensics

Education, Training and user facilities/networking
Knowledge Management, Education & Training

- Summer Schools
- Trainees, PhD students, Post-Docs
- Visiting scientists
- User Facility
- Network of excellence
- Actinide User lab

Information portals  www.nucleonica.net

- Workshops
- Conferences
- Training courses
- Upgrade and new nuclear databases
Quick view into the future...

New office building (2009-2012):

Wing M (2007-2014):

Quick view into the future...
Many thanks for your attention and your visit
Global Actinide Management

2020
- Implementation of MA partitioning
- Waste minimization (Vitrified FP)

MA Partitioning and storage

2030/2040
- GEN III+ LWR & GEN IV FR
  - 3rd generation Pu recycling
  - Full An recycling (GEN IV)
  - Recycling of stored MA
  - Dedicated MA burners if needed
Response to illicit trafficking

Detection

Nuclear Material (U, Pu, reactor or weapons grade) or other radioactive material ($^{60}\text{Co}, ^{137}\text{Cs}, ^{192}\text{Ir}, \ldots$)

Categorization

Detection equipment, intelligence

Nuclear Forensics

Source Attribution