PAUL SCHERRER INSTITUT

PSI

Andreas Pautz :: Head of Nuclear Safety and Energy Division (NES) :: Paul Scherrer Institut

Welcome to the Molten Salt Reactor Workshop at PSI

PSI, Switzerland, 24th January, 2017

Agenda of the MSR Workshop

13:30-13:45 Andreas Pautz – PSI

13:45-14:00 Jérôme Serp – GIF MSR

14:00-14:30 Hongjie Xu – China

14:30-15:00 David Holcomb – USA

15:00-15:30 Jan-Leen Kloosterman – EU

Coffee break

16:00-16:30 Lyndon Edwards – Australia

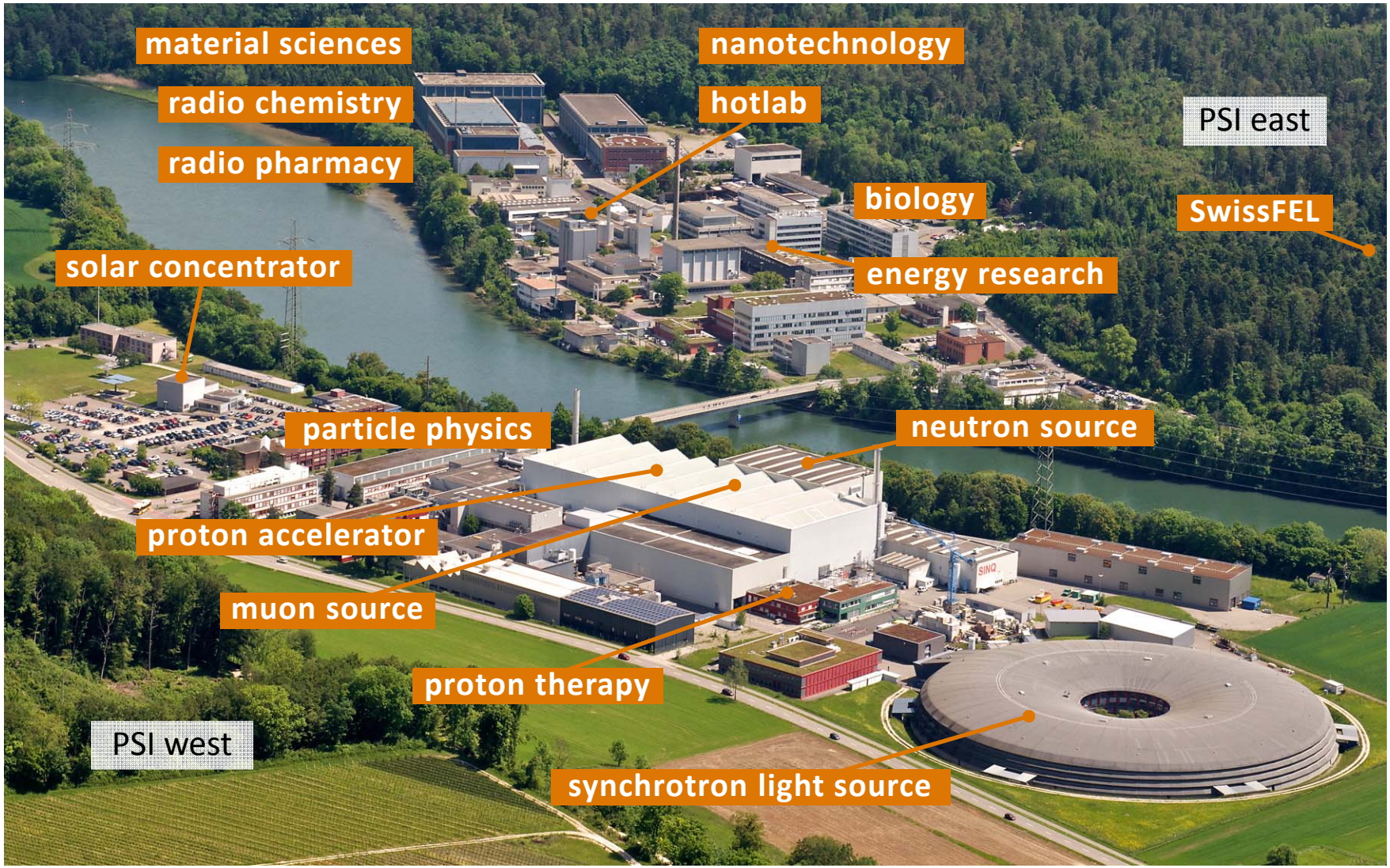
16:30-17:00 Elsa Merle-Lucotte – France

17:00-17:30 Victor Ignaev – Russia

17:30-18:00 Jiří Křepel – PSI

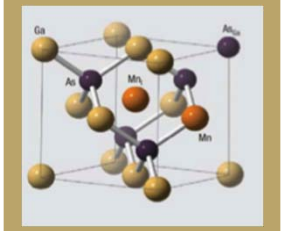
Apero

Aerial View of the Paul Scherrer Institut (PSI)

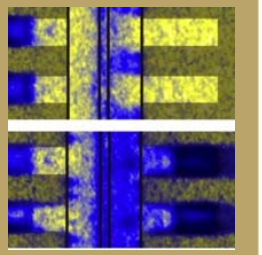


Mission of PSI

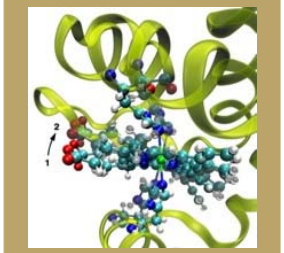
Matter and materials



Energy and environment



Human health



Development
Construction
Operation

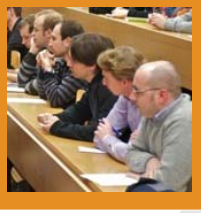
Large research facilities

Swiss and foreign users from academia and industry

more than 2400 external users/year (39 beamports)

Knowledge & expertise

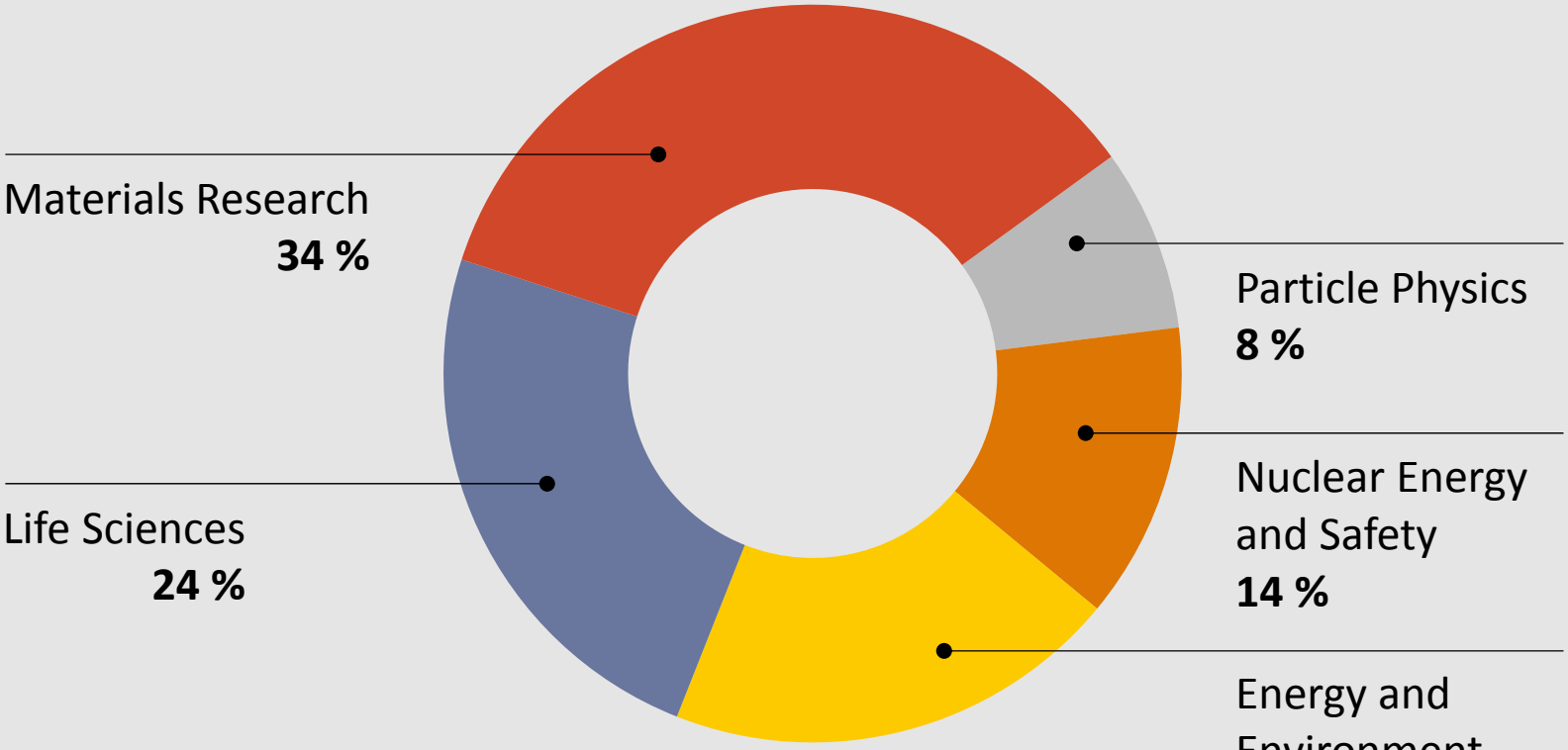
Education



Technology transfer

Major Research Topics

Distribution to main research areas (first- and third-party funding)



National context: NPPs in Switzerland

NPP	Type	Shut down	50 yrs	60 yrs	Net Elect. Power
Beznau I	PWR	(?)	2019 (?)	2029 (?)	365 [MWe]
Beznau II	PWR		2021	2031	365 [MWe]
Mühleberg	BWR	2019	-	-	373 [MWe]
Gösgen	PWR		2029	2039	1010 [MWe]
Leibstadt	BWR		2034	2044	1220 [MWe]

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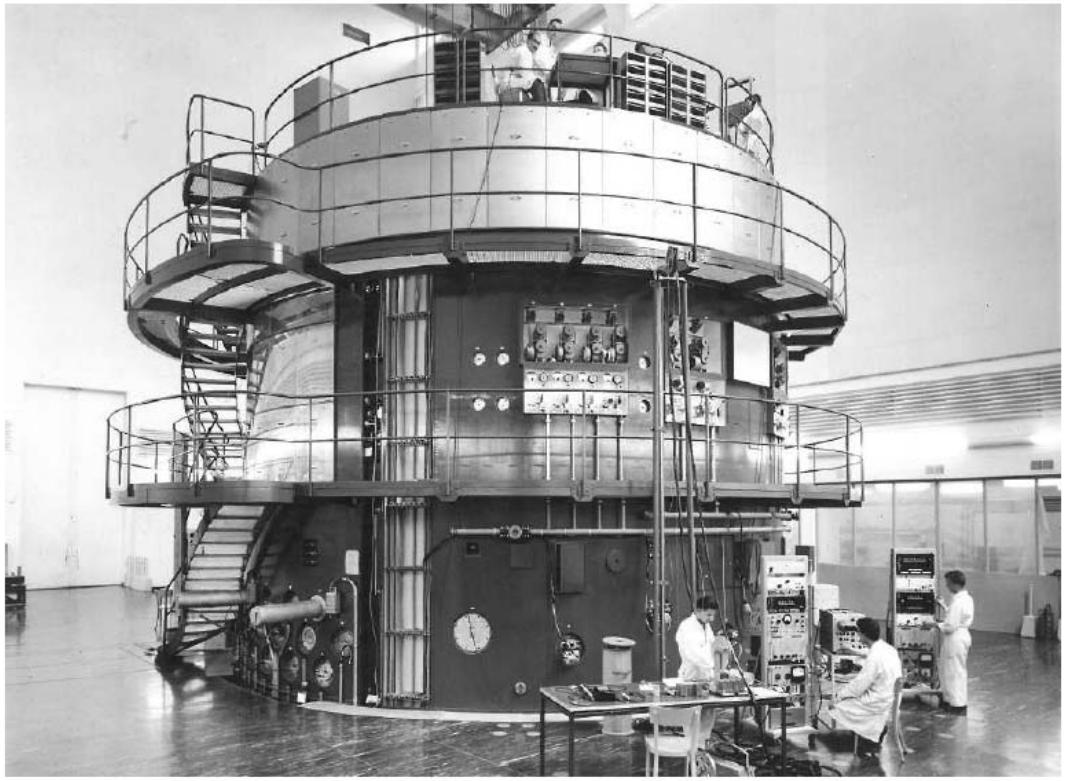
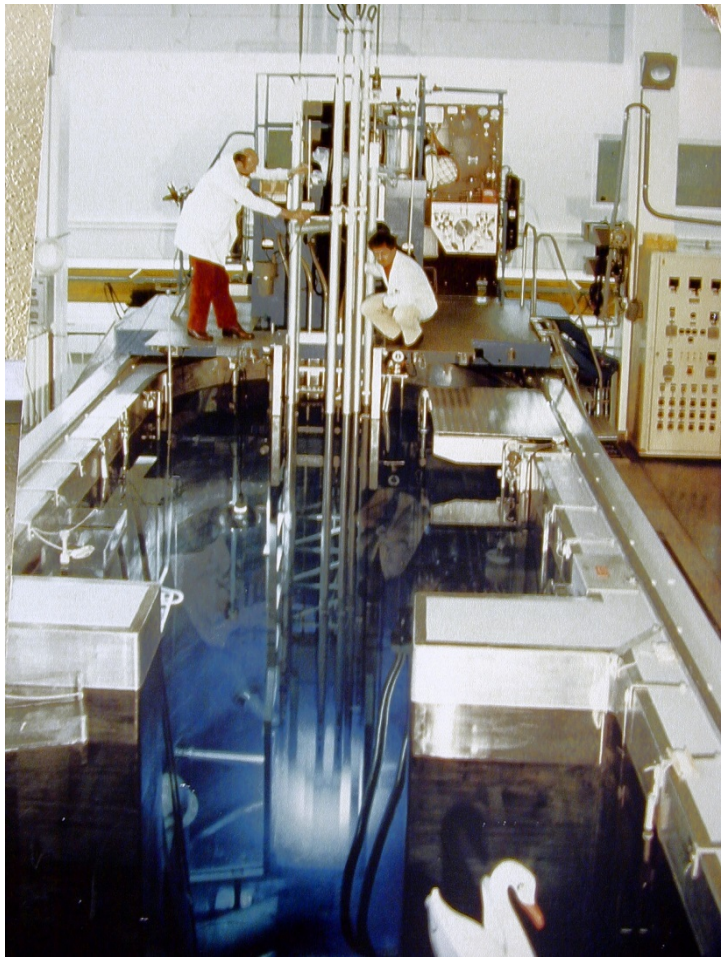
The Research Reactors of PSI



20. August 1960

DIORIT: Heavy-water moderated Research Reactor
Fueled with Natural Uranium, 20/30 MW Power
Start of Operation: 1960, Ultimate Shutdown : 1977



SAPHIR: 10 MW Pool-type reactor, Start of Operation: 1957, Ultimate Shutdown: 1993

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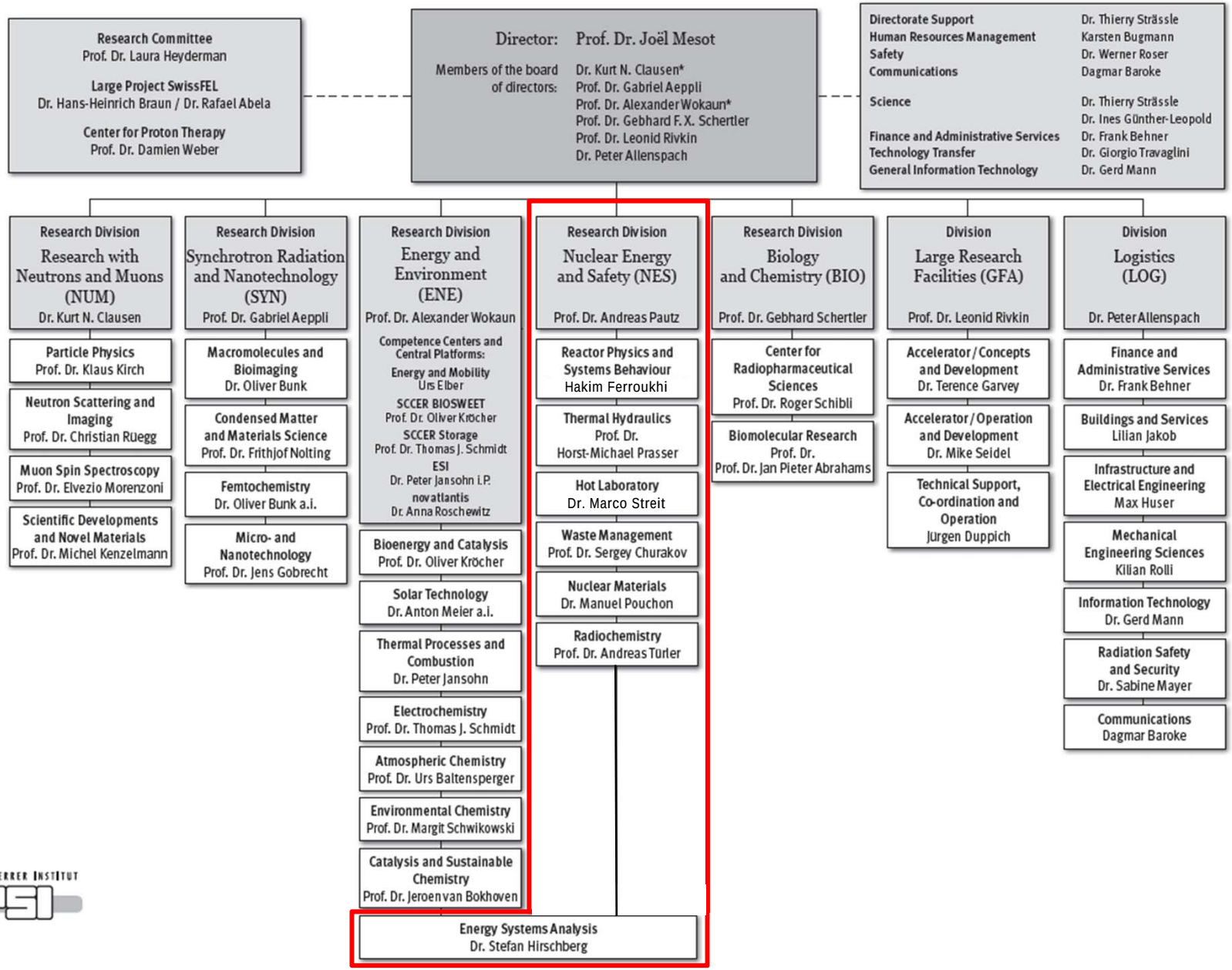
Federal Intermediate Storage for Radioactive Waste from Medicine, Industry, and Research

Organisation Chart of PSI



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NES Core Mission Statement

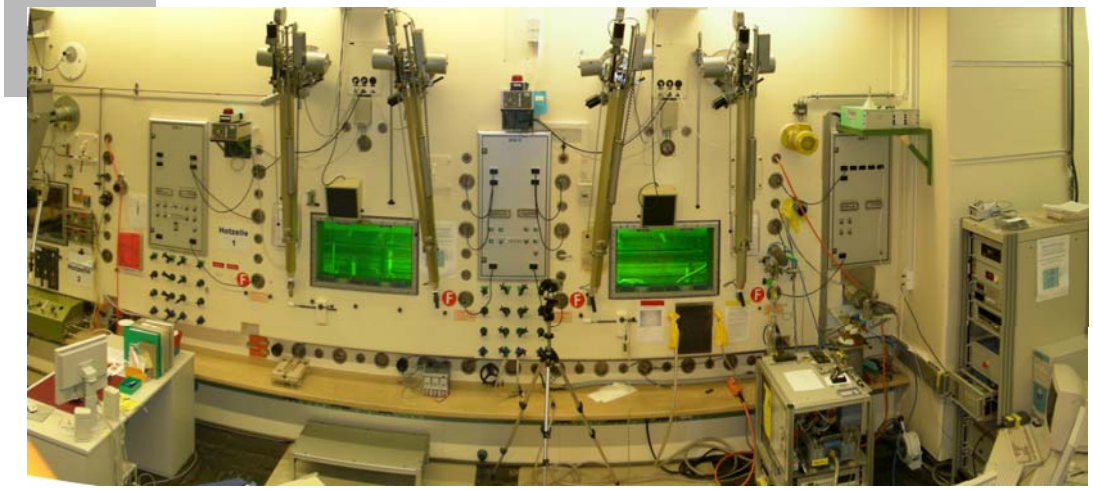
NES is the Swiss national center of excellence for nuclear energy:

- NES research focuses on the **safety** of the existing nuclear power plants, **waste management** issues, and **decommissioning** of nuclear installations
  - NES is the **Technical Safety Organization** (TSO) for ENSI
  - NES is the Swiss center for **geochemistry of disposal systems** and **transport mechanisms of radionuclides**

- NES addresses **advanced and innovative nuclear system concepts**, in particular with respect to safe operation and waste minimization strategies
  - NES has the Federal mandate of "Technology Monitoring" of Gen-IV reactor developments (*Membership Generation-IV International Forum)*

- NES strongly contributes to the **education** of nuclear engineers and cooperates closely with **ETHZ** and **EPFL**

Post-Irradiation Examination of Spent Fuel Rods in the PSI Hot Laboratory



NES maintains the capability of handling and fostering investigations of radioactive materials in the Hot Laboratory (AHL)

–The AHL is one of the very few facilities of its kind in Europe, and provides PSI with a decisive advantage over other nuclear research institutions

–It remains mandatory to operate the AHL due to the industrial demand, e.g. PIE of spent fuel rods

NES Mission: Maintaining Nuclear Competence

Safety

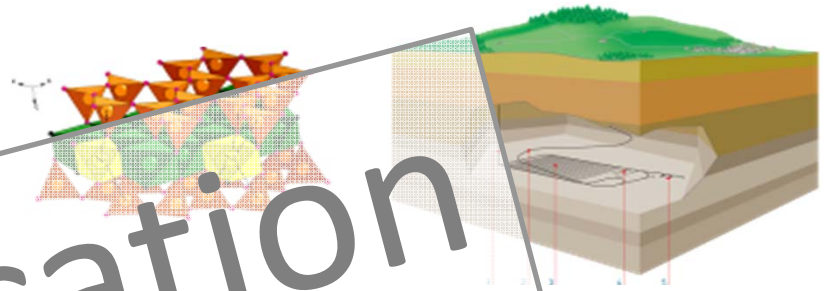
Understanding relevant phenomena

Normal Operation ··· Severe Accidents

Materials performance (barrier integrity)

Waste Management

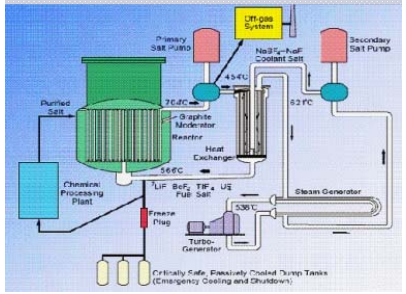
Multiscale reactive transport
of radio-isotopes
Safety of deep geological repository



Education

New Technologies

Reduced risk - Reduced waste



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Research Focus: Molten Salt Reactor Safety

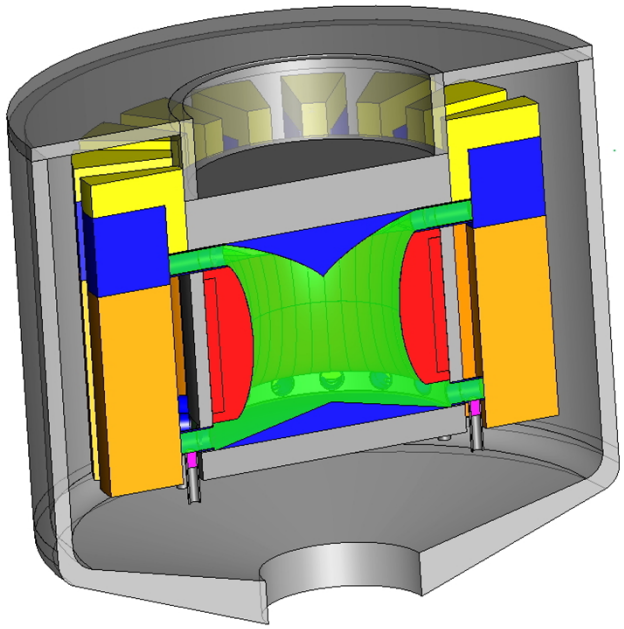
- In 2015, Switzerland joined the **GIF Molten Salt Reactor Project.**
- **NES Division Project** on Gen-IV MSR (umbrella for several project).
- Euratom **Horizon2020 project** SAMOFAR
  1) Safety Assessment of the Molten Salt Fast Reactor.
- **4 national projects** fully or partly related to MSR:
  2) **SNF** PhD: Modular MSR Designing for Low Waste Production.
  3) **SNF** PhD: Nuclear Data Assimilation in Reactor Physics (Pu & Th)
  4) **Swiss Electricity Producers & ETHZ** financed project:
     Feasibility and plausibility of innovative reactor concepts (HTR & MSR).
  5) **Swiss Nuclear** financed project:
     Chemical thermodynamic aspects of LWR Pu and MA burning in MSR.
- Involved labs: **LRS[1,2,3,4,5], LTH[1,4,5], AHL[1,5], LEA[1,4], LES[5]**.

International framework: H2020 SAMOFAR

SAMOFAR

The way forward to the ultimate safe nuclear reactor

- SAMOFAR is a 5M€ 4-year project of EU H2020 program.
  It Started in August 2015 and the consortium has 11 partners: CNRS, JRC, CIRTEN, IRSN, CINVESTAV, AREVA, CEA, EDF, PSI, KIT and TU Delft.
- Goals:
  - prove innovative safety concepts of MSFR by advanced experimental and numerical techniques
  - deliver a breakthrough in nuclear safety and optimal waste management
  - create a consortium of stakeholders to demonstrate MSFR beyond SAMOFAR.



Molten Salt Fast Reactor Concept

Some Areas of interest at NES

Neutronics & fuel cycle:

Tools: EQL0D & EQL3D equilibrium cycle routines based on SERPENT and ERANOS codes.

Aim: fuel cycle safety and performance characteristics.

MSR safety evaluation:

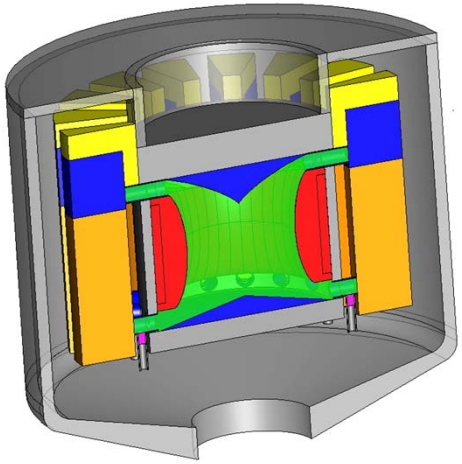
Tools: TRACE-PARCS, TRACE-point-kinetics, GeN-Foam (Open-FOAM).

Validation: based on available reactor data from MSRE (ORNL) and. MSFR benchmark.

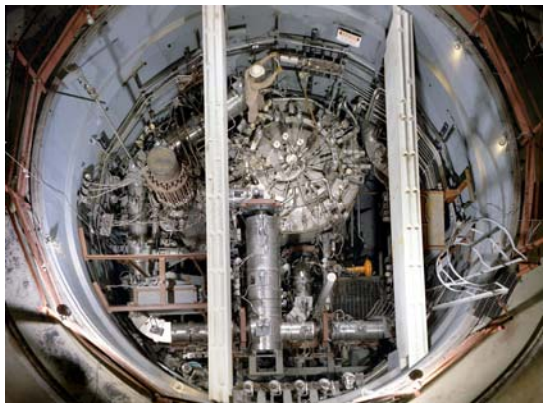
MSR design studies:

Aim: waste minimization and high fuel utilization.

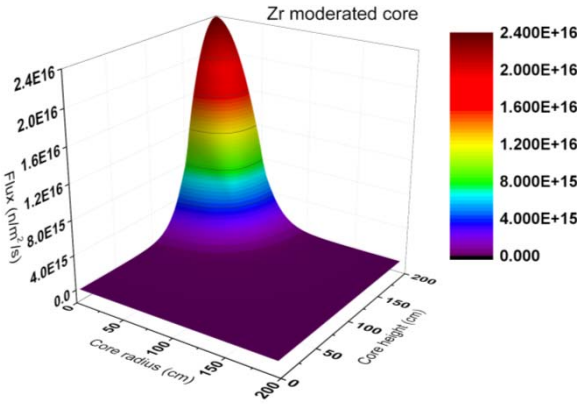
Cases: Moderation level, hybrid spectrum core, refueling strategies, reprocessing strategies, breed-and-burn mode.



Molten Salt Fast Reactor Concept



Molten Salt Reactor Experiment



Hybrid spectrum MSR

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Molten Salt Reactor Research: Master theses

- **Coupled multi-physics simulations** of the Molten Salt Fast Reactor using coarse-mesh thermal-hydraulics and spatial neutronics (E. Pettersen)
- "Development of the model for the **multiphysics analysis** of Molten Salt Reactor Experiment using GeN-Foam code" (J. Bao)
- **Static and transient analysis** of Molten Salt Reactor Experiment using SERPENT-2/TRACE/PARCS codes (H. Kim)
- Empirical **Decay Heat Correlations** and Fission Products Behavior in MSRs (J. Choe)
- **Heat exchanger analysis** for innovative molten salt fast reactor (V. Ariu)
- **Parametric Lattice Study** for Conception of a Molten Salt Reactor in Closed Thorium Fuel Cycle (B. Hombourger)
- **Probabilistic Safety Analysis** for the Licensing of Molten Salt Reactors (D. Pyron)
- **Behaviour of Fission Products** in the Molten Salt Reactor Fuel (N. Vozarova)

Thanks a lot for your attention, and enjoy the MSR workshop and your stay in Switzerland !