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
Mission of PSI

- Matter and materials
- Energy and environment
- Human health
- Development
  Construction
  Operation

Knowledge & expertise

- Education

Technology transfer

Large research facilities

Swiss and foreign users from academia and industry

more than 2400 external users/year (39 beamports)
Major Research Topics

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

- Materials Research: 34%
- Life Sciences: 24%
- Particle Physics: 8%
- Nuclear Energy and Safety: 14%
- Energy and Environment: 20%
### National context: NPPs in Switzerland

<table>
<thead>
<tr>
<th>NPP</th>
<th>Type</th>
<th>Shut down</th>
<th>50 yrs</th>
<th>60 yrs</th>
<th>Net Elect. Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beznau I</td>
<td>PWR</td>
<td>(?)</td>
<td>2019 (?)</td>
<td>2029 (?)</td>
<td>365 [MWe]</td>
</tr>
<tr>
<td>Beznau II</td>
<td>PWR</td>
<td></td>
<td>2021</td>
<td>2031</td>
<td>365 [MWe]</td>
</tr>
<tr>
<td>Mühleberg</td>
<td>BWR</td>
<td>2019</td>
<td></td>
<td></td>
<td>373 [MWe]</td>
</tr>
<tr>
<td>Gösgen</td>
<td>PWR</td>
<td></td>
<td>2029</td>
<td>2039</td>
<td>1010 [MWe]</td>
</tr>
<tr>
<td>Leibstadt</td>
<td>BWR</td>
<td></td>
<td>2034</td>
<td>2044</td>
<td>1220 [MWe]</td>
</tr>
</tbody>
</table>

- NPP stands for Nuclear Power Plant.
**DIORIT**: Heavy-water moderated Research Reactor
Fueled with Natural Uranium, 20/30 MW Power

**SAPHIR**: 10 MW Pool-type reactor,
Federal Intermediate Storage for Radioactive Waste from Medicine, Industry, and Research
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
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

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

Education

Safety
- Understanding relevant phenomena
  - Normal Operation … Severe Accidents
  - Materials performance (barrier integrity)

New Technologies
- Reduced risk - Reduced waste
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**\(^5\).
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.
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
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)
Wir schaffen Wissen – heute für morgen

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