

PAUL SCHERRER INSTITUT

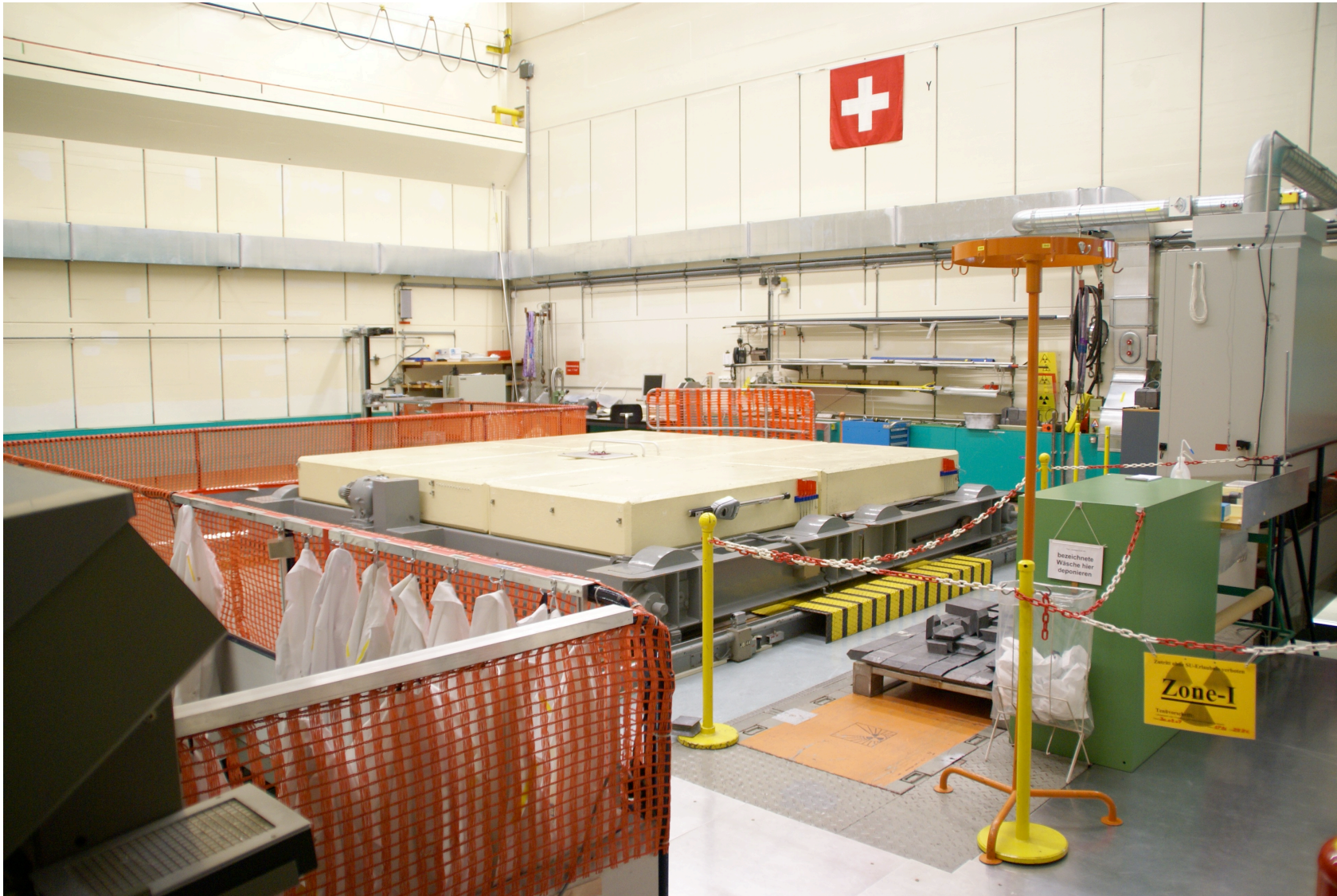


Wir schaffen Wissen – heute für morgen

Paul Scherrer Institut – IGORR conference

O. Köberl, G. Perret, K.A. Jordan, et al.

PROTEUS zero-power reactor refurbishment





Zero power research fission reactor

- First operation: 1968
- Power < 1kW
- Thermal flux < 5×10^9 n/cm²/s
- Driven system
(graphite / D₂O / buffer / test zones)



Motivations

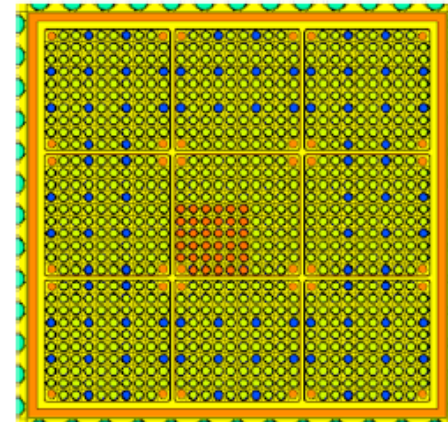
- Extend PROTEUS life-time
- Upgrade PROTEUS to host innovative experimental programs with large amount of spent fuel

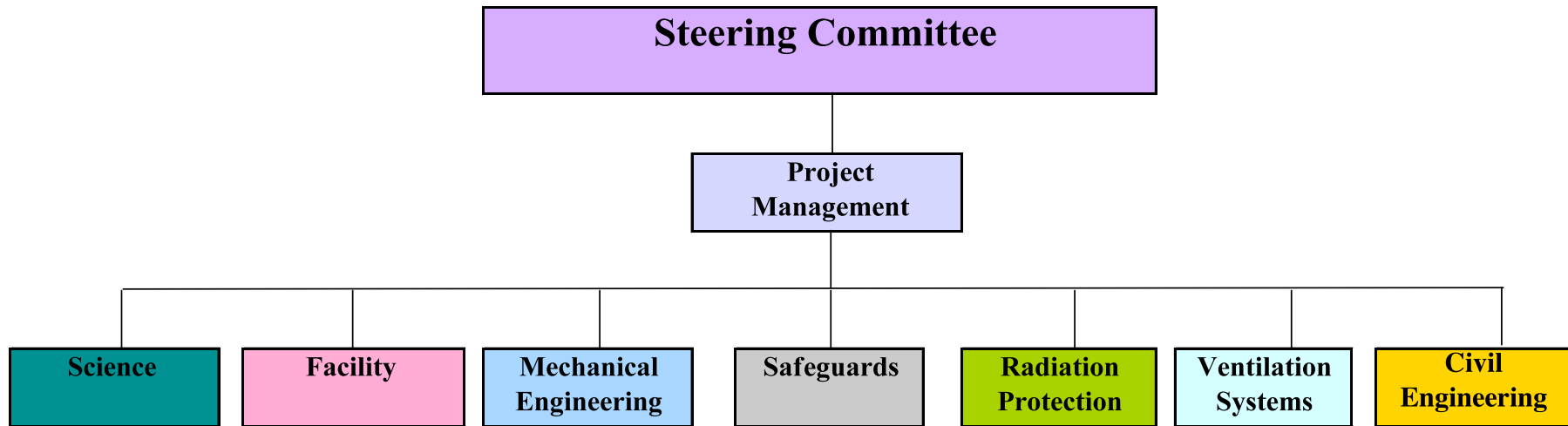
Requirements – Construction License

- Upgrade system and components of reactor to modern safety standards
- Remain a low risk facility – dose to the public lower than 1mSv for all incidents
- Upgrade the facility to Safeguard Category II
- Handle and store up to 100 full length PWR pins having a burn-up of 60 GWd/t

Requirements – Operation License

- Allow the LIFE@PROTEUS program
 - Study fresh-burnt fuel interface
 - Up to 36 full length PWR pins (60 GWd/t)

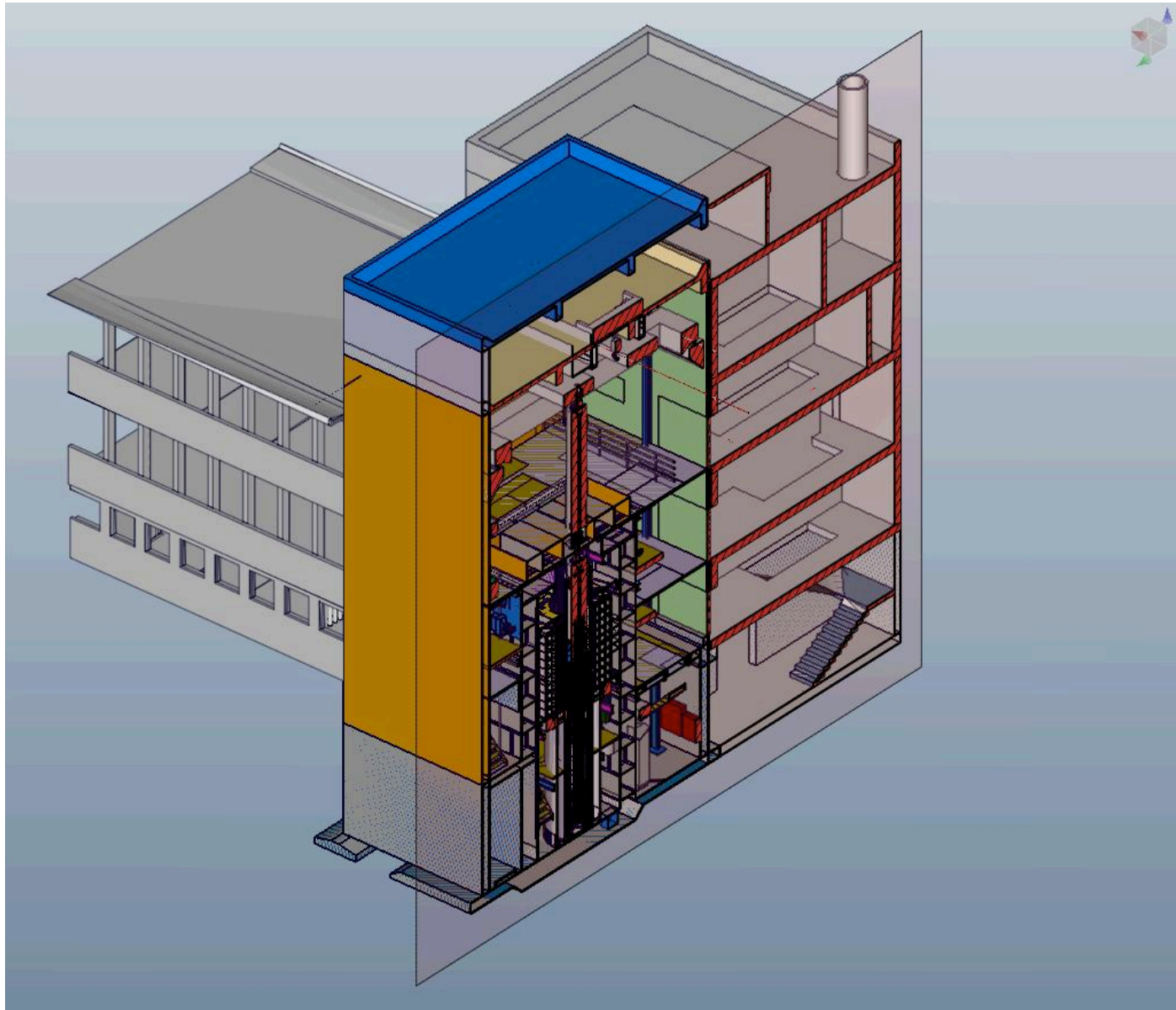




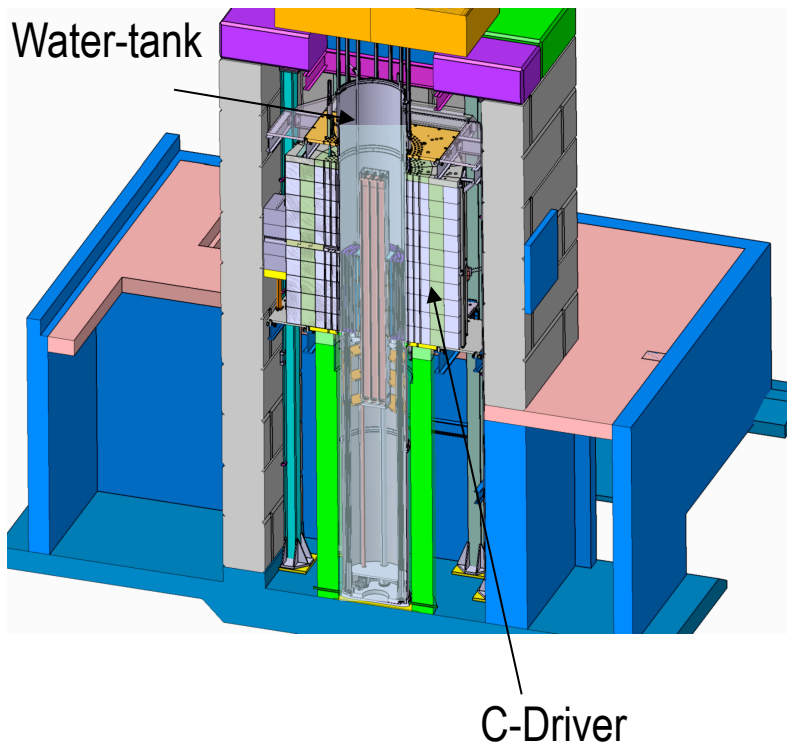
External support and work

- Earthquakes and incident analysis, water loops etc. – External firms
- Mechanical components – Intern Paul Scherrer Institute
- Expertise (e.g. seismic) – Swissnuclear
- Civil engineering – General contractor
- Reactor protection system – Supplier of NPP

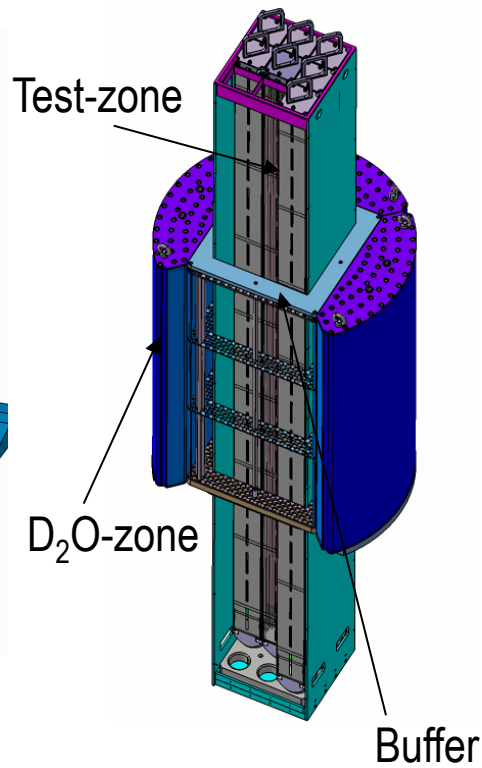
A vision of the Upgraded PROTEUS



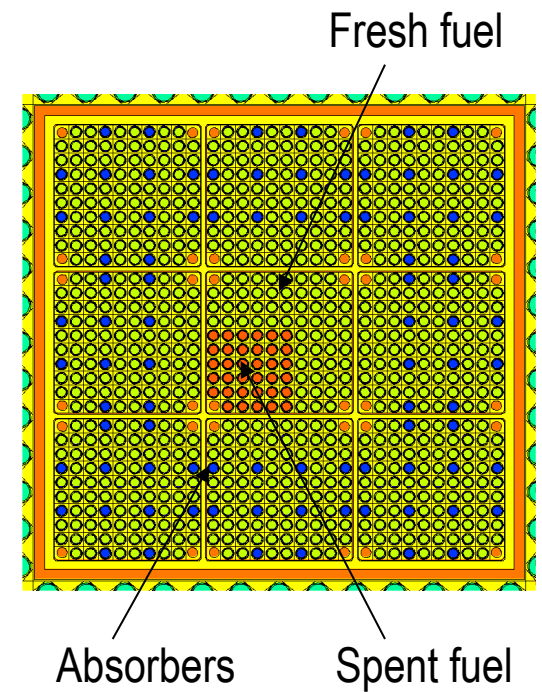
Reactor block

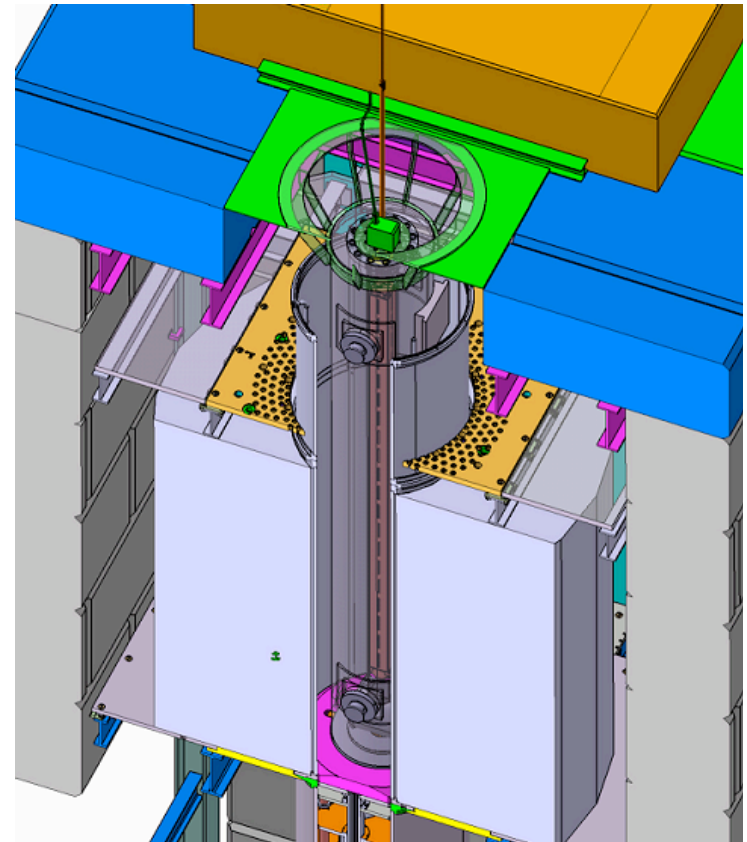
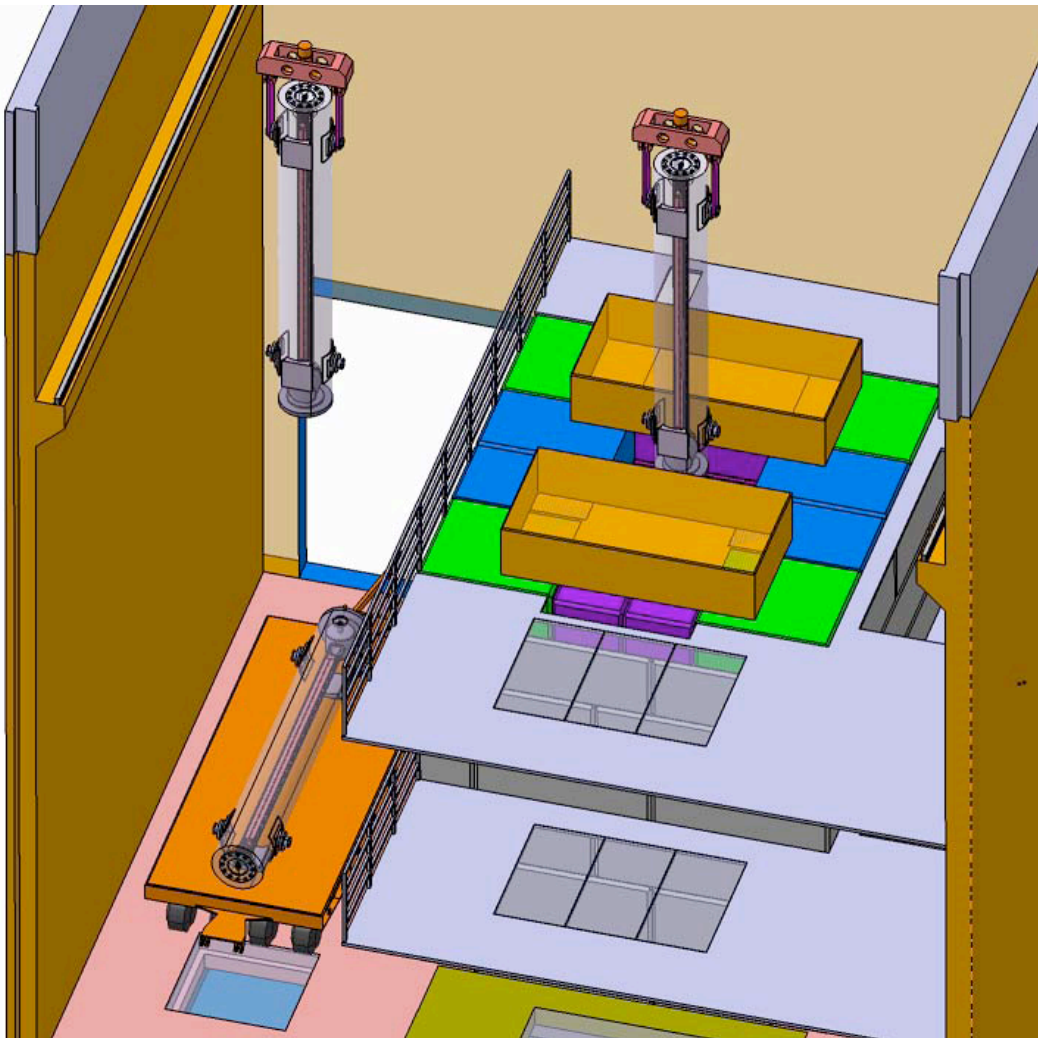


Reactor components

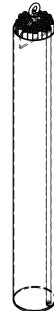
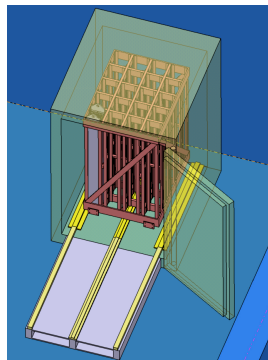
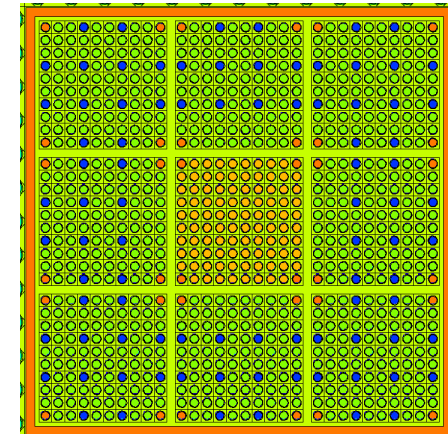


Test zone loading

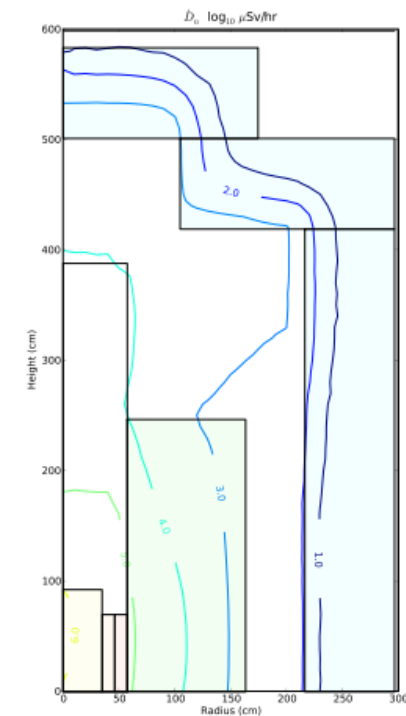
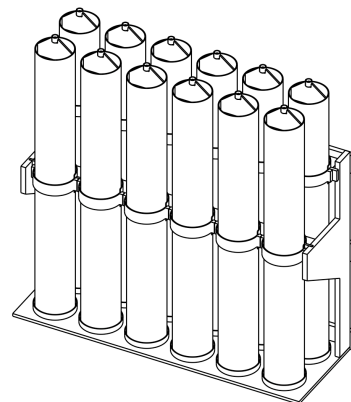




- Construction license application for 100 spent fuel rods
 - Covering activity inventory
 - Incident analysis and dose rate estimation
- Reactor safety parameters assessment
- Calculation of neutron and gamma dose rate maps in normal, measurement and accidental conditions
- Calculation of storage criticality and dose rates



Behälter
max. Beladung
40 Pufferstäbe
Gewicht: 425kg



Process

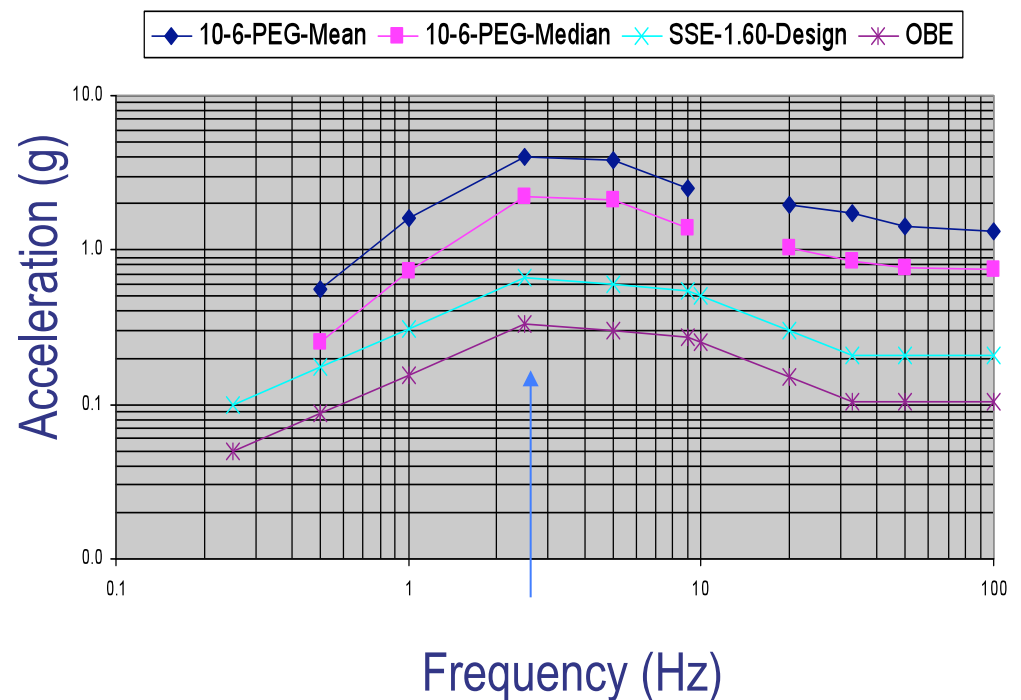
- Definition and requirements of earthquake spectra for the PROTEUS facility
- Measurement of soil properties – 40 to 50 m
- Simulation of earthquake scenarios using finite element methods for the reactor block, reactor components and the buildings
- Reinforcement strategies and cost evaluations
- Decision based on comparativeness (median vs. mean) by the regulatory authority



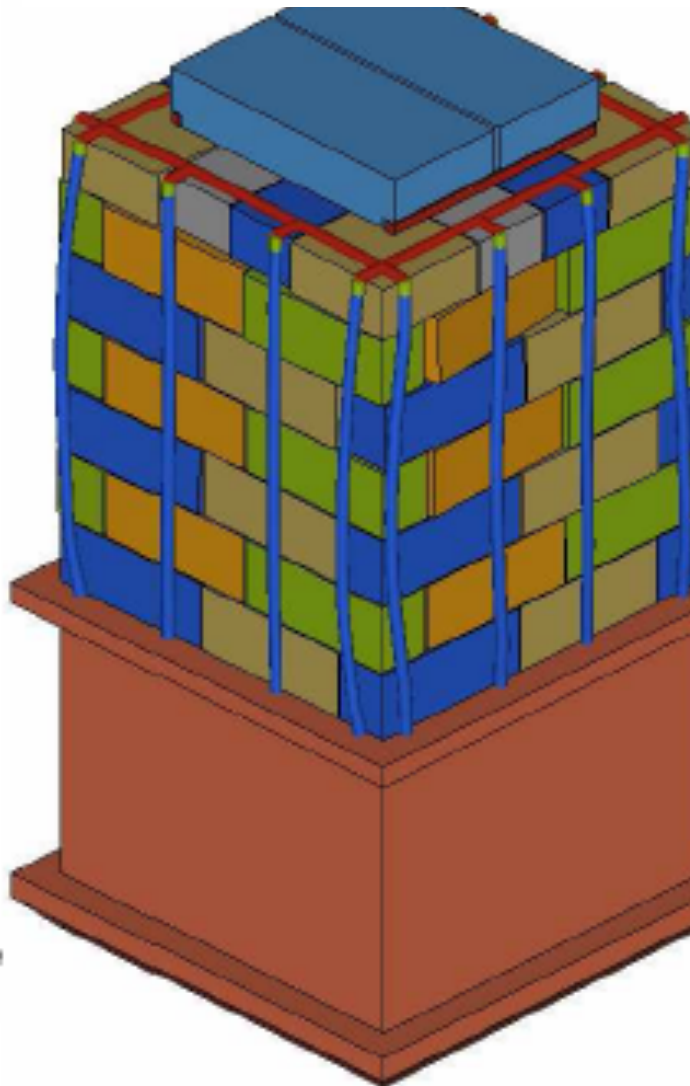
Categories

- **Operating Basis Earthquake (OBE)**
10⁻² per year, max acc. 0.4g
- **Safe Shutdown Earthquake (SSE)**
10⁻⁴ per year, max acc. 0.65g
- **Heavy Earthquake (HE)**
10⁻⁶ per year, max acc. 2.1g / 4g
- OBE and SSE are considered for nuclear power plant
- Heavy Earthquake (HE) is beyond the design basis but is considered as the covering event for low risk facilities

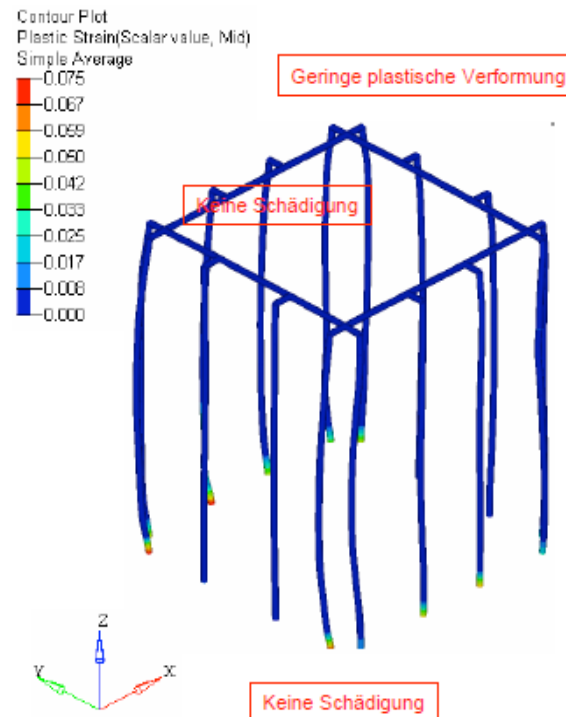
Spectra



Reactor block: 10^{-6} median earthquake (PEGASOS), after 16s of simulation



Plastic Strain of the drawbars



Results

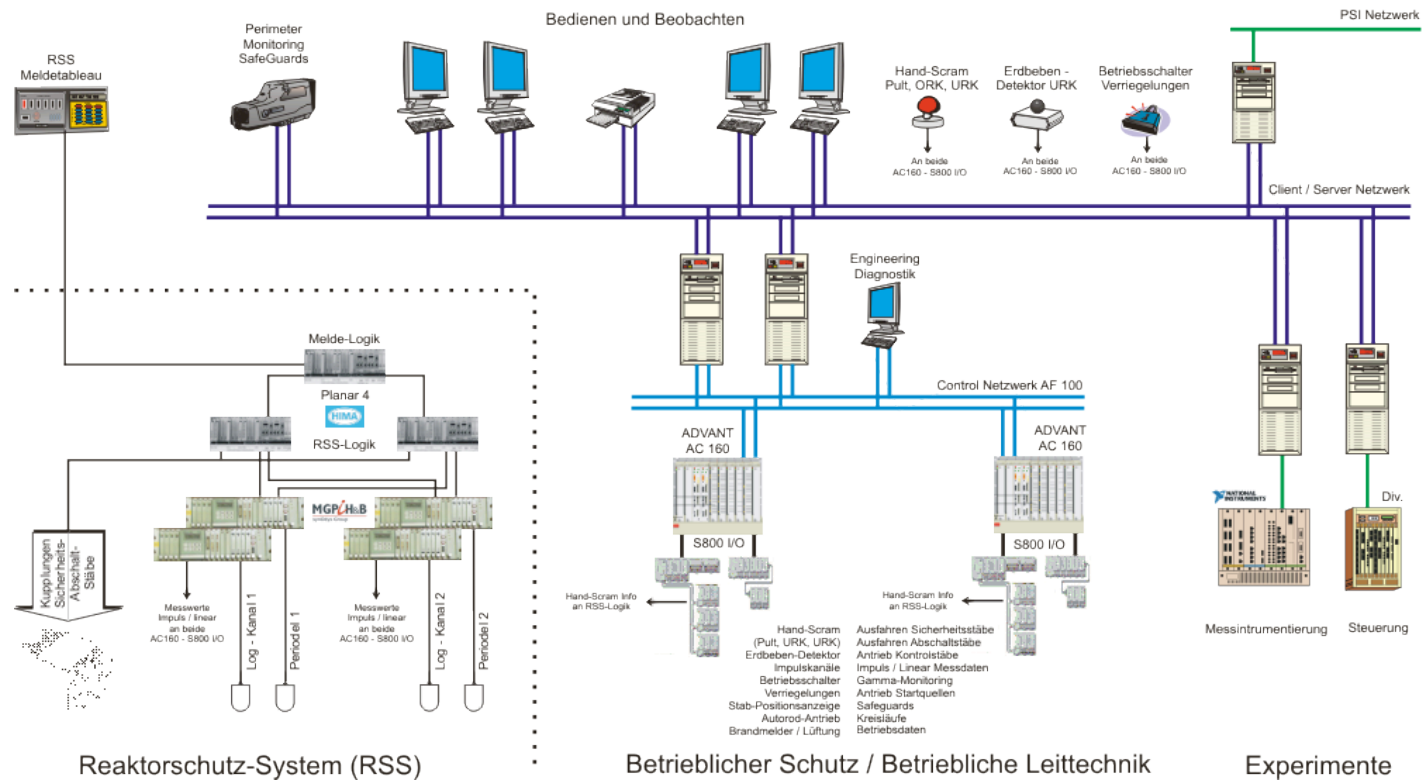
- Block integrity insured
- Small plastic deformation

Modernization of the I&C systems

- Reactor Protection System
- Control System for Operation
- Experiment related instrumentation systems
- HOF aspects

MIPRO System - Übersicht

PROTEUS



- A versatile state-of-the-art nuclear facility to carry out experiments with fresh fuel and small quantities of burnt fuel (overcladed)
- Profile
 - Highly flexible versatile experimental set-up
 - Research and Development
 - Training and education
 - Low risk facility
 - Modern Instrumentation and Control (I&C)
 - Modern safety systems

Next Steps

- Investigation of safety cases with a reduced activity inventory
- Focus on the preparation of the modified construction license application
- Modernization of the I&C systems taking into account Human and Organization Factors (HOF)

Key Dates

- Submission of the construction license application in 2011
- Submission of the operation license application in 2012
- Submission of applications for safety systems in 2012
- Starting with construction work in 2012
- Commissioning of the facility 2013/14

Many thanks to

- The PROTEUS operating team for their constant availability and support to experiments
- **swissnuclear** for their partnership in the LIFE@PROTEUS program

Thank you for your attention !

