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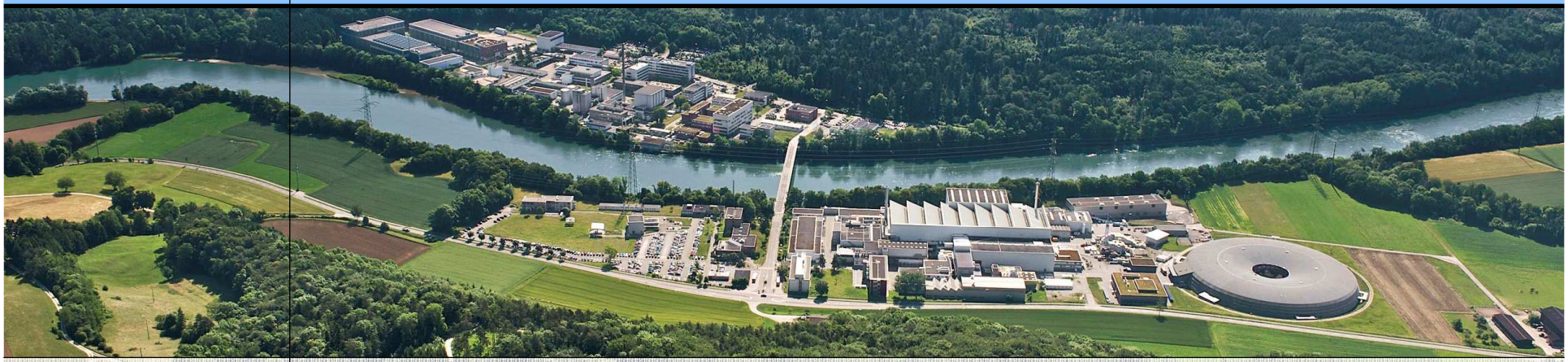


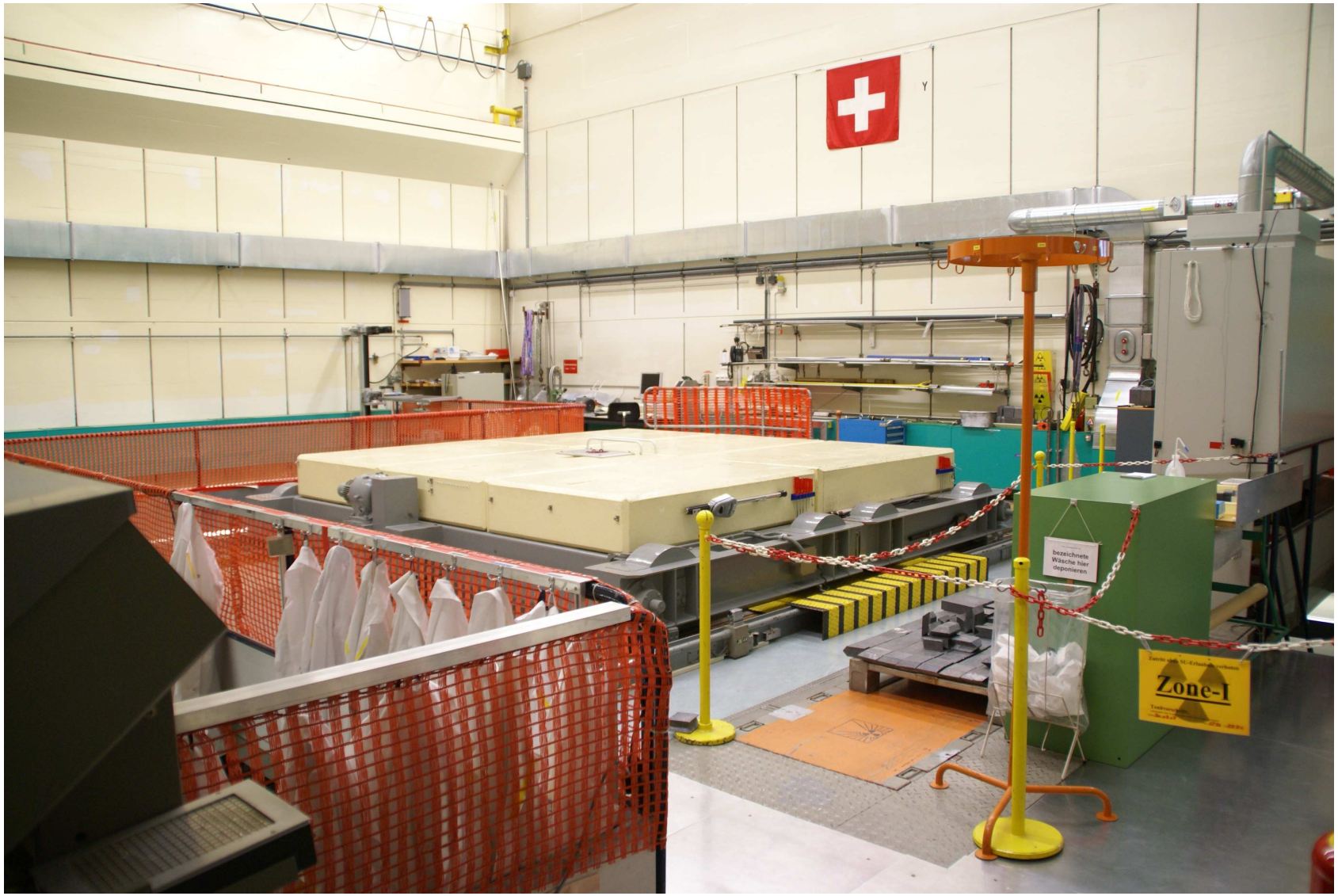
Wir schaffen Wissen – heute für morgen

Paul Scherrer Institut – IGORR conference

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

PROTEUS zero-power reactor refurbishment

PROTEUS facility



PROTEUS facility – Details

Zero power research fission reactor

- First operation: 1968
- Power < 1kW
- Thermal flux < 5×10^9 n/cm^2/s
- Driven system
  (graphite / D_2O / buffer / test zones)

PROTEUS Refurbishment

Motivations

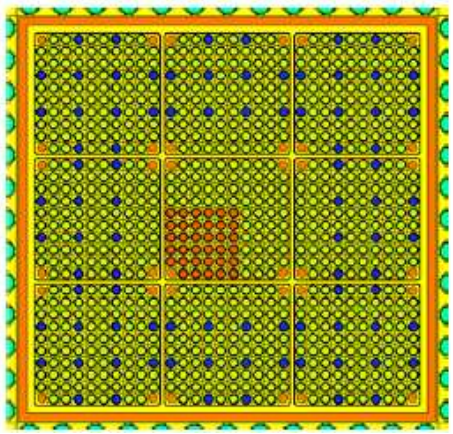
- Extend PROTEUS life-time
- Upgrade PROTEUS to host innovative experimental programs with large amount of spent fuel

Requirements – Construction License

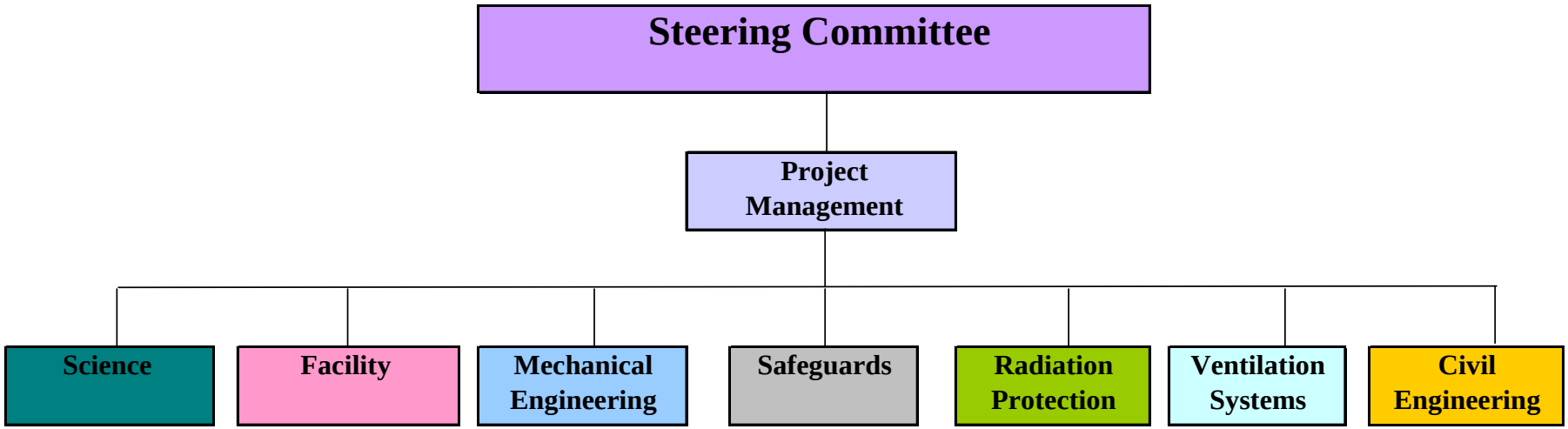
- Upgrade system and components of reactor to modern safety standards
- Remain a low risk facility – dose to the public lower than 1mSv for all incidents
- Upgrade the facility to Safeguard Category II
- Handle and store up to 100 full length PWR pins having a burn-up of 60 GWd/t

Requirements – Operation License

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



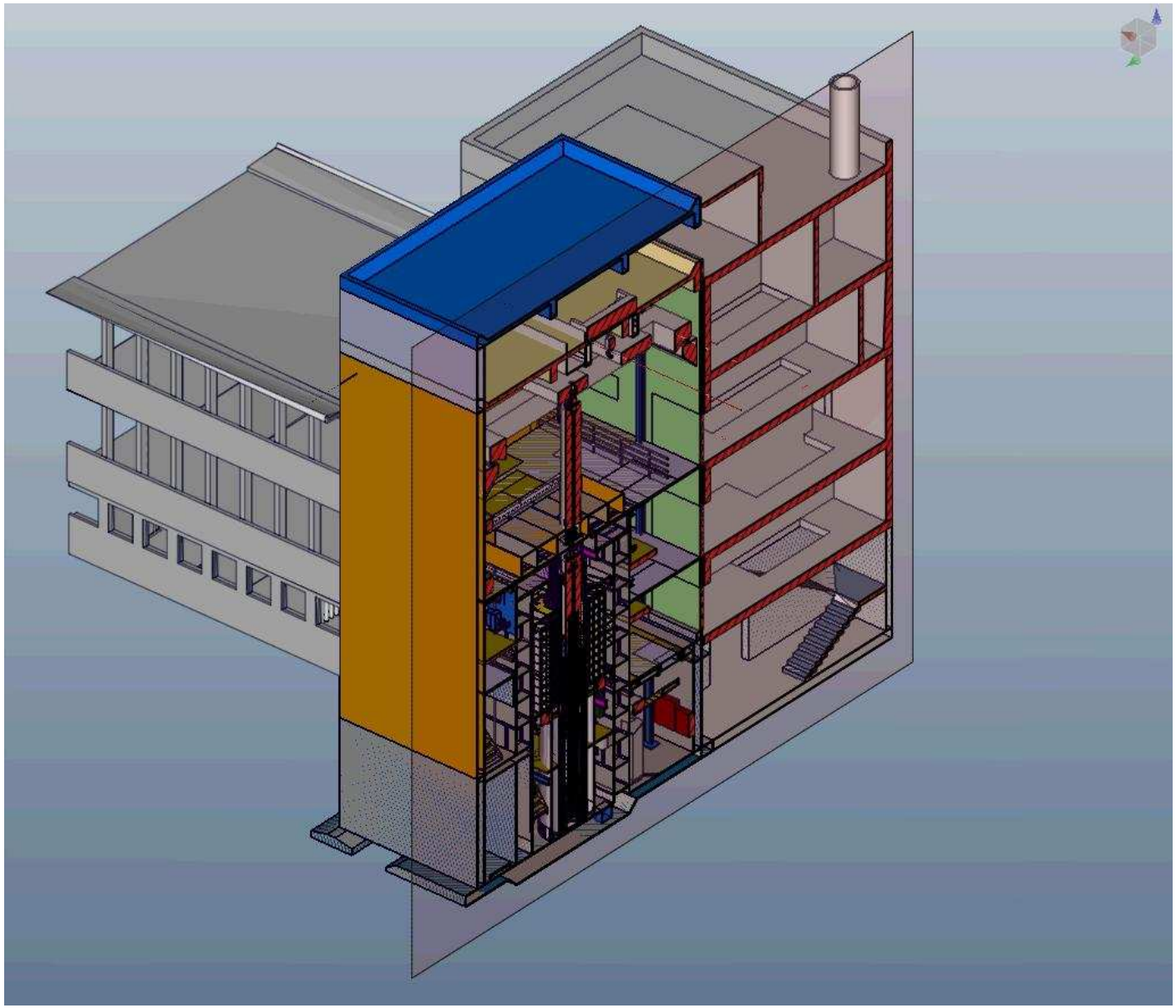
Project Organisation



External support and work

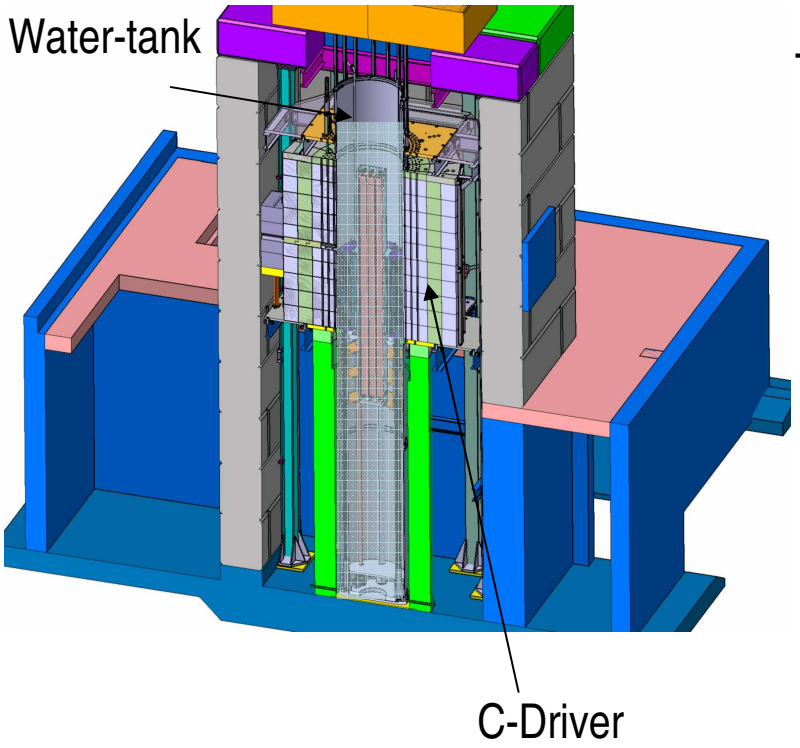
- Earthquakes and incident analysis, water loops etc. – External firms
- Mechanical components – Intern Paul Scherrer Institute
- Expertise (e.g. seismic) – Swissnuclear
- Civil engineering – General contractor
- Reactor protection system – Supplier of NPP

A vision of the Upgraded PROTEUS

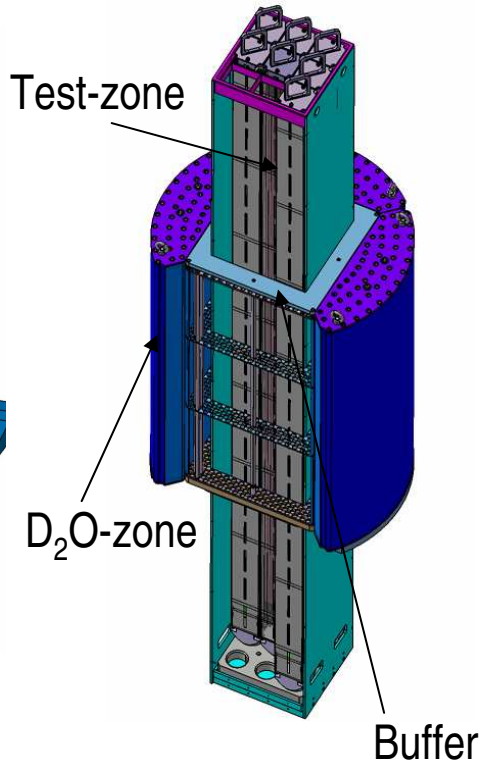


A vision of the Upgraded PROTEUS – Details

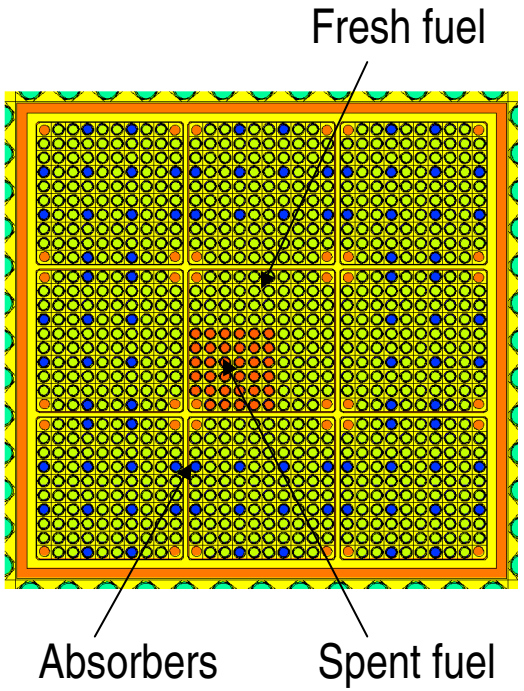
Reactor block



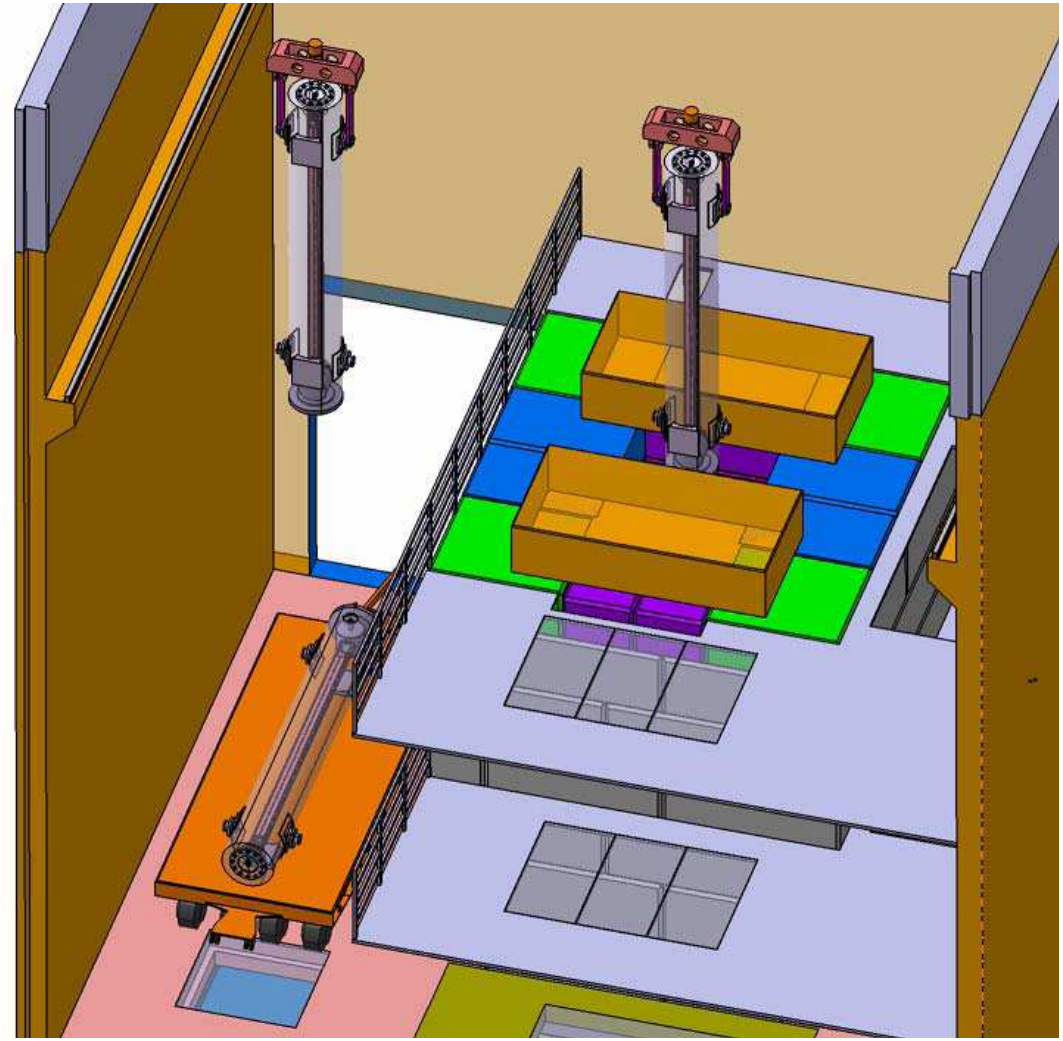
Reactor components

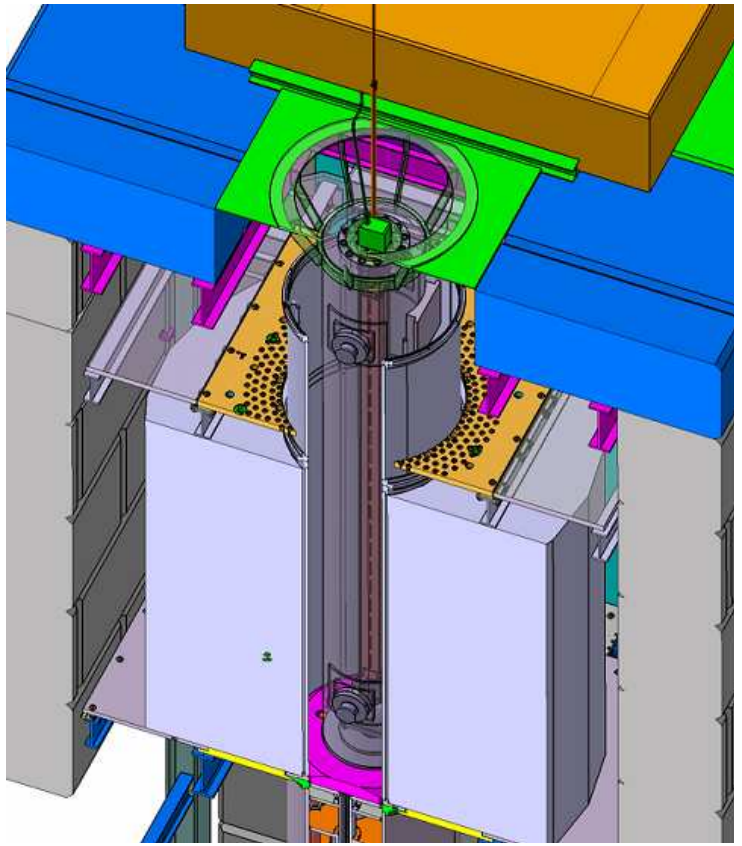


Test zone loading



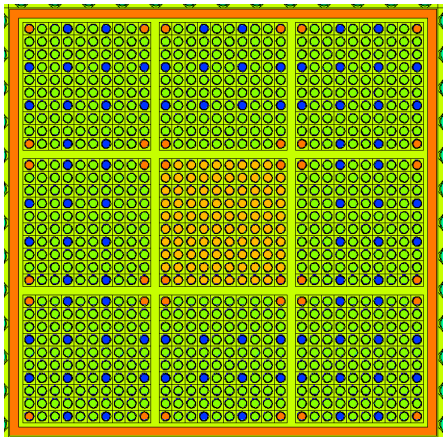
Loading and Handling of Spent Fuel

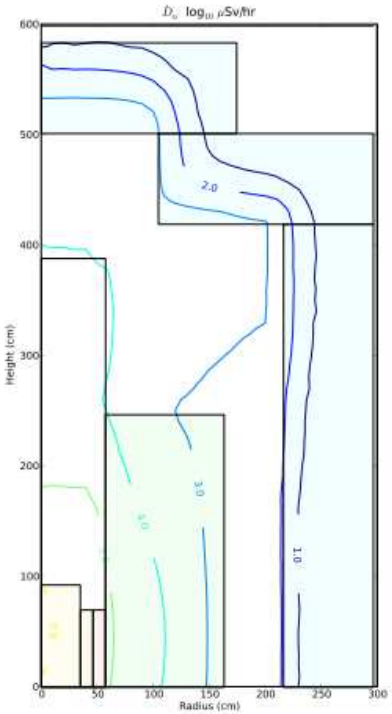


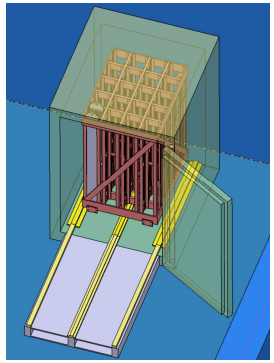


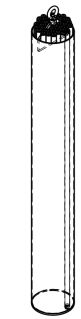
Technical issues – Dose rate and reactivity calculations

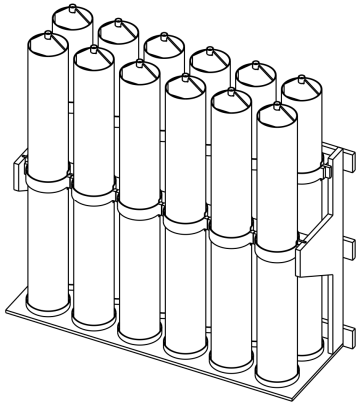
- Construction license application for 100 spent fuel rods
  - Covering activity inventory
  - Incident analysis and dose rate estimation
- Reactor safety parameters assessment
- Calculation of neutron and gamma dose rate maps in normal, measurement and accidental conditions
- Calculation of storage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











Technical issues – Earthquake analysis

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

Technical issues – Earthquake categories & spectra

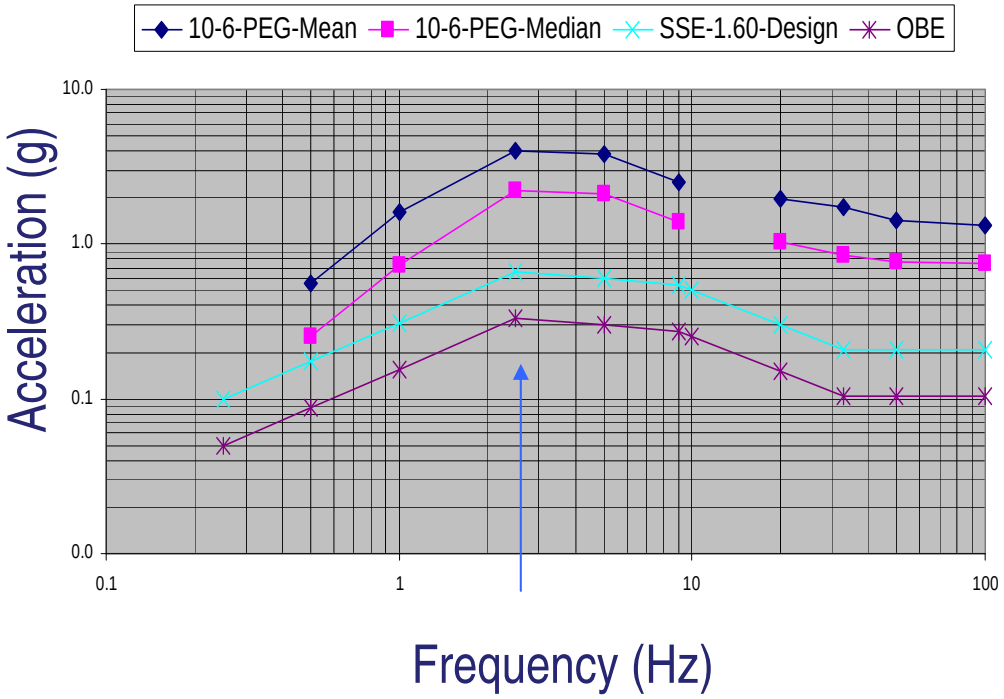
Categories

- 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

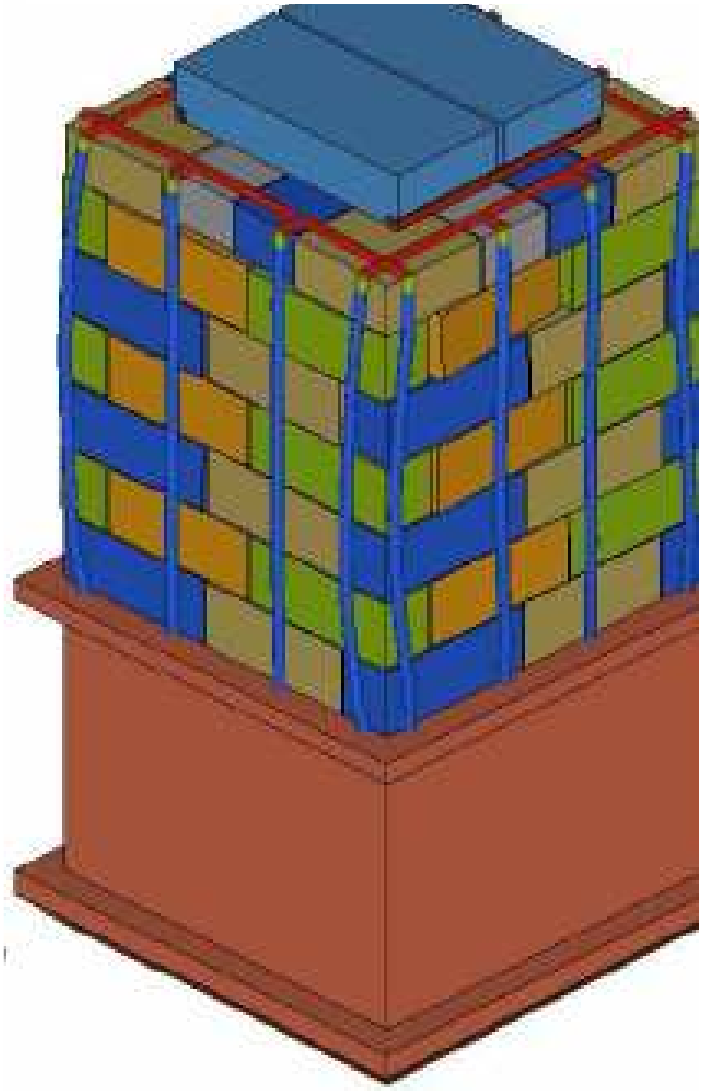
- Heavy Earthquake (HE) is beyond the design basis but is considered as the covering event for low risk facilities

Spectra

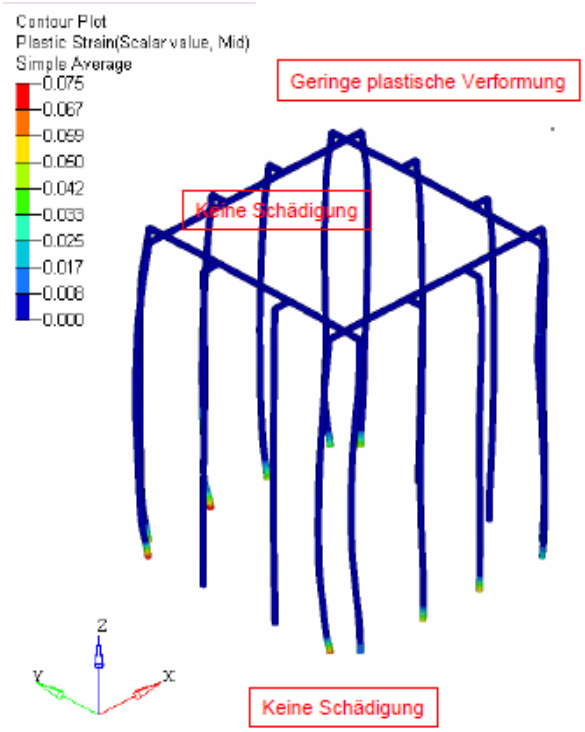


Technical issues – Improved earthquake resistance

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



Plastic Strain of the drawbars



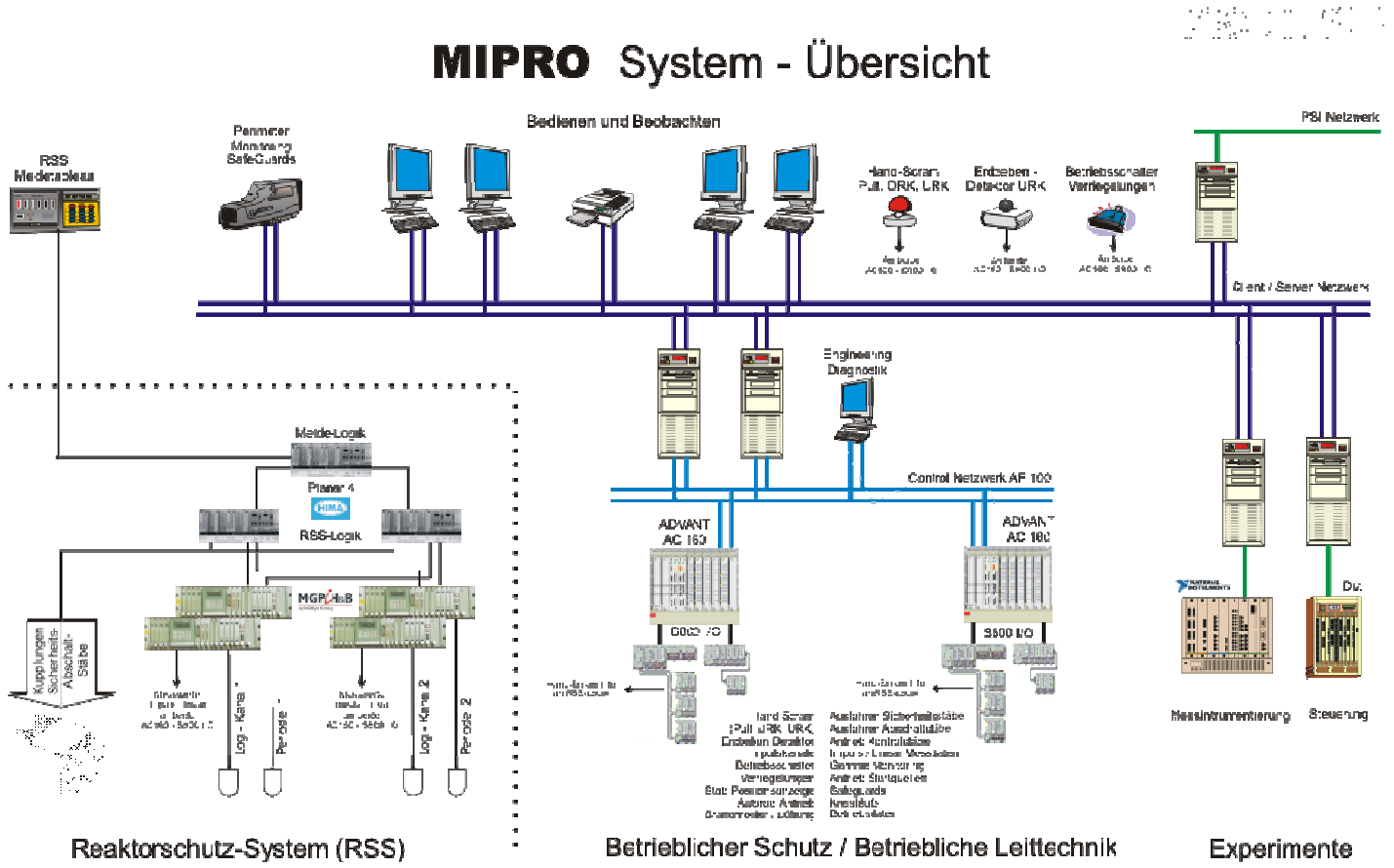
Results

- Block integrity insured
- Small plastic deformation

Technical issues – Instrumentation & Control Systems

Modernization of the I&C systems

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



Recent decision and profile of the facility

- 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

Outlook for the future

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

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Many thanks to

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

Thank you for your attention !