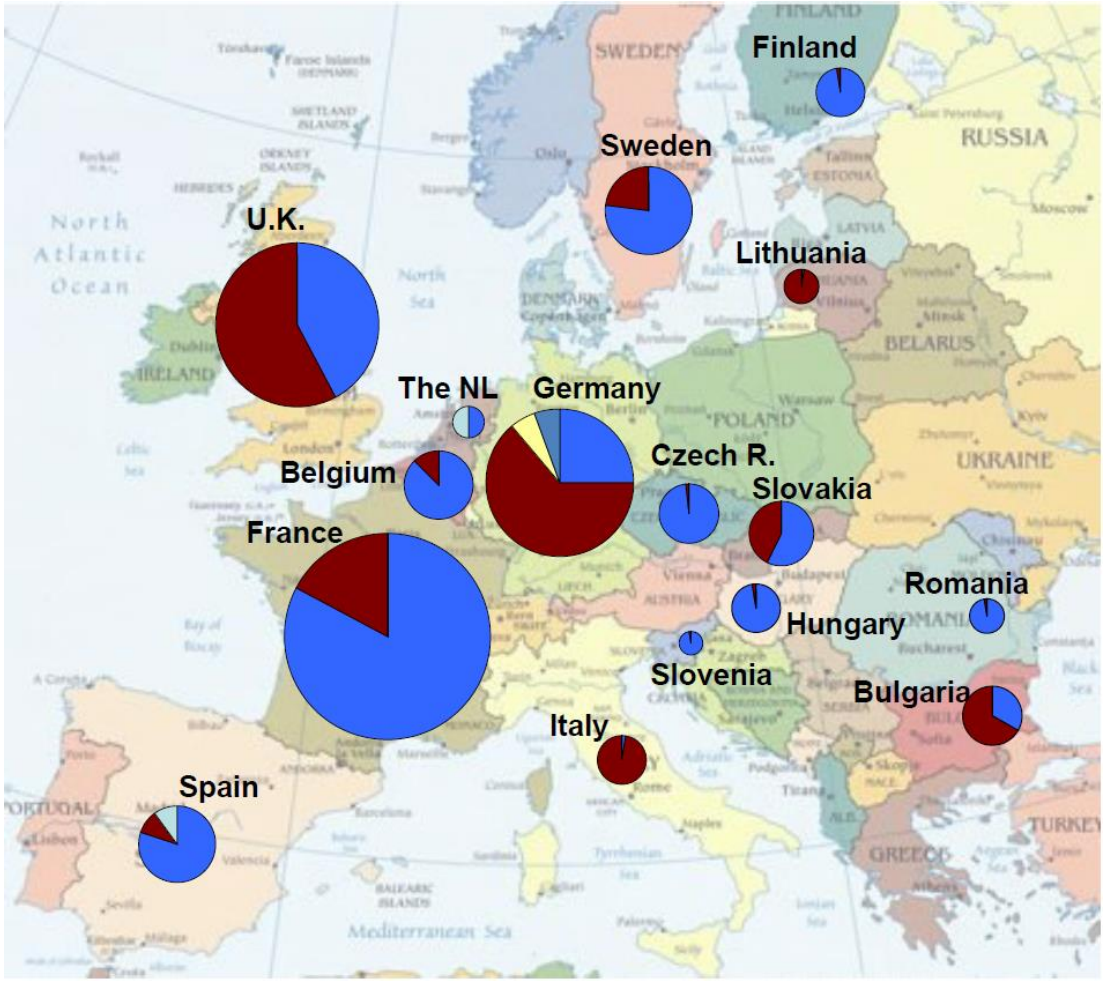
Karlsruhe Institute of Technology

Decommissioning of Nuclear Facilities

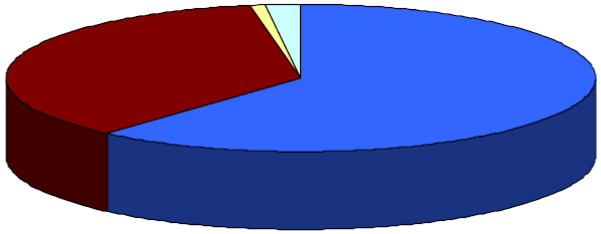
Th. Walter Tromm, Programme Nuclear Waste Management, Safety and Radiation Research



Situation of nuclear power reactors in the EU



- Operational
- Shutdown - Dismantling
- Fully Dismantled
- Long Term Safe Enclosure



TOTAL
Power reactors in EU: 220
Operating reactors: 135

Source: European Commission

Overview of German NPPs

Karlsruhe Institute of Technology

NPPs in operation:

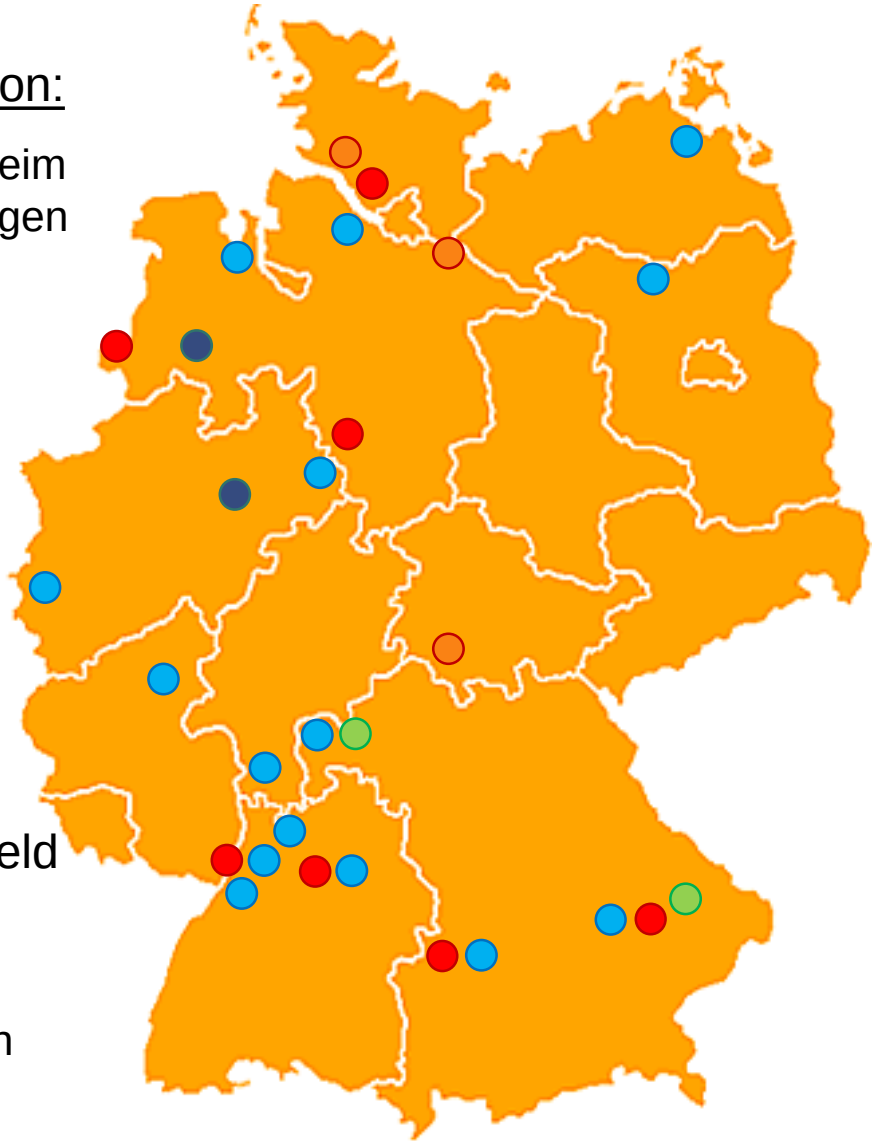
GKN-2 Neckarwestheim
KRB C Gundremmingen
KBR Brokdorf
KWG Grohnde
KKP-2 Philippsburg
KKE Emsland
KKI-2 Isar

Shut down NPPs:

KKB Brunsbüttel
KKK Krümmel
KKG Grafenrheinfeld

„Green field“:

KKN Niederaichbach
HDR Großwelzheim
VAK Kahl



NPPs in dismantling:

KKU Unterweser
KRB B Gundremmingen
GKN-1 Neckarwestheim
KKP-1 Philippsburg
KWB A Biblis
KWB B Biblis
KKI-1 Isar
MZFR Karlsruhe
AVR Jülich
KKW Mülheim-Kärlich
KKR Rheinsberg
KGR 1-5, Greifswald
KNK II Karlsruhe
KKS Stade
KWO Obrigheim
(KWW Würgassen)
(KRB A Gundremmingen)

Plants in safe store:

FR2, KWL Lingen,
THTR Hamm-Uentrop

Remaining terms according to current legislation

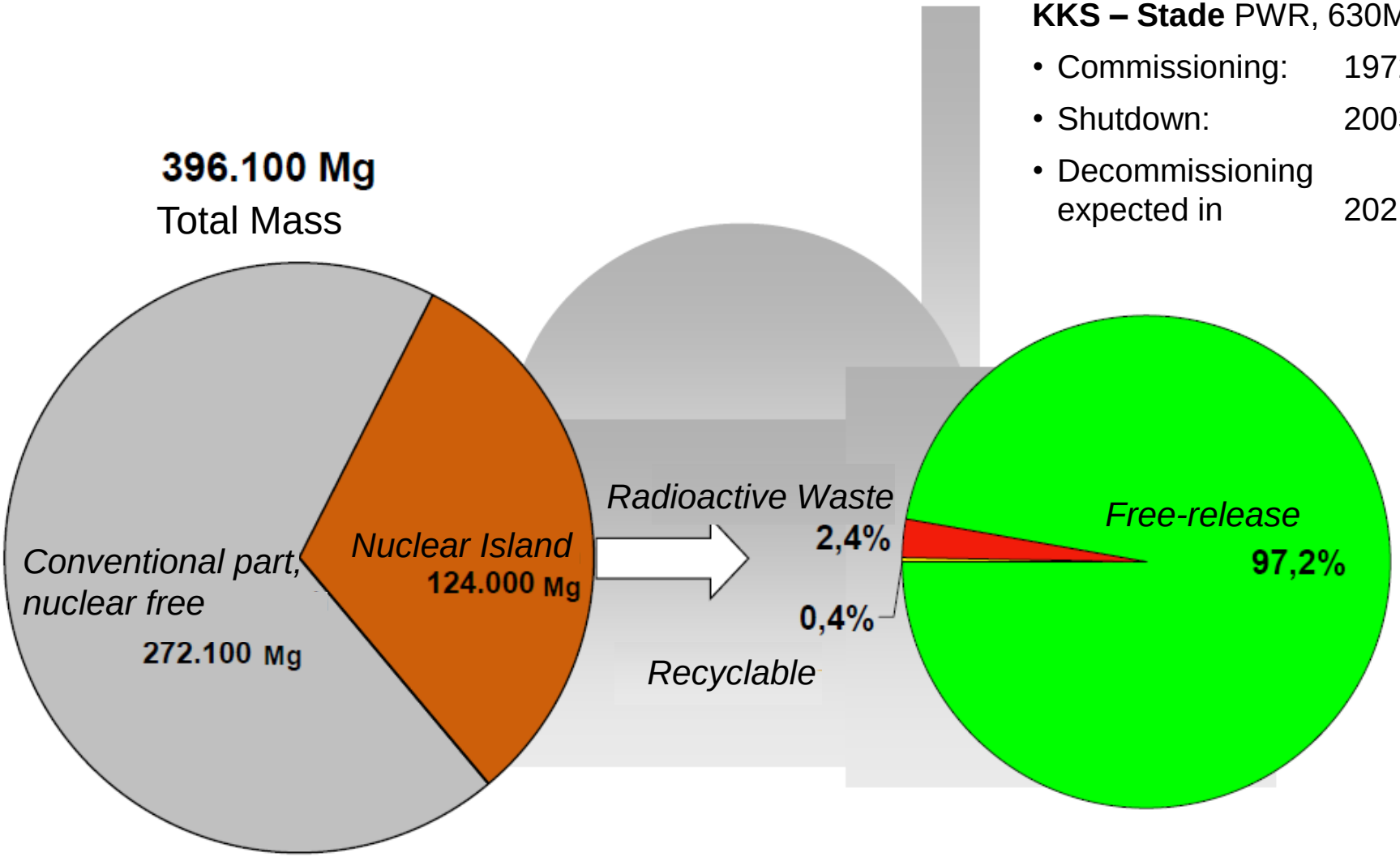
Power Plant	First criticality	Capacity MW_e	Scheduled Shut-Down
Philippsburg 2	13.12.1984	1 468	12/2019
Grohnde	01.09.1984	1 430	12/2021
Gundremmingen C	26.10.1984	1 344	12/2021
Brokdorf	08.10.1986	1 480	12/2021
Isar 2	15.01.1988	1 485	12/2022
Emsland	14.04.1988	1 400	12/2022
Neckarwestheim 2	29.12.1988	1 400	12/2022

Source: http://www.kernenergie.de

Example of Stade

KKS – Stade PWR, 630MWel

- Commissioning: 1972
- Shutdown: 2003
- Decommissioning expected in 2021



Source : http://www.eon-kernkraft.com

Federal Nuclear Waste Repository in Germany

- **Nuclear waste repository for high-level radioactive waste, heat generating materials/fuel elements**
  - 9. April 2013 a new approach to finding a repository was started
  - Decision for a location expected in 2031
- **Repository for low and medium radioactive materials/waste:**
  - **<u>Konrad:</u>**
    - Former ore mine
    - Deposit depth 800-1300m
    - Approved storage volume 303.000m³
    - Waste: 40% public and 60% utilities
    - Completion was planned for 2013 -> expected 2027!!
    - Estimated costs about 2.2 billion €

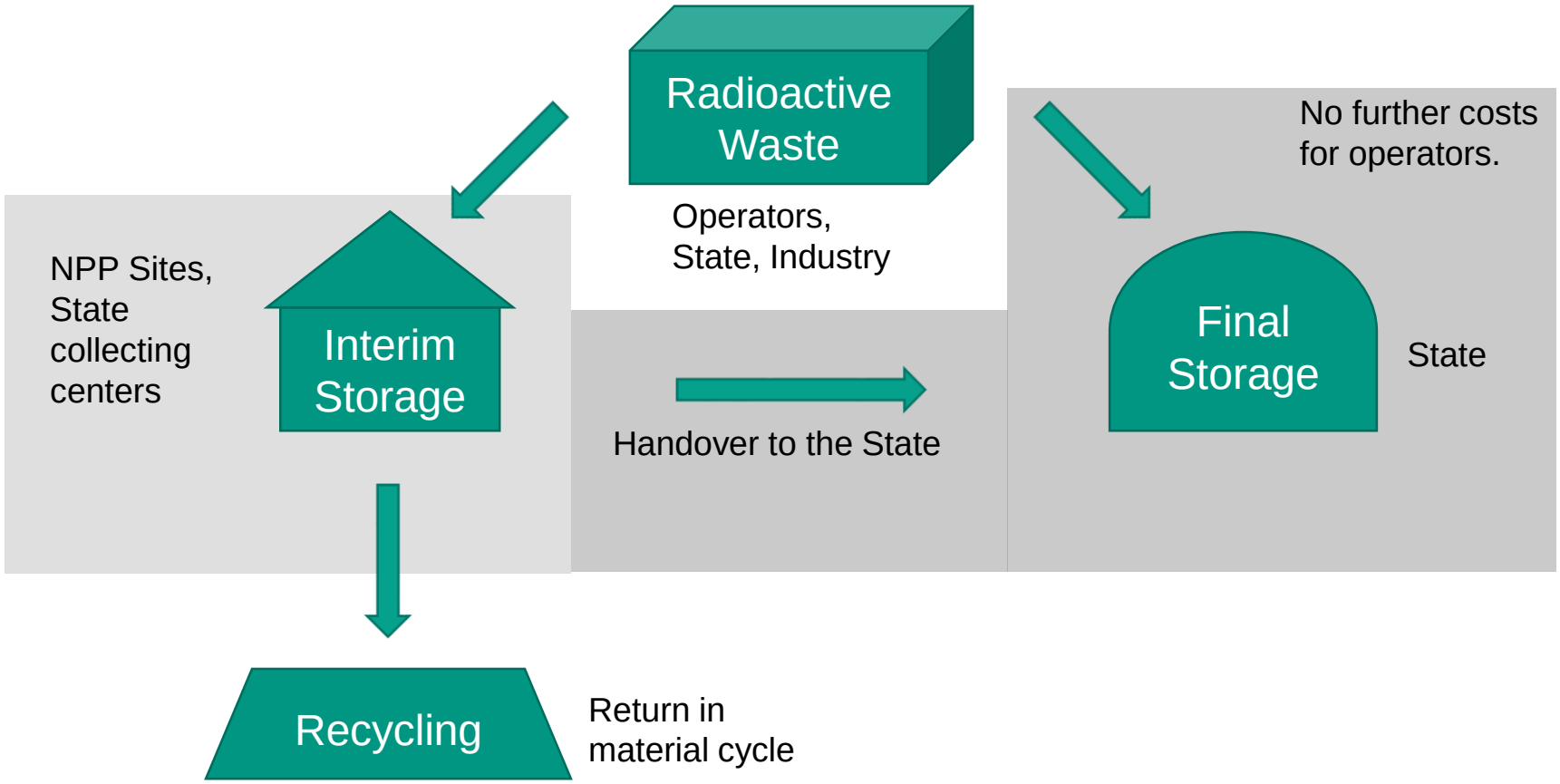
Interim storages in Germany

- At most NPP for used/spent fuel and decommissioning waste
- Federal state collecting facility (waste from industry, research and medicine)
- Central collecting points (Gorleben, Esenshamm, Mitterteich, ZLN, Ahaus)
- Interim storage at research facilities (for operational waste)

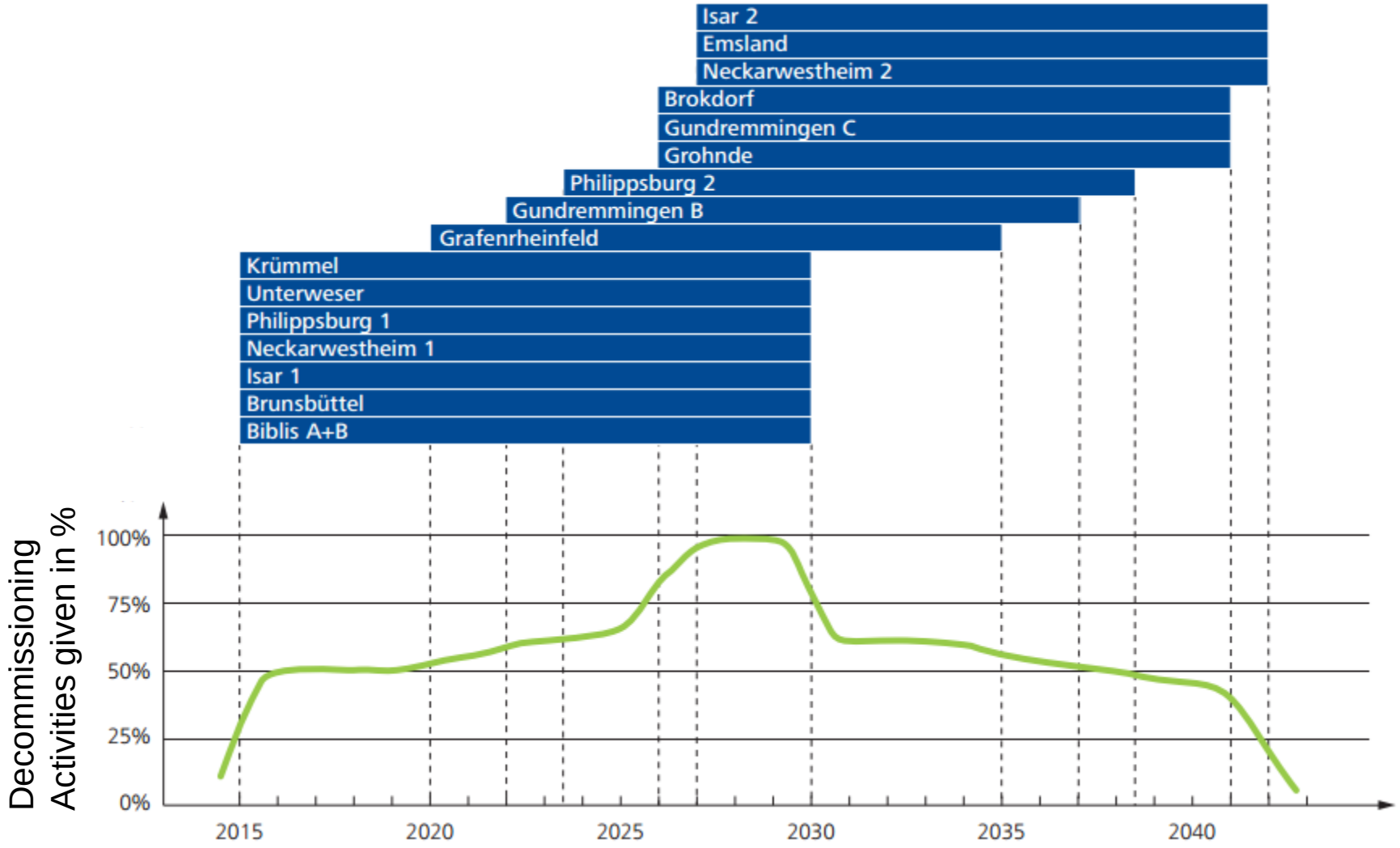
- In December 2016 a new law: the nuclear waste management liabilities are passed to the state
- Operators have transferred **24 billion €** on the 3rd of July 2017
- Started in 2019, the ownership of the radioactive waste will be passed to the federal state

Waste Liability (change in 2017 by law)

- Types of storage facilities



Future Challenges in Germany



Source: http://www.eon-kernkraft.com

Nuclear Waste Management, Safety and Radiation Research

Participating Helmholtz - Centres

Forschungszentrum Jülich GmbH (FZJ)

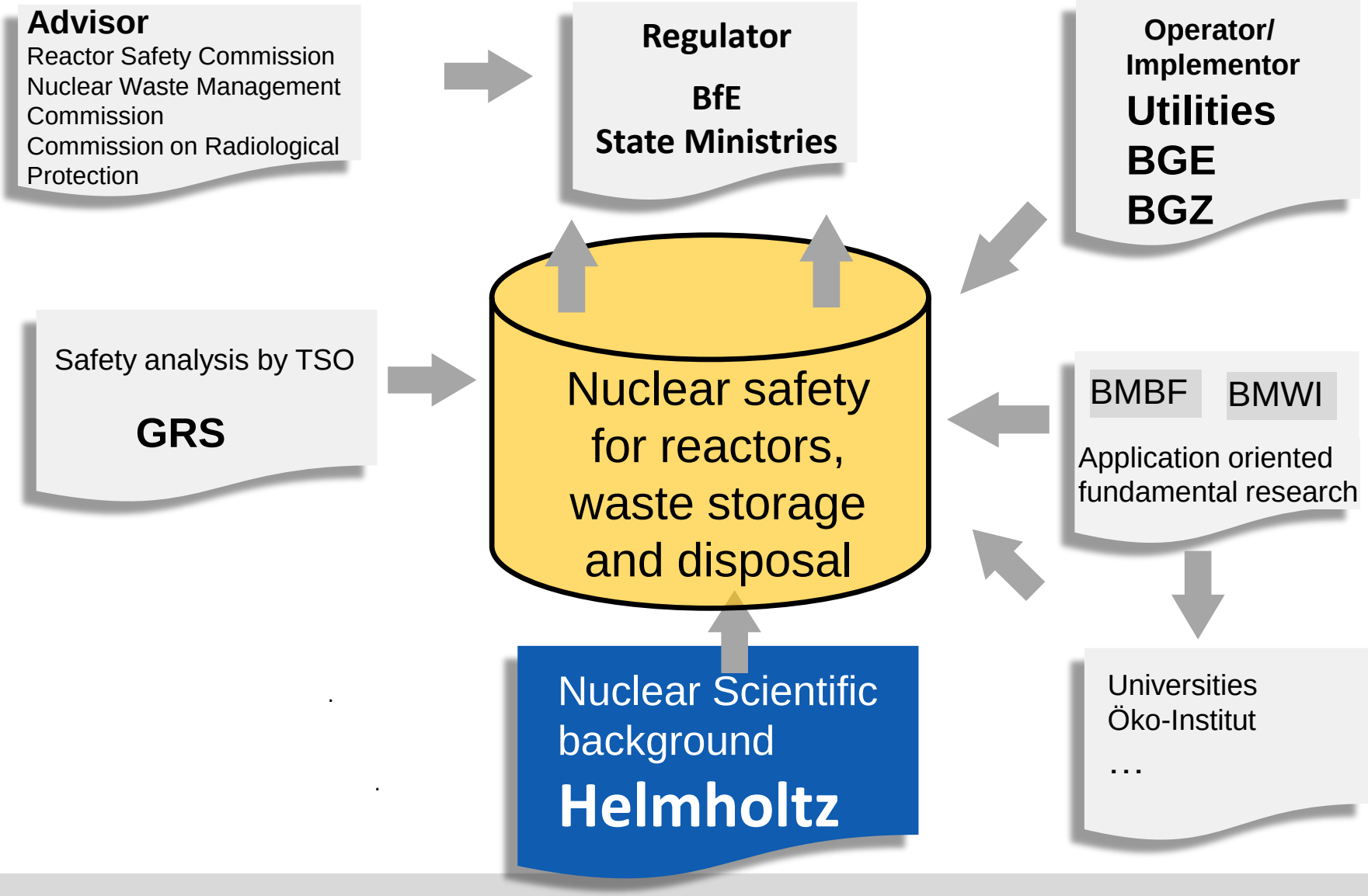
Helmholtz – Zentrum Dresden – Rossendorf (HZDR)

Karlsruher Institut für Technologie (KIT)

Statements from Mid-term evaluation 2018:

- The research in all three centers yielded outstanding outcome over POF III
- The work is well recognised at international level
- The research facilities constitute a particular strength

Nuclear Safety Organisations in Germany



Competences at KIT in Decommissioning of nuclear Facilities

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INE
- Hot cells
- Radio analytics
- Waste characterization
- Product characterization
- Product behavior (long-term)
- Conditioning
- Radionuclide behavior
- Radiation protection research

TMB/RKKB
Innovative mechanical decontamination
- Crushing techniques
- Automation
- Minimizing dose rate
- Minimizing waste
- Management

INR
- Shielding calculations
- Determining radionuclide vector
- Detectors
- Instrumentation

IAM
- Material behavior
- Fuel
- Cladding tubes
- Characterization

IMB/MPA
- Concrete and Building Physics
- Materials and components
- Measurement and Nuclear Safety
- Chemistry and Physics of Materials

Long-term KIT-Cooperation
- EU (EURATOM)
- IAEA, OECD-NEA
- F: CEA, ANDRA. EdF
- CH: PSI, ENSI, NAGRA

SUM
- Radiation protection
- Personal dosimetry
- Radioactive monitoring
- Contact to authority

IHM
- Microwave application
- Innovative separation techniques

IKET
- Long term activity inventory
- Emergency Response Management

ITAS
- Socio-scientific, political issues
- Public involvement
- Governance

Education / Teaching
- KIT School of Energy
- TMB-Module „Dismantling of nuclear facilities“
- AREVA Professional School
- Radiochemistry
- Radiation protection

IIP
- Decommissioning planning and optimization
- Project management in decommissioning

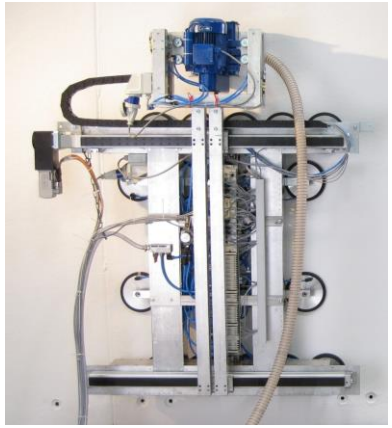
IfGG
- Regional and local influences
- Socio-geographic analysis
- Economic, social issues
- Scenario development

PTKA-WTE
BMBF/BMWI funding
- Decommissioning projects
- Research and development for dismantling

Division of Deconstruction and Decommissioning of Conventional and Nuclear Buildings (RKKB)

- Development and improvement of processes and technologies
- Automation and remote handling of procedures
- Project management (reduction of time, cost and risk)
- Preservation of competence (lectures, doctoral candidates, internships)

Prof. Dr.-Ing. Sascha Gentes



Manipulator for the decontamination of walls as an R&D example

Decommissioning of nuclear facilities lecture

IAEA workshop dismantling of nuclear facilities

Decommissioning Department at TMB


Front view


Test Facilities


Workshop

Test Facilities and Resources

Decommissioning Department at TMB

- Underwater testing facility

- Mock-up on a scale of 1 : 1

Test Field

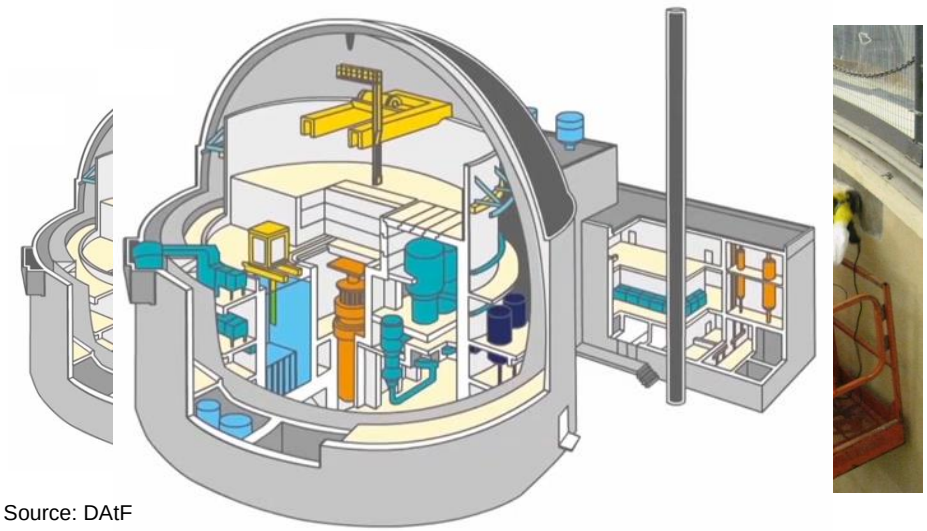
Mock-up at TMB

Cold test at the institute

Practical application in the KNK plant

Dismantling and extraction of heavy concrete with chisel and suction pipe

KIT TMB approach: Industrial application: R&D example: Concrete Decontamination Technologies



Source: DAtF

Manual work during:

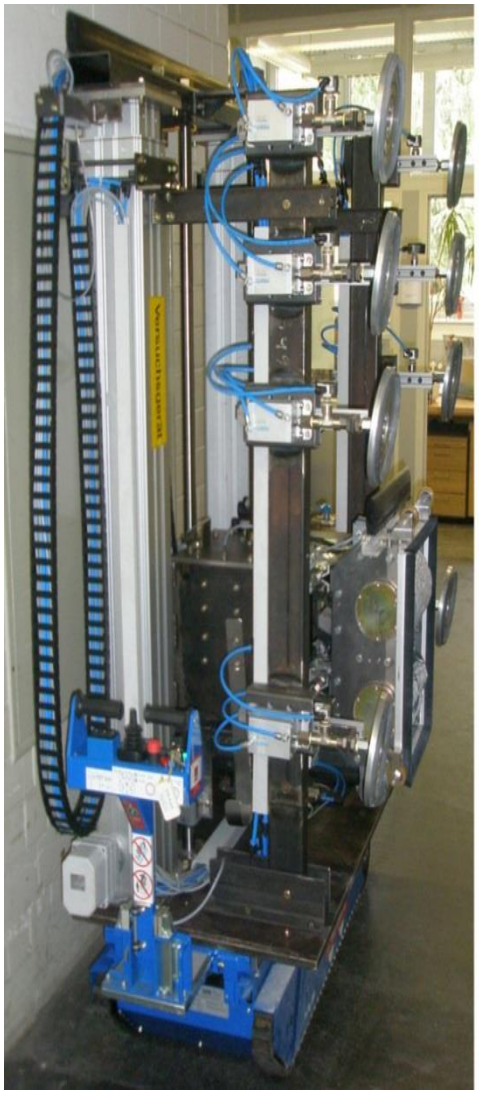
- Removal, dismantlement and transport of contaminated components
- Characterization and decontamination of surfaces

Driver for automated systems and manipulators with high precision

Optimization and Application of the Technology

Outlook:

- Further analysis of parameters
- Experimental investigation at KIT and application in the nuclear power plant Obrigheim



Project partner

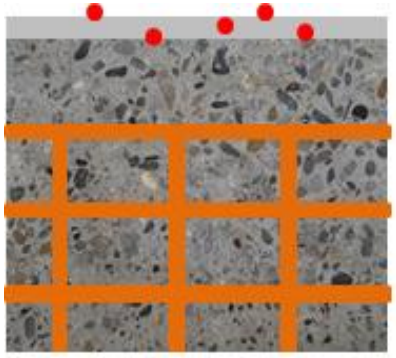
- Energie Baden-Württemberg AG (EnBW)
- Patent awarded

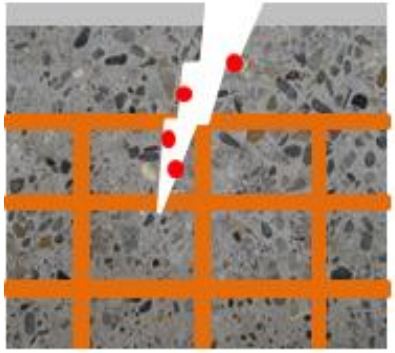
➡ **Minimization of secondary waste**

➡ **Minimization of exposure time**

Selective Removal of Highly Reinforced Concrete Structures

- **Problem:** Cracks in the surface not to be measured
- **Solution:** Combined tool to remove both materials
- Decontamination of cracks (up 300mm depth)
- Removal of built-in elements (e.g. anchor plates, dowels)





- Cooperation between:

Kraftanlagen Heidelberg

Karlsruher Institut für Technologie

HERRENKNECHT Tunnelling Systems

Leibniz Universität Hannover

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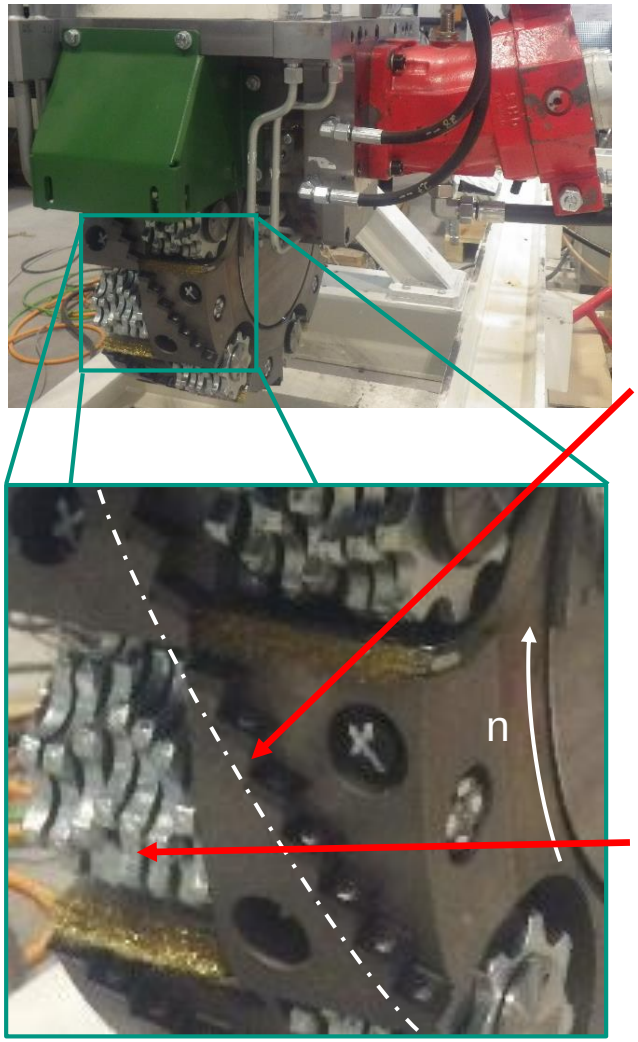
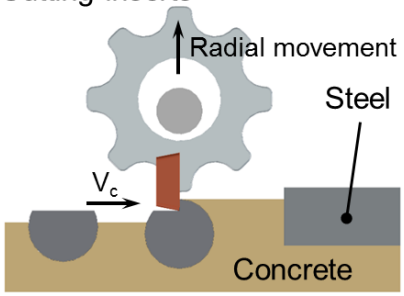
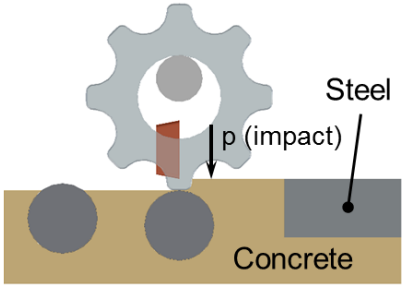
Deep Decontamination of Concrete Surfaces

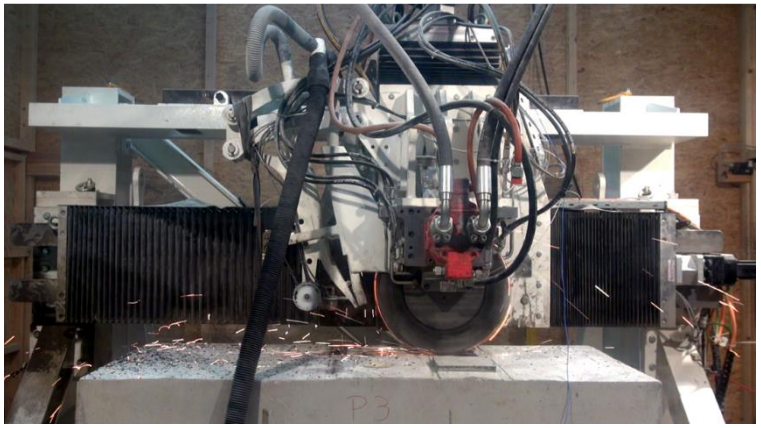


Cutting inserts



Impact cutters



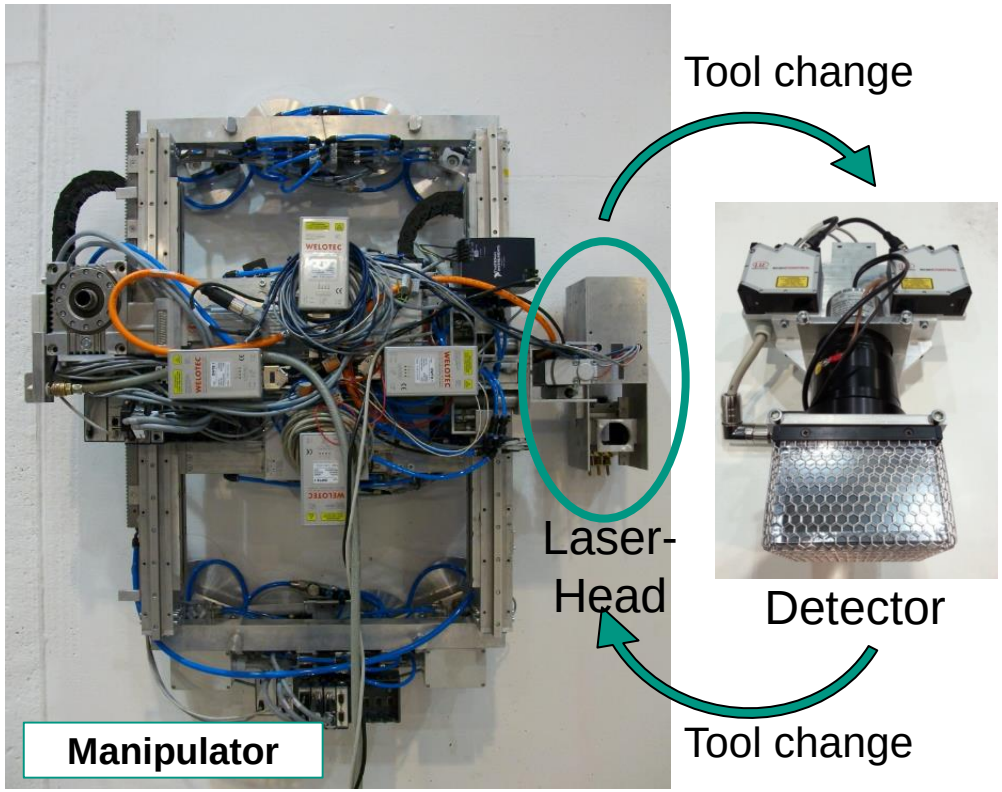


Kaiser, S. et al. (2017) Development of a tool system for the surface decontamination of reinforced concrete structures, KONTEC

Manipulator Operated Laser Ablation and Release Measurement of Surfaces (MANOLA/MAFRO)

- Procedural chain for decontamination (in general):

Contamination Measurement → Decontamination → Release Measurement



Problem:

Measurement of surfaces is still performed manually

Goals:

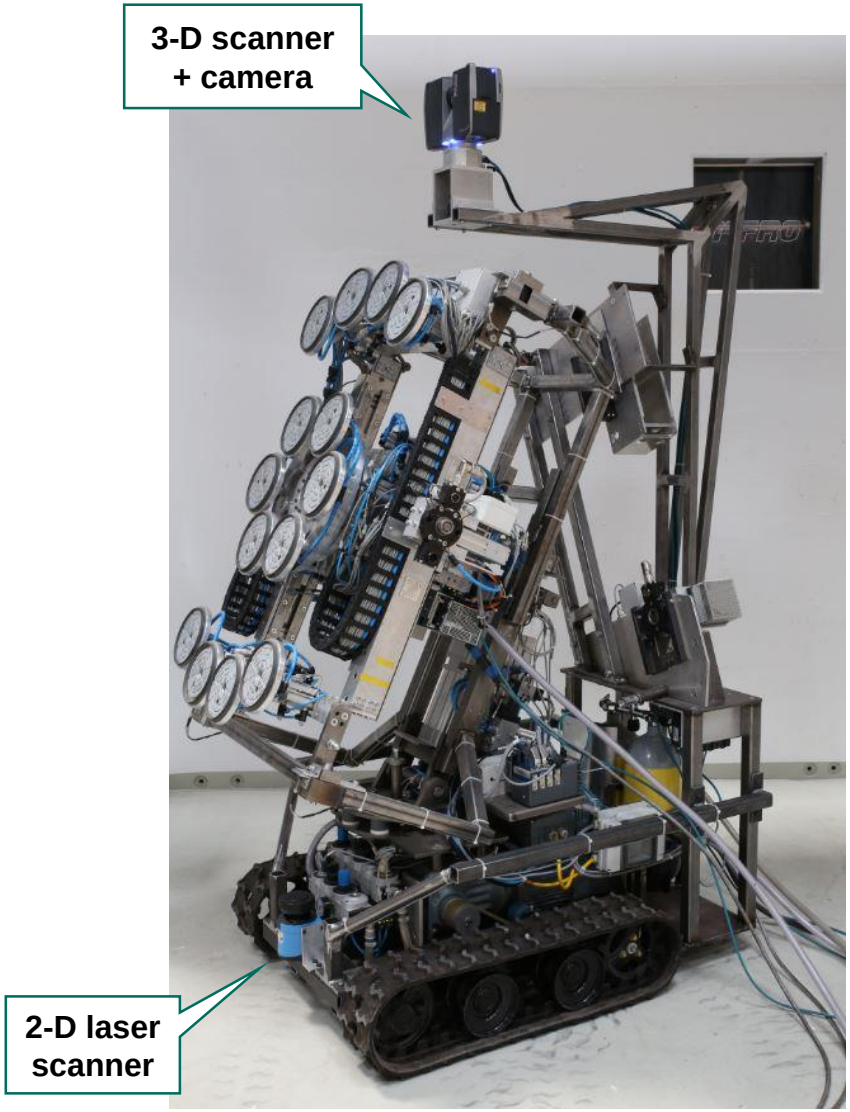
Combining the individual steps

- Contamination Measurement
- Decontamination
- Release Measurement in a single system!
- Autonomous navigation and documentation

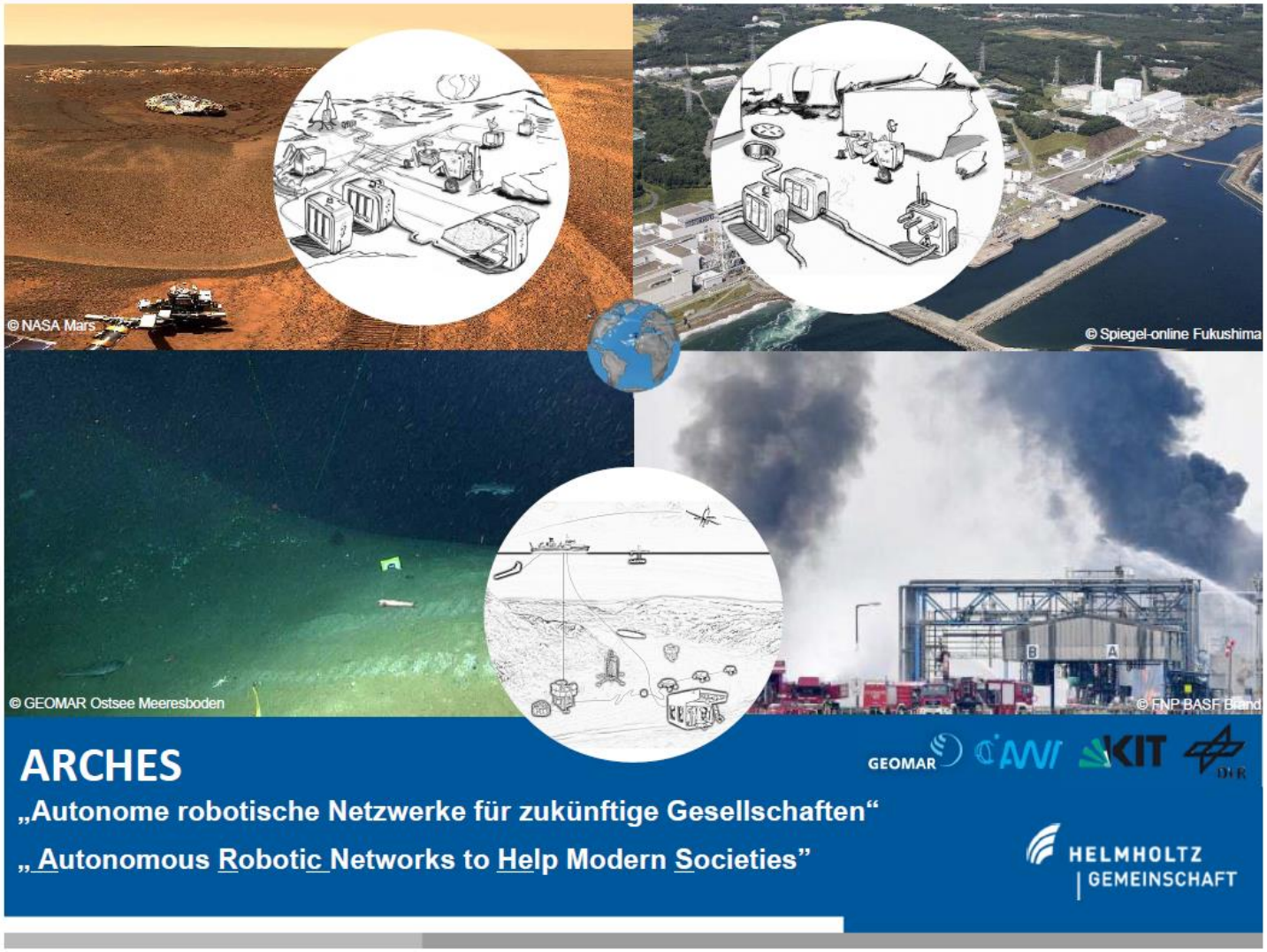
Trolley System

Specifications:

- Crawler tracks for difficult terrain
- Rotatable device to carry, deploy, and retrieve manipulator (also for the quick-coupling system)
- Additional sensors
- High-resolution 3-D laser scanner for exploration and environmental model generation
- 2-D laser scanner and camera for navigation and localization



HELMHOLTZ IVF: ARCHES



Robotic systems for decontamination in hazardous environments (ROBDEKON)

- Goal: Creation of an innovation laboratory / competence center
- Decontamination and free measurement in hazardous environments, for example in nuclear installations
- Budget: 12 Mio. € (thereof € 1.2 million at KIT-TMB) by the BMBF
- Duration of 4 years with possible follow-up funding (Start: 15.06.2018)
- Project network of IOSB, KIT, DFKI and FZI, as well as outstanding research infrastructure and living labs for students, scientists and representatives of the industry
- Partner:

Fraunhofer IOSB, DFKI, KIT Karlsruher Institut für Technologie, FZI, GÖTTING, Kraftanlagen Heidelberg, KHG Kerntechnische Hilfsdienst GmbH, ICP

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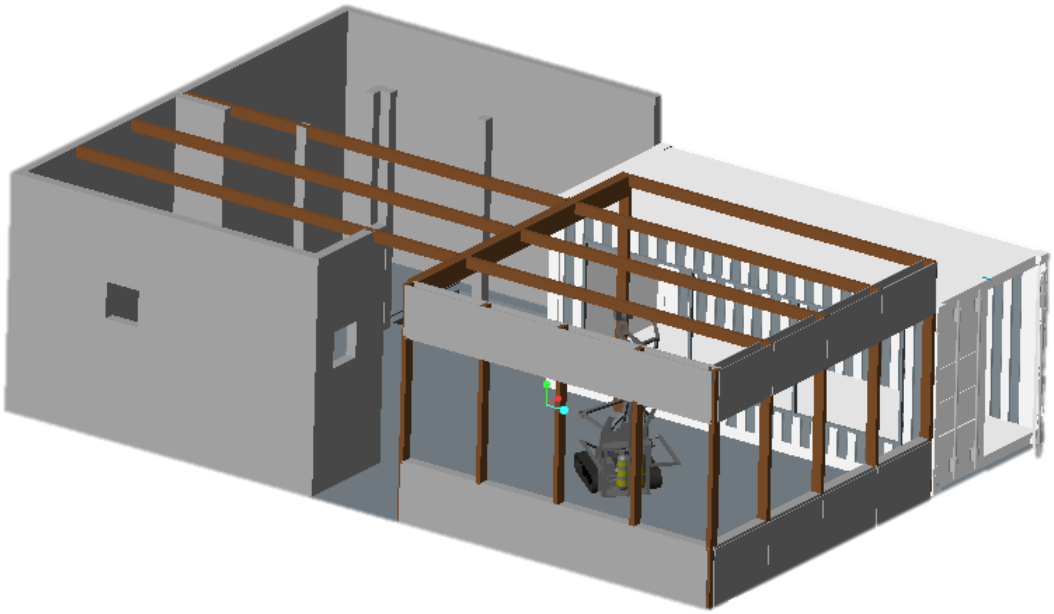
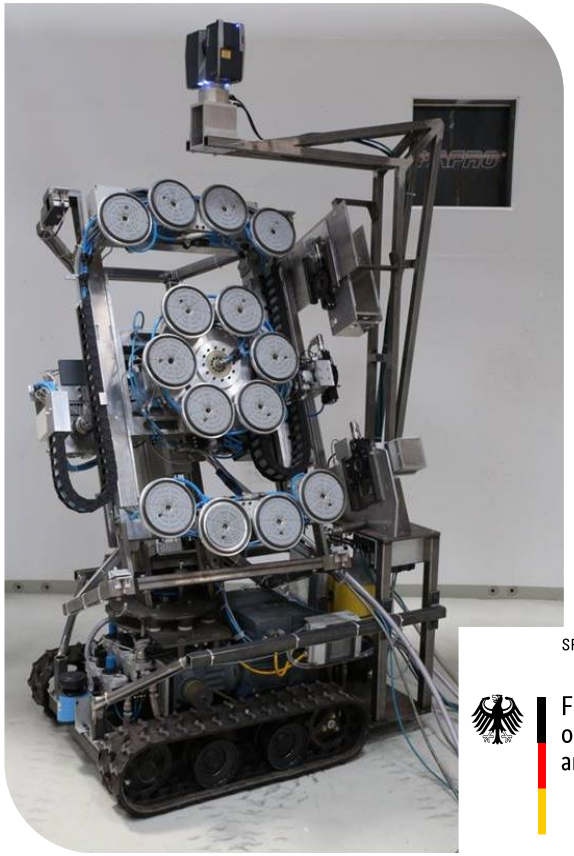
Part of the KIT Institute for Technology and Management in Construction (TMB)



Design of the robot Living Labs for mapping, characterization, decontamination and free release measurement



Manipulator for mapping and characterization (MAFRO)

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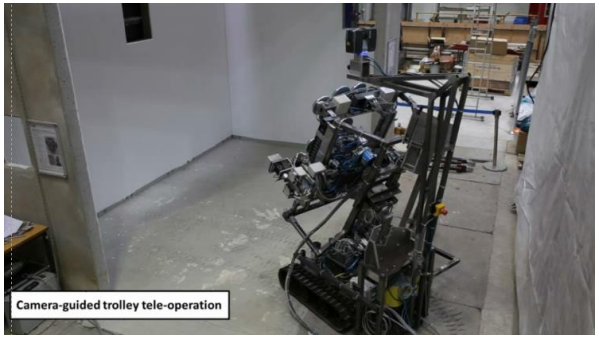
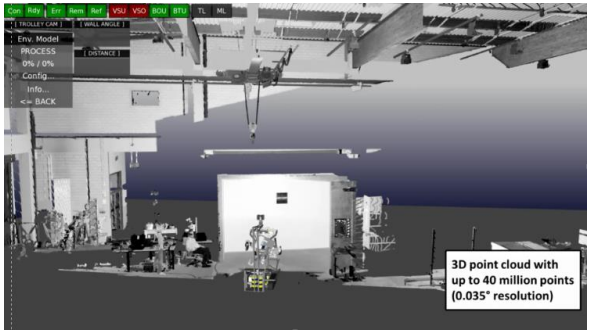
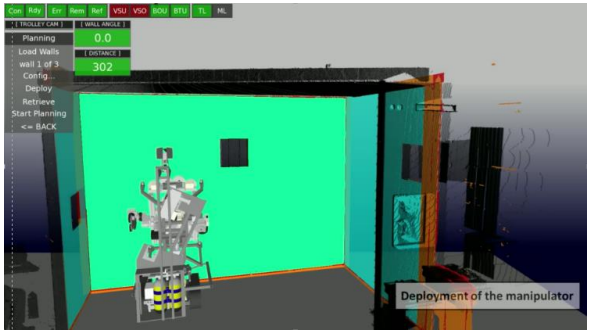
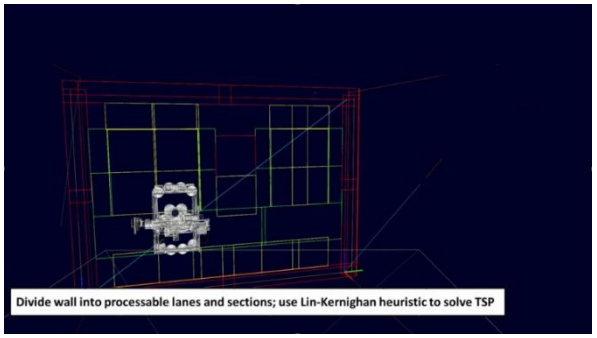
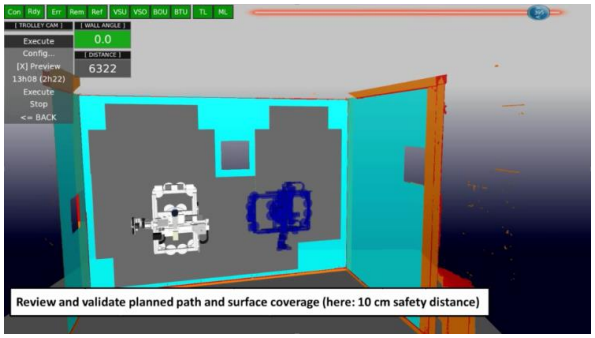
Decontamination and Characterization (MAFRO)

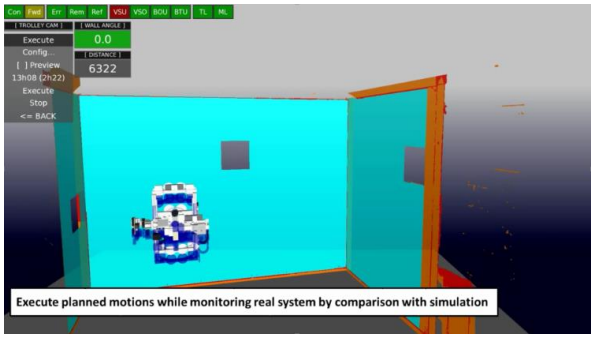












In cooperation with the Institute for Intelligent Process Automation and Robotics Lab (IPR)
Partner of the ROBDEKON consortium:

https://www.ipr.kit.edu/

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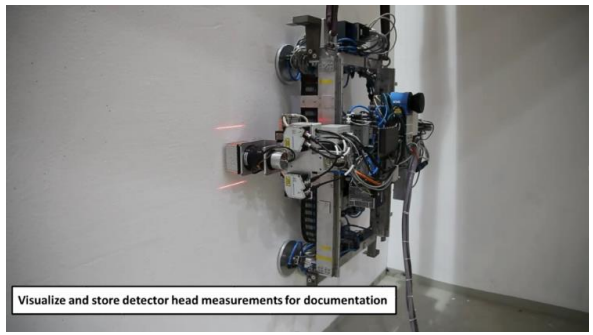
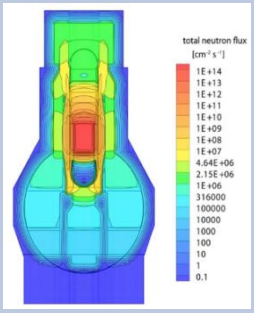


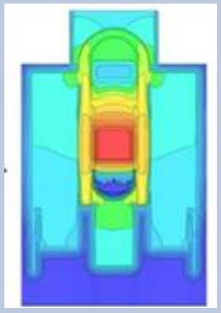
Knowledge of the radiation transport and distribution

- Neutron-flux distribution

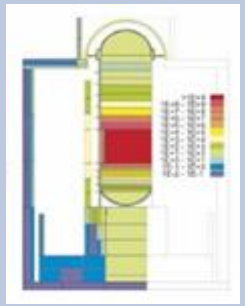


- Activation of NPP components

- Doserate-distribution



- Material-composition



Aim:

- Development of appropriate decommissioning concepts
- Packiging
- Characterisation of components
- Planning of work steps

Objective to facilitate:

- Regulatory decisions
- Radiation protection measures
- Safety demonstration

Foundation of the Decommissioning Cluster

- Involved Institutions:

DHBW Karlsruhe

Universität Stuttgart
IKE u. MPA
Universität Stuttgart

Karlsruhe Institute of Technology
KIT Competence Center for Decommissioning

JRC-ITU und
JRC-IRMM

PAUL SCHERRER INSTITUT
PSI Schweiz

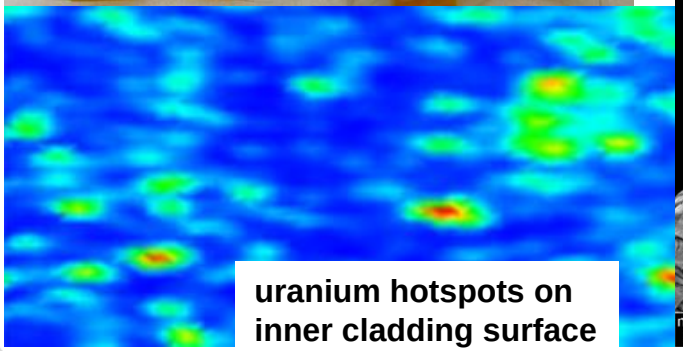
Zircaloy cladding performance under prolonged dry interim storage

- Integrity of spent fuel assemblies (FA) after dry interim storage important.
  → safe reloading of spent FA from interim storage cask to final disposal canister.
- Integrity of Zircaloy cladding affected by:
  - coolant (oxidation and hydride uptake).
  - mechanical stress (fuel pellet swelling and He accumulation).
  - fuel-clad-chemical-interaction (corrosion with volatile fission products at cladding / fuel interface).
- Black/blueish precipitates on the inner surface of irradiated Zircaloy-4 cladding observed at KIT-INE.

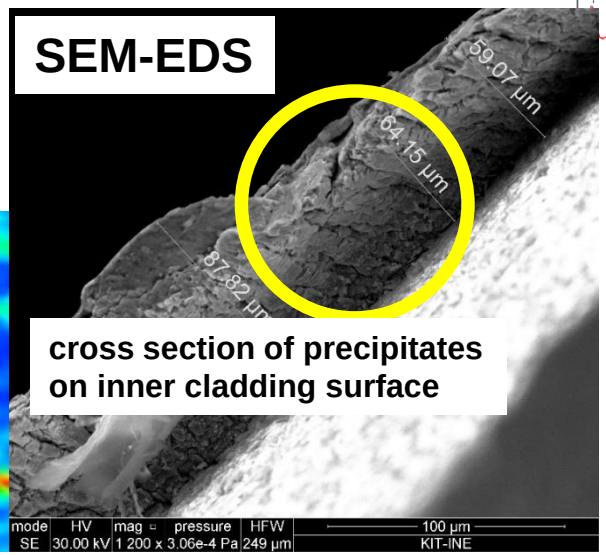
Zircaloy cladding performance under prolonged dry interim storage

- Investigations at KIT-INE focus on:
  - interaction of irradiated UOX and MOX fuel pellets with the cladding.
  - minor actinides / fission products accumulation on inner cladding surface.
- Use of various chemical / theoretical / spectroscopic techniques for characterization of cladding surface precipitates.

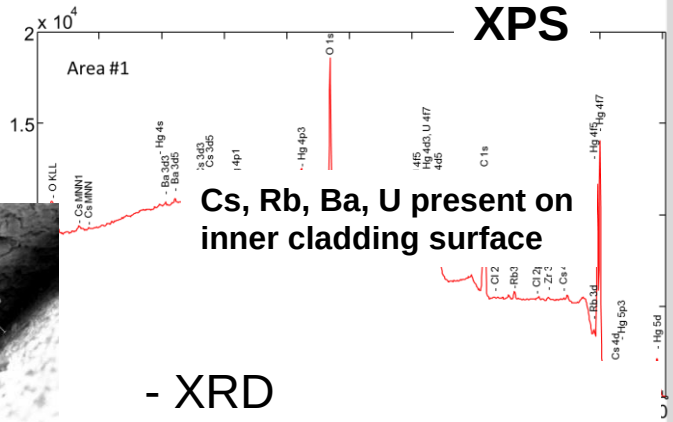
XAS/XRF @ ANKA



SEM-EDS



XPS



- XRD
- Raman
- ICP-MS
- α-, γ-spectroscopy
- LIBD
- **MCNP calculations**

Strategic objectives of the decommissioning cluster

- Coordination and bundling of activities:
  - in research, teaching and training
- Enhanced cooperation:
  - with other universities, research centers, government agencies and industry, in Germany and in Europe.
  - Cooperative support international initiatives to maintain competence (as Summer Schools in Decommissioning).
  - Tracking of trends in job development and representation of training capacity
  - Further research and development for an integral approach related to predisposal activities.

Thank you for your attention

Th. Walter Tromm
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Programme Nuclear Safety Research

walter.tromm@kit.edu