Decommissioning of FiR 1 research reactor: status, challenges and solutions

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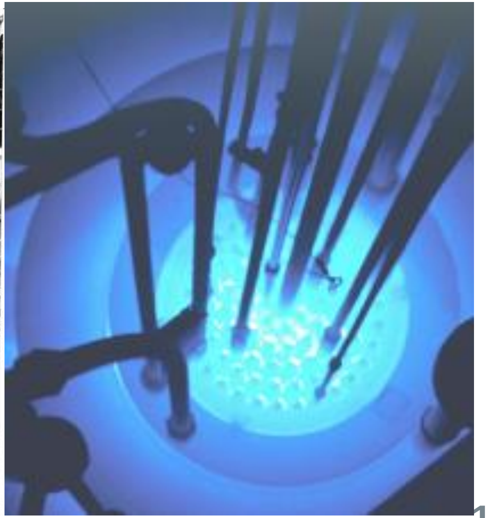
NKS Radworkshop 8-12th October 2018



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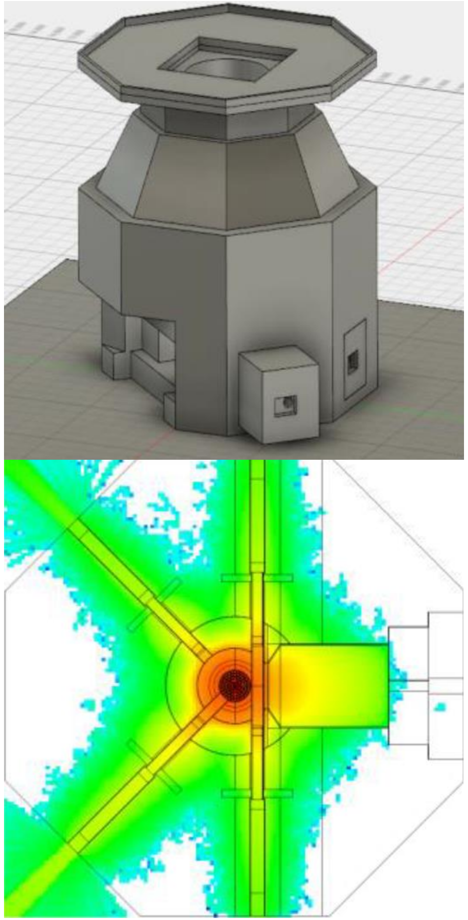
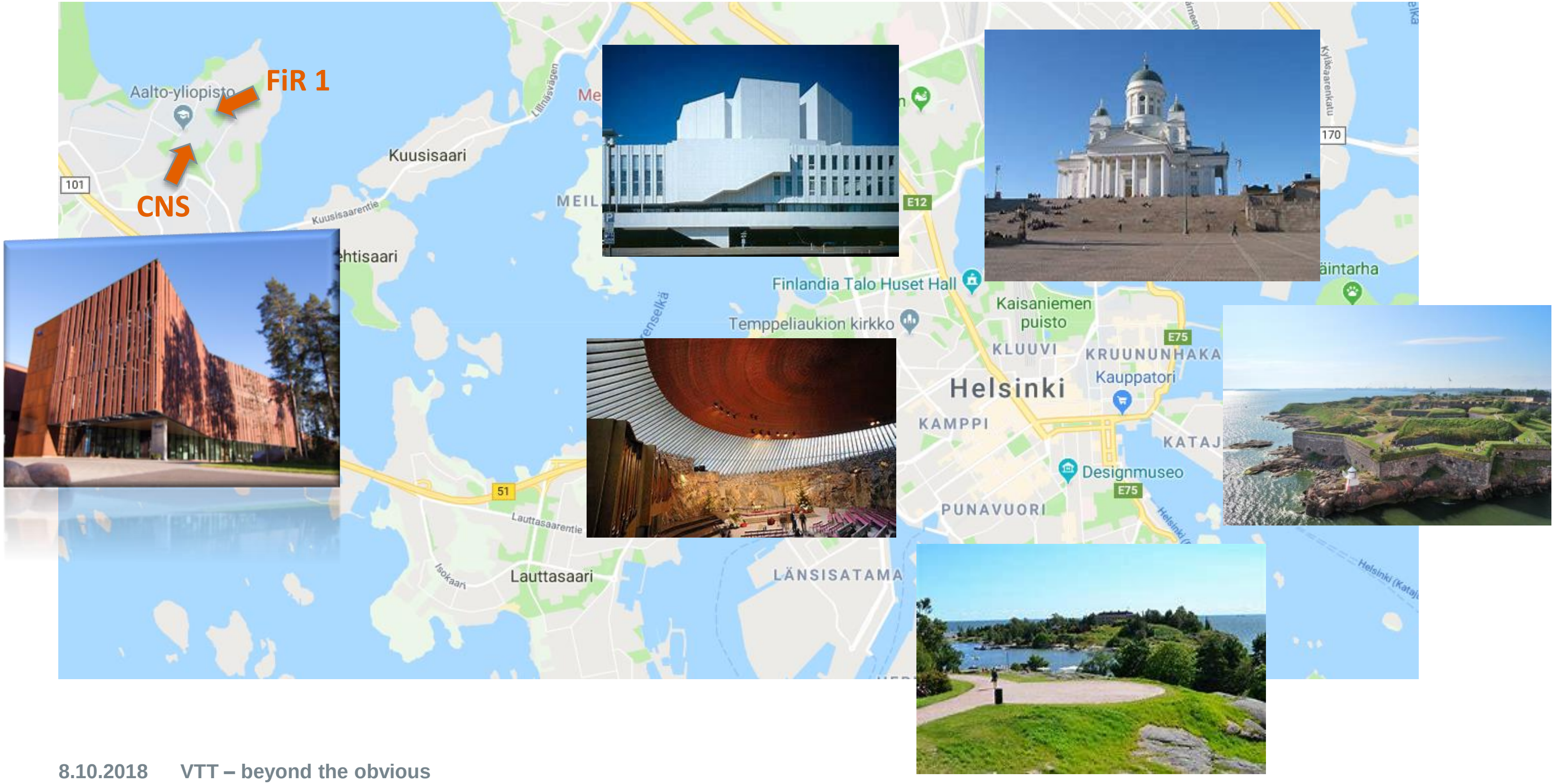
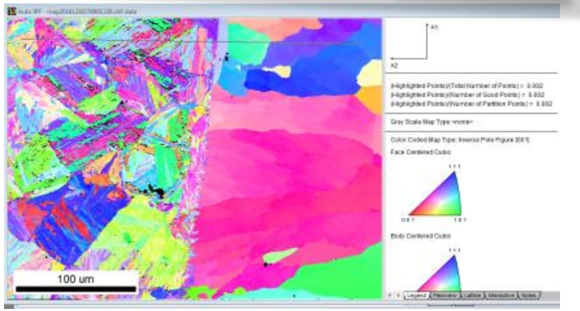


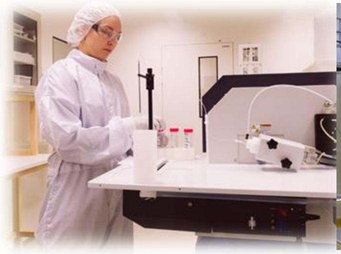
VTT – Centre for Nuclear Safety and FiR1



Centre for Nuclear Safety

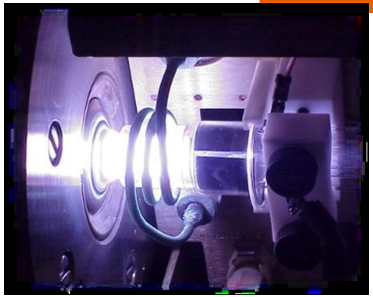
- CNS in Aalto University campus
- Old facilities: FiR 1, research laboratories and hot cells
- New facility: Centre for Nuclear Safety (CNS) since 2016
- 3,300 m^2 office wing, flexible office space for 150 people
  - Computational capabilities
- 2,360 m^2 laboratory wing
  - Basement – receiving hot cells, waste management, specimen storage
  - 1st floor- hot cells for mechanical testing, SEM, TEM, radiochemistry laboratories
  - 2nd floor – aerosol, analytical and radiochemistry laboratories

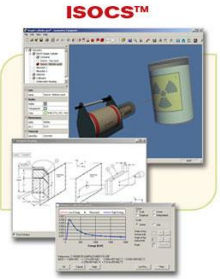




Measurement capabilities

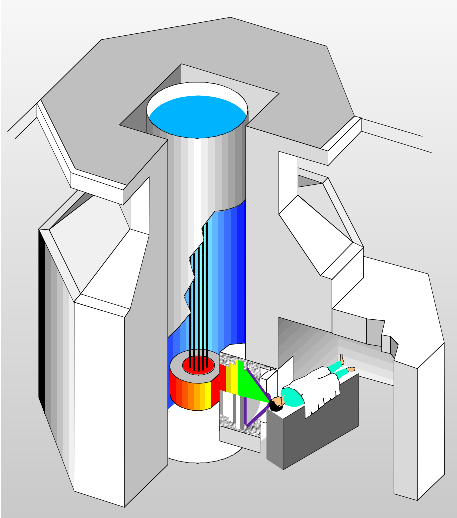
- **Elemental analysis**
  - HR-ICP-MS
  - ICP-OES
- **Gamma measurements**
  - ISOCS (In Situ Object Counting System) gammaspectrometry with HP Ge detector
- **Beta and alpha activities**
  - Radiochemical separations
  - Hidex LSC
  - Ortec Alphaspectrometer





FiR 1 Research Reactor

- **General Atomic's TRIGA Mark II type**
  - First reactor in Finland
  - Initial power of 100kW in 1962, raised to 250 kW in 1967
- **Operation** (1962-2015)
  - Intensive neutron beam research, activation analysis, irradiation testing, isotope production
  - Facility for Neutron Capture Therapy constructed
  - BNCT treatments (> 200 patients) in 1997–2012
  - Special materials to be managed in decommissioning



Status of decommissioning

- 2012 VTT's decision to shut down FiR 1
- 2013–15 EIA for decommissioning
- 2015 End of operations

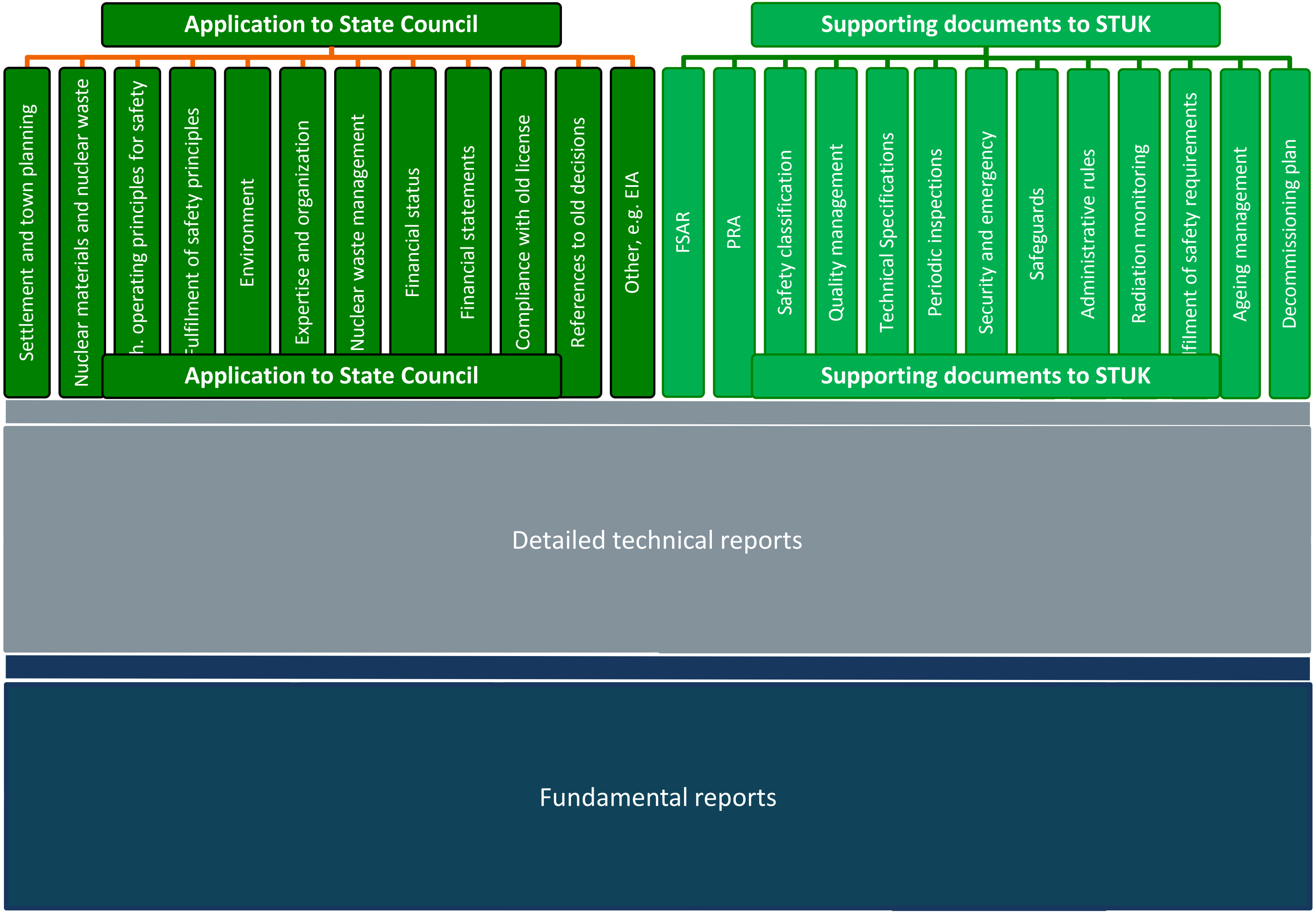
2016 Dismantling planning

2017 License application for decommissioning

- Public hearing → 31.3.2018
- STUK's safety assessment → 31.3.2019

Challenges and solutions – licensing

- **First nuclear reactor to be decommissioned in Finland**
  - Interest of stakeholders
  - Regular communications with STUK
- **”License application for decommissioning”**
- **Complience to regulations**
  - Wide range of documentation
  - Data management


Application to State Council
Settlement and town planning
Nuclear materials and nuclear waste
h. operating principles for safety
ulfilment of safety principles
Environment
Expertise and organization
Nuclear waste management
Financial status
Financial statements
Compliance with old license
References to old decisions
Other, e.g. EIA
Application to State Council
Supporting documents to STUK
FSAR
PRA
Safety classification
Quality management
Technical Specifications
Periodic inspections
Security and emergency
Safeguards
Administrative rules
Radiation monitoring
lfilment of safety requirements
Ageing management
Decommissioning plan
Supporting documents to STUK
Detailed technical reports
Fundamental reports

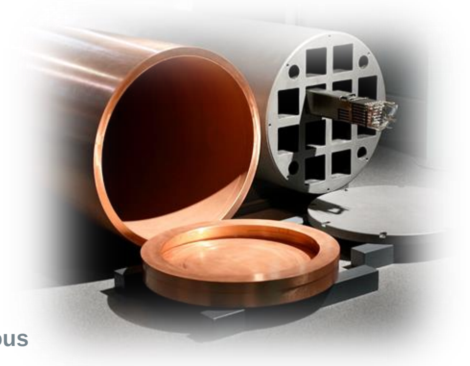
Challenges and solutions – resources

- **Funding**
  - National Nuclear Waste Management Fund in Nuclear Energy Act
  - VTT

- **Human factors**
  - External and internal people
    - In-house expertise (30-40)
    - No dedicated project workers
  - People involved also in other decom activities

Challenges and solutions - SNF

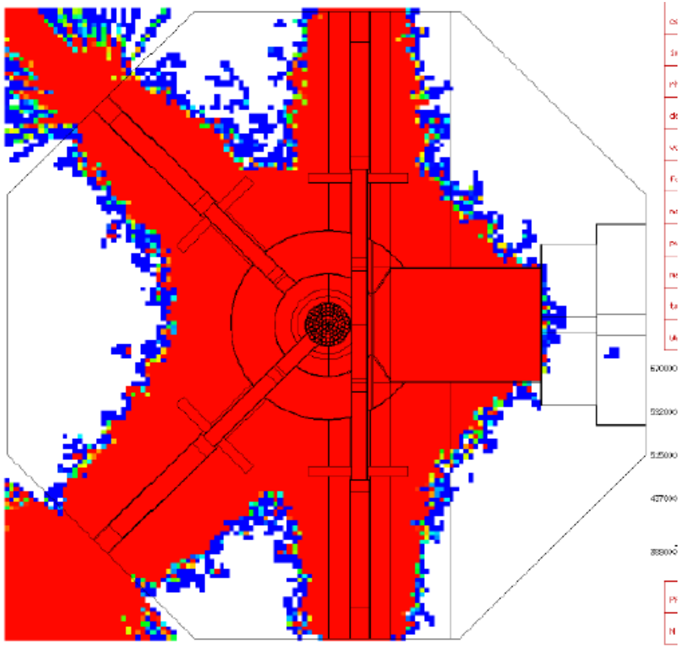
- **Spent Nuclear Fuel**
  - 124 fuel rods with < 20% enrichment
  - Primary option to return to Idaho national Laboratory, USA
    - Covered by the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program of US DoE
  - Second option is a domestic solution (Posiva)



Fuel inspection by INL 4/2016

Challenges and solutions – decom waste

- **Inventory estimates (excluding fuel):**
  - Mass 75 tons (mainly concrete) – amount is small, but variety of materials
  - Volume 40 m^3
  - Activity 3.3 TBq
    - BNCT moderator and steel > 1 TBq
  - Operational and dismantling waste
    - Loviisa NPP interim waste repository



Challenges and solutions - characterisation

VTT

- **Legal requirement for each waste package**
  - total activity, nuclide vector, external dose rate
- **Data on radionuclides and activities is needed**
  - Choosing correct methods for dismantling
  - Planning of waste packaging, transportation, final disposal etc.
  - Categorisation of waste
- **Aim is to ensure**
  - SAFETY – minimisation of radiation doses
  - COST-EFFICIENCY – optimisation of the amount of waste and choosing correct packages
- **Tools in characterisation**
  - Calculations together with measurements

Characterisation by modeling

- **Aims for modeling**
  - Estimates of component level activation and radionuclide inventory
  - Overall estimations of activation
- **Step one:** Input data
  - Plant geometry ✓
  - Material inventory ✓ ✗
  - Chemical compositions of the materials ✓ ✗
  - Operating history ✓ ✗
  - → Conservative assumptions for missing data
- **Step two:** Calculation of the neutron fluxes
  - 3D reactor model with MCNP-code
- **Step three:** Combination of data on fluxes with operating history using ORIGEN-S


RESEARCH REPORT VTT-R-03599-16 REPLACES VTT-R-02457-15

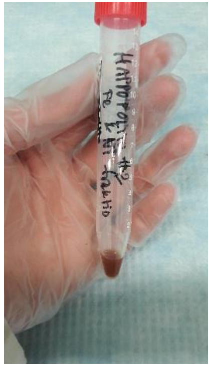
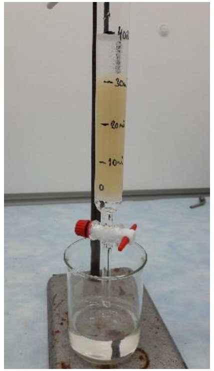
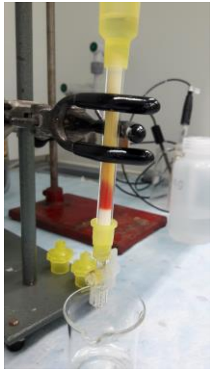
FiR 1 activity inventories for decommissioning planning

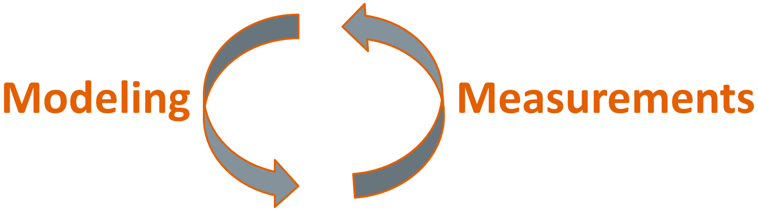
Authors: Petri Kotiluoto and Antti Räty

Confidentiality: Public

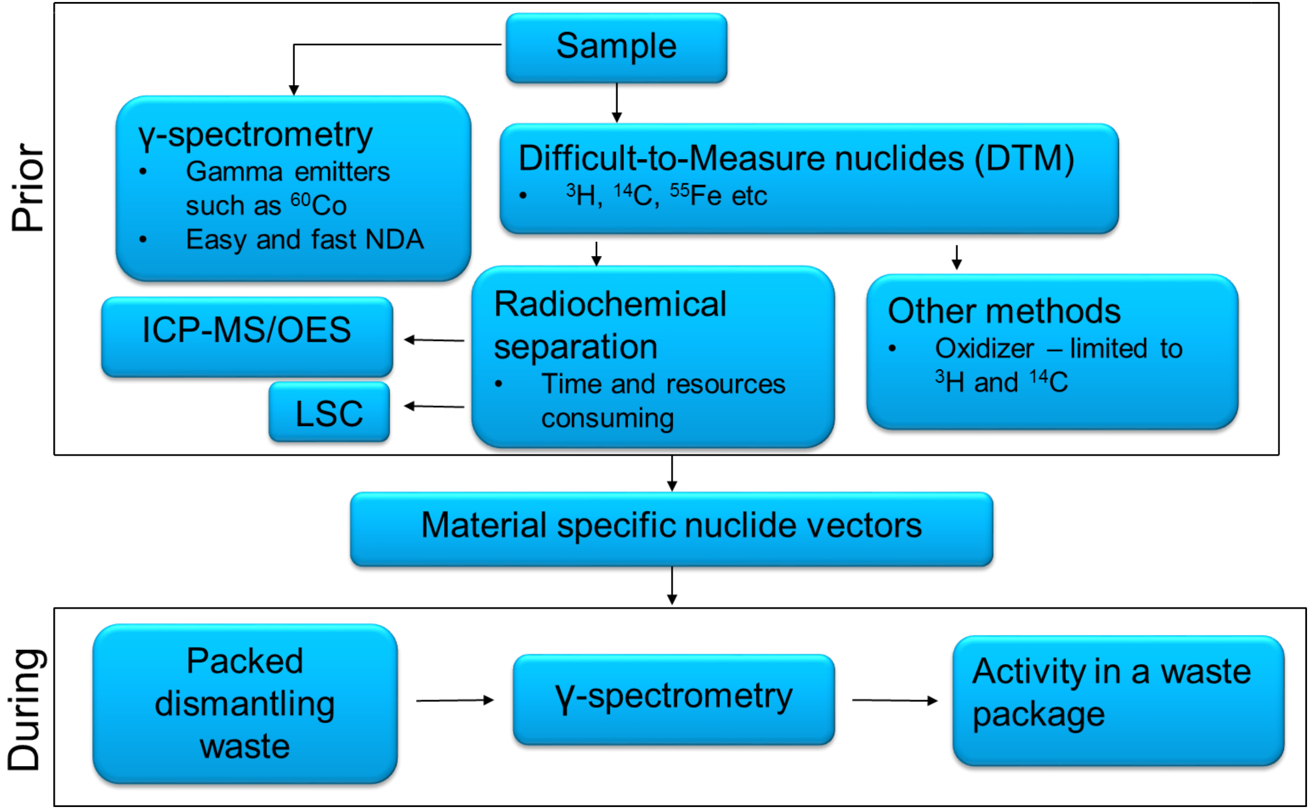
Characterisation with measurements

- **Aim for measurements**
  - Chemical composition of original materials
  - Radionuclide inventory in each material
  - Formation of scaling factors - material and reactor specific!
- **Activated materials consist of different types of radionuclides**
  - Gamma – easy to measure using gamma spectroscopy
  - Beta (and alpha) – difficult to measure (DTM) radionuclides
    - Solid to liquid, separation, purification, measurement



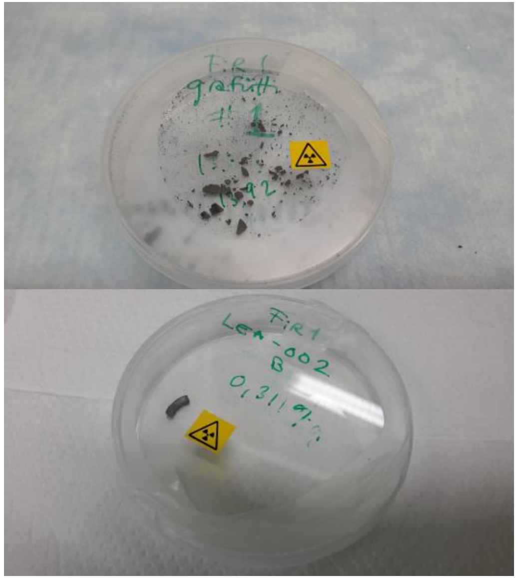
Characterisation with measurements



Challenges and solutions - characterisation

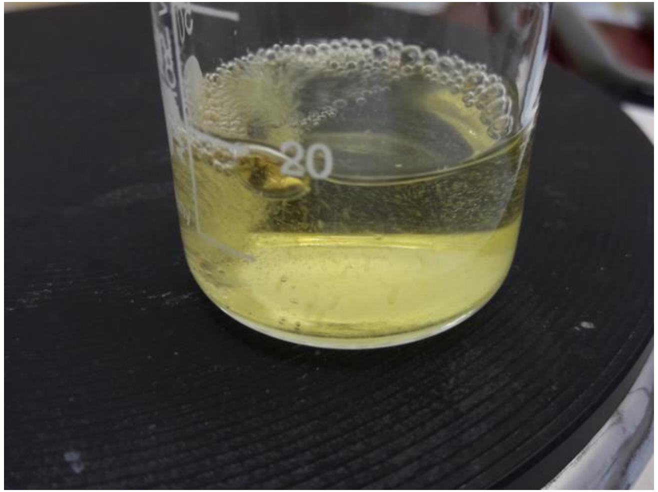
VTT

- **Access to samples**
  - Prior to dismantling
    - Constraints caused by the SNF
  - During dismantling
- **Sampling – crucial step**
  - Can a gram represent a ton of material?
  - Is it homogeneus
  - How many replicates are needed?
    - Justification for waste production and use of resources
  - Correct sampling technique
    - Volatility of radionuclides



Challenges and solutions - characterisation

- **Analysis – Gamma spectromertry (non-destructive analysis)**
  - Well established
  - Measurement of large number of waste packages
- **Analysis – DTM (destructive analysis)**
  - Variety of materials
  - Validation of radioanalytical method
    - Radionuclides of interest from modelling
  - Interferences
  - High activities possible



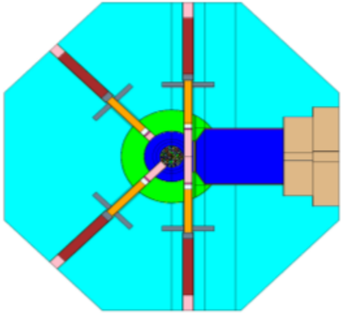
FiR 1 – main materials*

Material	Volume (m3)	Mass (tons)	Main isotopes	Total activity (TBq)
Concrete	25	61	H-3, Eu-152, Co-60, C-14	0,1
Graphite	2,6	4,4	H-3, C-14, Eu-152, Eu-154	0,46
Steel	0,4	3,5	Fe-55, Ni-63, Co-60	1,91
Aluminium	0,8	2,2	Zn-65, Co-60, Ni-63	0,39
Fluental	0,45	1,3	H-3	1,3
Other	10	2,7	H-3, C-14, Ni-63	0,4

*P. Kotiluoto, A. Räty, FiR 1 activity inventories for decommissioning planning, VTT-R-03599-16

Examples from FiR1 - Graphite

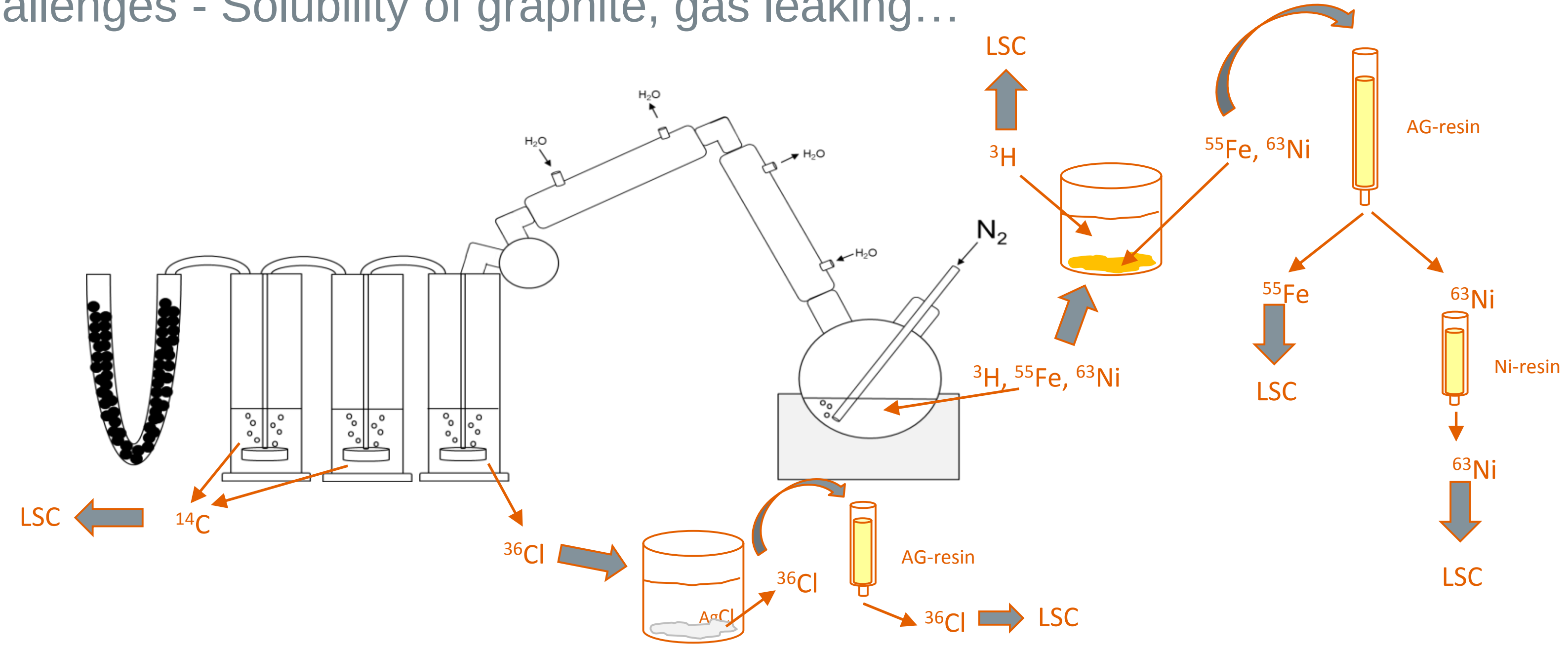
- **Core reflector (hermetically sealed!) and dissassembled thermal column**
- **Special nuclides:**
  - ^{14}C – final disposal safety
  - ^{36}Cl – unhomogenous distribution
- **Samples from thermal column**
  - Chemical composition
  - Oxidation measurements for ^{14}C at University of Helsinki
  - Gamma spectrometry
    - Eu-152 (key nuclide), Eu-154 and Co-60
  - Preliminary results for beta analysis at CNS
  - New sampling campaign in planning



Examples from FiR1 - Graphite

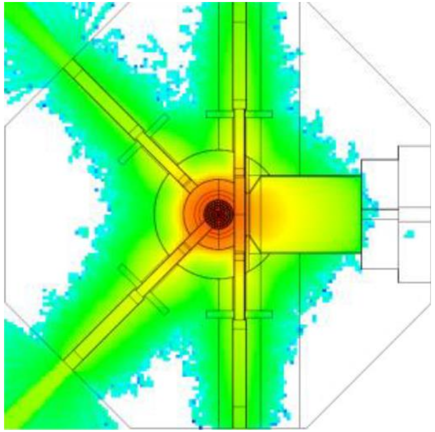
VTT

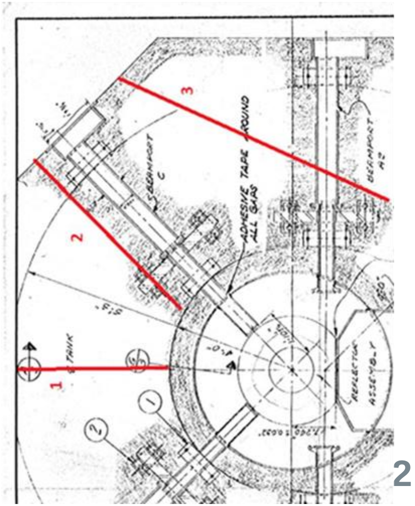
- Radiochemical separation method for graphite – combination of published articles
  - ^{3}H (< 42 kB/g), ^{14}C (< 2 kBq/g), ^{36}Cl, ^{55}Fe (<LOD) and ^{63}Ni
- Challenges - Solubility of graphite, gas leaking…



Examples from FiR1 - Concrete

- **Concrete in several places**
  - Biological shield, heavy concrete door, supporting structures of BNCT station etc
- **Biological shield**
  - Activated concrete only around the core and beam tubes.
  - Largest volume of active waste from FiR 1
  - Large variations in specific activities depending on the distance from the core (10 Bq/g to 1 MBq/g)
- **Currently**
  - Drilling campaign for active concrete
  - Three cores
    - Characterisation with NDA and DA
    - Mechanical testing
    - Solubility in final disposal

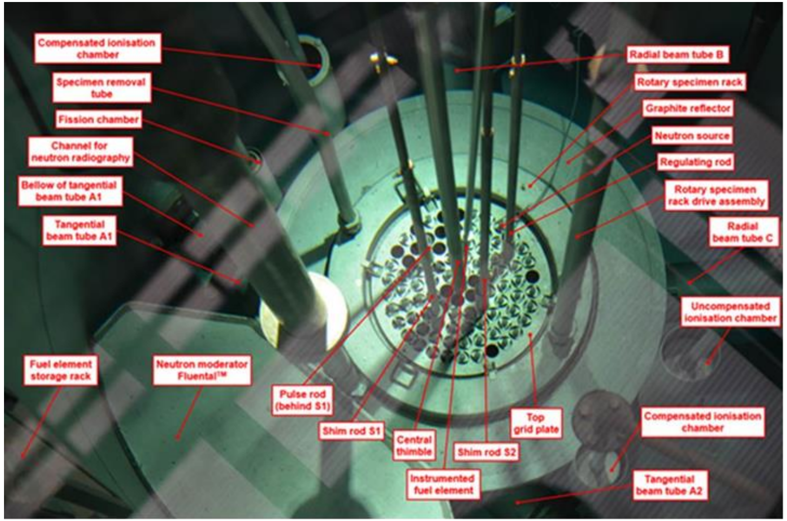




Examples from FiR1 - Steel

- **Steel in several places**
  - ”Accessible” – screws, pins, beam tube shadow shields
  - ”Non-accessible” - irradiation ring, beam tube plugs, beam tube bellows
- **Same steel? What would be a representative sample?**

- **DTM method development**
  - National project together with Helsinki University
  - NKS project proposal on Intercalibration of DTM analysis in activated stainless steel



Picture: Babcock Noell GmbH, "Dismantling and Waste Management Planning of Decommissioning FiR 1 TRIGA Mk II: Description of the facility state", Technical report FiR-TRE-BNG-1001, 2016 (restricted)

Summary

- **First reactor in Finland to be decommissioned**
- **Planning, documentation, application of best practices, licensing etc**
- **Fate of the SNF**
- **Characterisation**
  - Representativeness of the studied sample
  - Validation of the DTM analysis
    - Intercalibration and collaboration

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