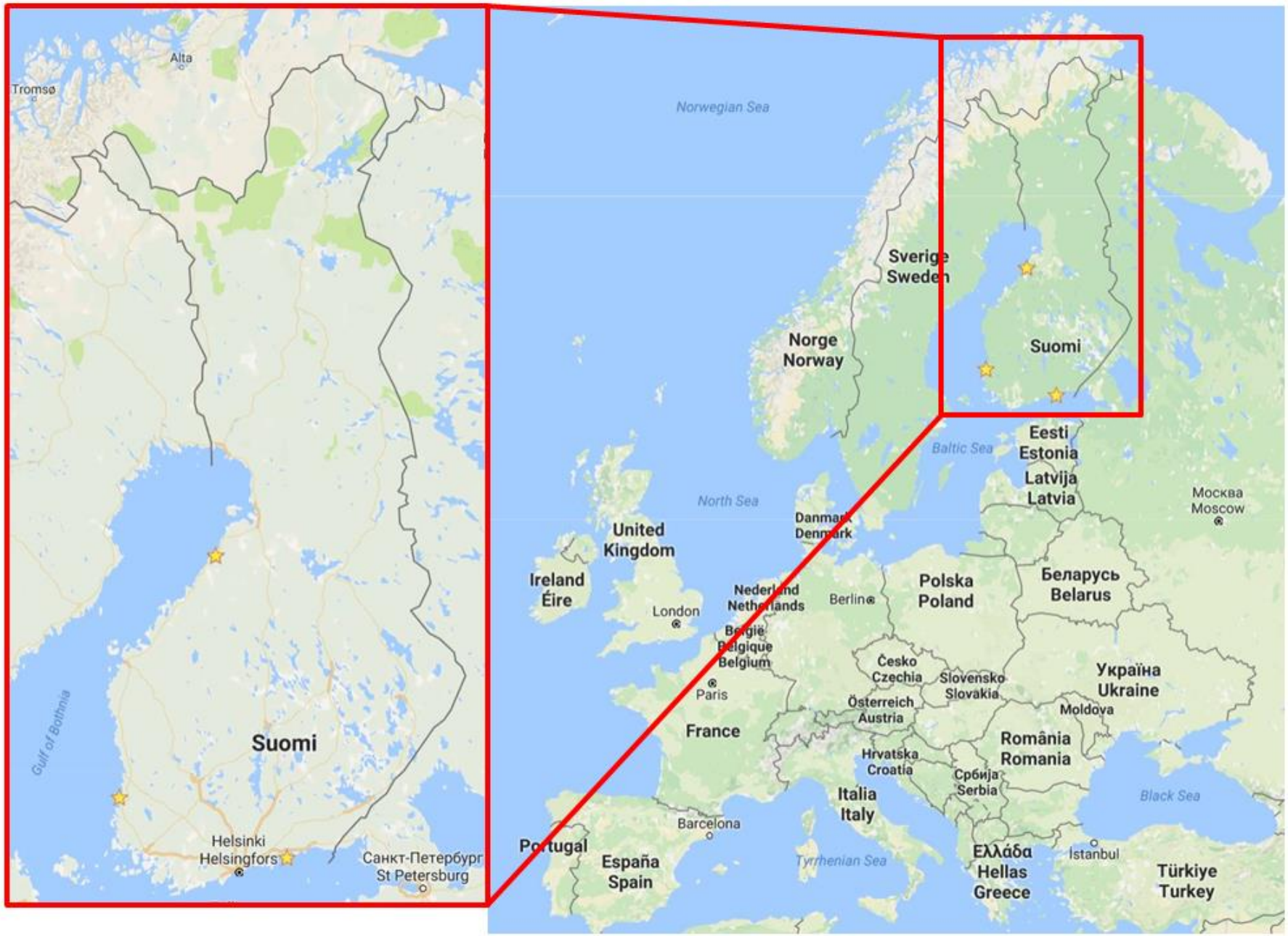
Finnish Research Programme on R&D related to Nuclear Safety

CSN, Madrid, July 2017

Ari Koskinen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- VTT is one of the leading R&D&I organisations in Northern Europe.
- We provide expert services for our domestic and international customers and partners, both in private and public sectors.

* Loikkanen, T. et al. Roles, effectiveness, and impact of VTT. Towards broad-based impact monitoring of a research and technology organisation. 2013. VTT, Espoo. VTT Technology 113. 106 p. + app. 5 p.

Net turnover and other operating income 269 M€ (VTT Group 2016)

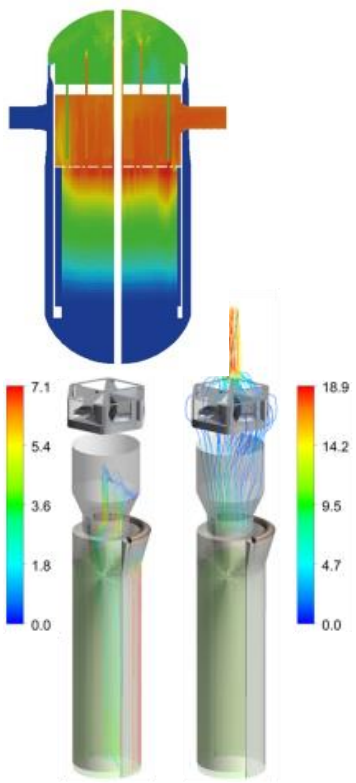
Personnel 2,414 (VTT Group 2016)

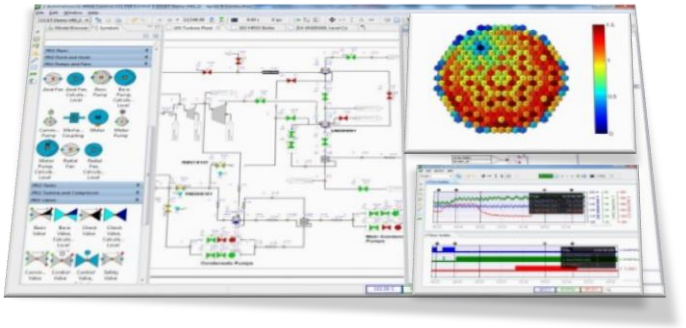
Unique research and testing infrastructure

Wide national and international cooperation network

The VTT Centre for Nuclear Safety

- 3,300 m^2 office wing includes a ground-level conference centre, and three floors of modern, flexible office space for 150 people.
- Altogether VTT has ca. 200 experts and scientists connected to nuclear energy studies
- Excellences included:
  - computerized fluid dynamics
  - process modelling (APROS)
  - fusion plasma computations
  - severe accidents
  - core-computations
  - waste-management
  - safety assessments





Nuclear Waste

Nuclear Materials

National Finnish research programmes
The Finnish Research Programme on Nuclear Power Plant Safety SAFIR 2018

National Finnish research programmes
The Finnish Research Programme on Nuclear Waste Management KYT 2018

EU-funded research
-Currently e.g. TeamCables, NOMAD, ATLAS+, MEACTOS

EU-funded research
-Currently e.g. DISCO, BEACON, THERAMIN, CHANCE)

Jules Horowitz Reactor –project
(partners e.g. EDF, Studsvik, UJV, CIEMAT, Areva…)

VTT Center for Nuclear Safety

Nuclear Waste Disposal network in Finland and Sweden
-Posiva, SKB, Fortum, TVO, Fennovoima, STUK, etc…

EU-NOMATEN (VTT-CEA-CNBJ)
Center of excellence in multifunctional materials for industrial and medical applications

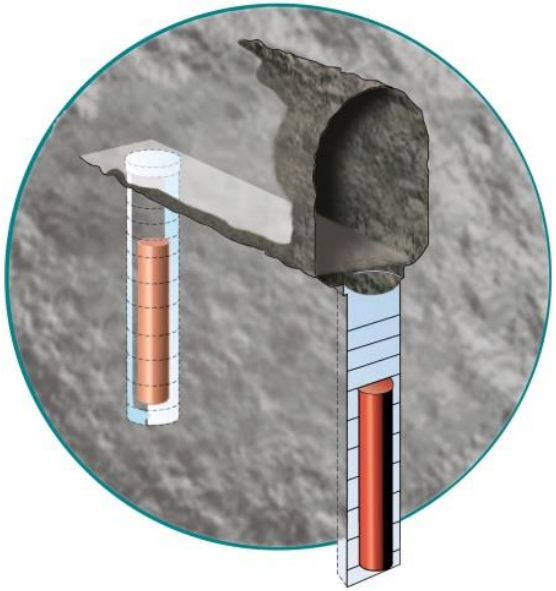
Alliance networks for irradiated material studies
-EERA, NUGENIA, NKS,…

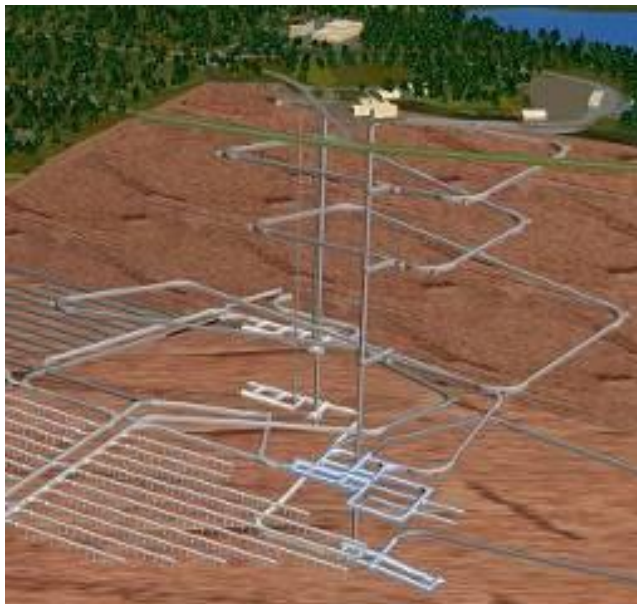
Scientific collaboration with

- the Academy of Finland,
- Aalto University,
- Lappeenranta University of Technology,
- Helsinki University,
- University of Eastern Finland,
- Geological Survey of Finland,…

VTT nuclear energy R&D competencies
Safety of radioactive waste disposal solutions

- Characterization of radioactive waste
- Operating waste and decommissioning
- Design of disposal concept (KBS-3)
- Operating waste and decommissioning
- Bedrock and groundwater characterization
- Long-term safety of materials, disposal facilities and safety case
- Engineering barrier system component manufacturing and quality control
- Operational safety of disposal facilities, incl. PRA
- New and alternative waste management technologies
- Licensing support
- Low and Intermediate waste storage.





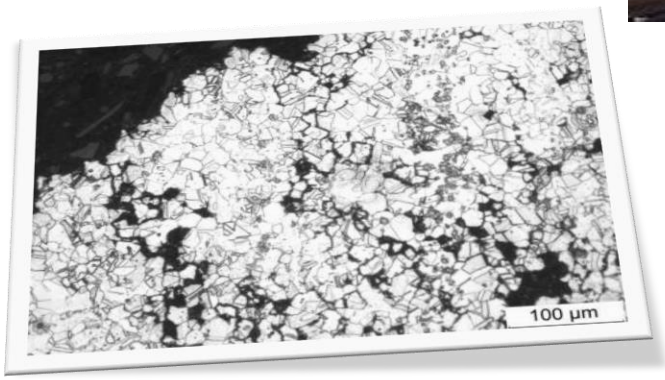
VTT nuclear energy R&D competencies
Materials research and testing for safe operation

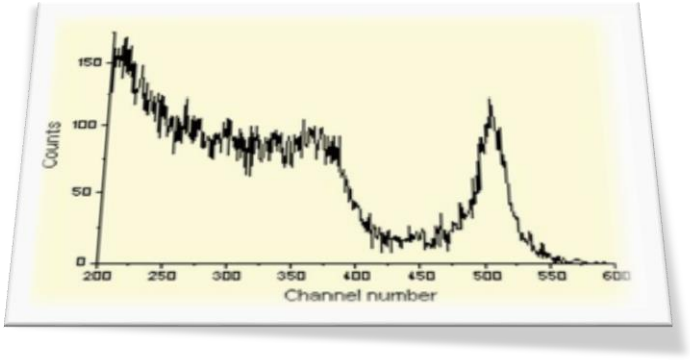
- VTT has been hosting the national hot laboratory infrastructure since it was first constructed and equipped in the 1970's.
- Principle use has been for **handling, testing and examining RPV materials for surveillance testing**.
- Many critical plant life management issues for operating nuclear power plants are related to materials.
- Lifetime extension, power upgrading, and construction of new plants require investigating and solving problems related to components and structural integrity.

- **Aging degradation of structures and components** is an important aspect of power plant safety.
- Ageing management requires activities related to the **utilization, inspection, surveillance, testing, examination, and degradation mitigation of materials**.

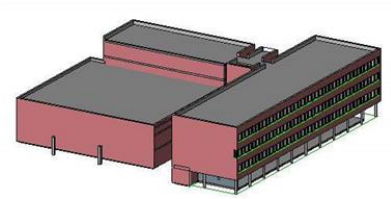
The VTT Centre for Nuclear Safety

- **2,360 m² laboratory wing**: a basement level and two floors of laboratory space.
- Basement mainly for storage and handling of radioactive materials and waste.
- Laboratory space arranged around a main high-bay, which houses the hot-cells proper:
  - mechanical and microstructural characterisation of materials
  - Radiochemistry & dosimetry
  - HR-ICP-MS
  - iodine filter testing
  - nuclear waste management
  - failure analysis





The VTT Centre for Nuclear Safety



VYR-funding instrument

VTT decision

Senaatikiinneistö investment decision

VTT-Senaatti rental agreement

Building permit

Office completion 12.1.2016

Laboratory Release 10.5.2016

Hot Cell completion 8/2017

2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

Requirements and initial Conceptual design Senaatti-kiinteistöt, ISS Proko

Exploration of alternatives Senaatti & ISS Proko

Draft design Senaatti & A-Insinöörit

Engineering Design, Senaatti & A-Insinöörit

Final design and construction Senaatti, A-Insinöörit, SRV, subcontractors

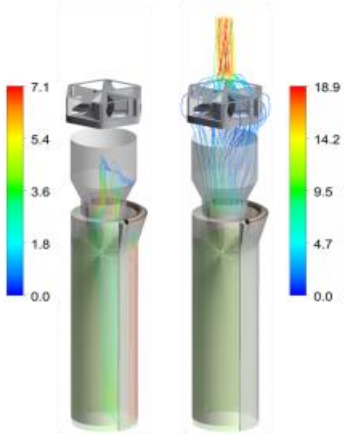
Users' equipment installation

SAFIR Programme

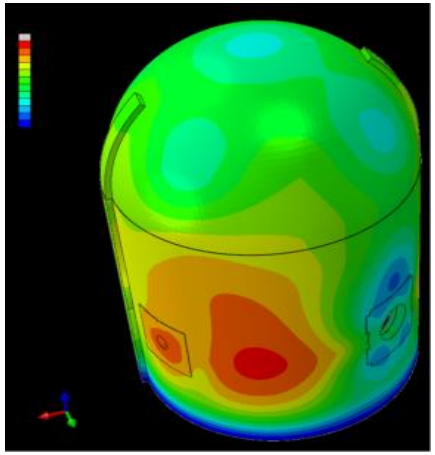
SAFIR2018

The Finnish Nuclear Power Plant Safety Research Programme 2015-2018

Plant safety and systems engineering



Reactor safety

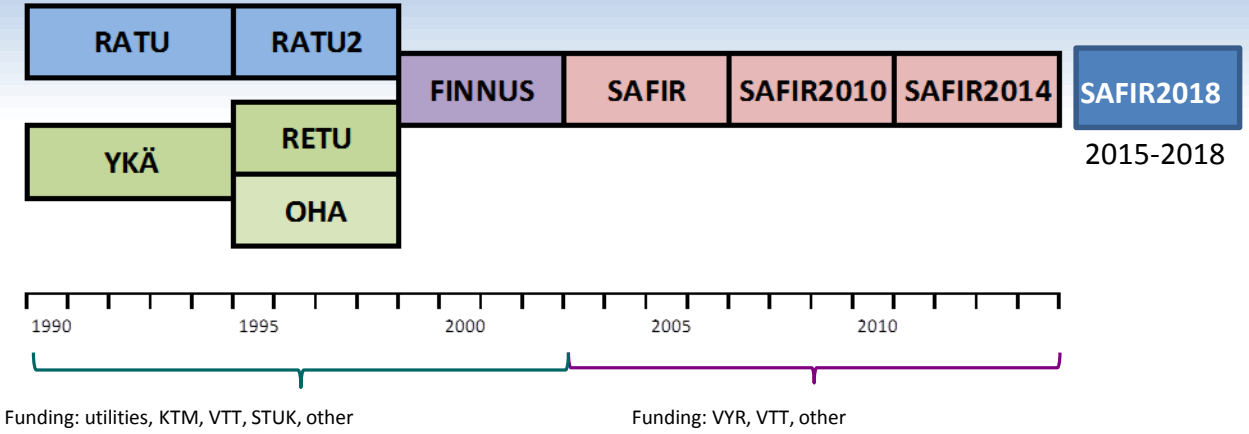


Structural safety and materials

Jari Hämäläinen, Programme director

Vesa Suolanen, Project coordinator

Finnish Nuclear Power Plant Safety Research



The nuclear facility operator shall be obliged to participate in financing research aimed at ensuring that, should such new factors concerning safe operation of nuclear facilities emerge that could not be foreseen, **the authorities have such sufficient and comprehensive nuclear engineering expertise and other facilities at their disposal** that can be used, when necessary, to analyse without delay the significance of such factors. (Nuclear Energy Act Chapter 7a, Section 53a, enacted in 2004)

- The objective of SAFIR2018 is in accordance with the Finnish Nuclear Energy Act, i.e., to ensure that *should new matters related to the safe use of nuclear power plants arise, the authorities possess sufficient technical expertise and other competence required for rapidly determining the significance of the matters.*
- National research programmes have had a significant role in NPP safety research since 1990 and from 2003 the programmes have been known as SAFIR programmes.
- The nuclear facility operators are obliged to participate in financing and they fulfil the obligation by paying an annual fee into the Finnish State Nuclear Waste Management Fund (VYR) that finances research projects in the programmes.
- Finnish Research Programme on Nuclear Waste Management KYT2018 is also going on.
- The research projects shall be of a high scientific standard and their results shall be published.

Nuclear Power Plants in Finland

Operating nuclear power plants

- Loviisa (2 x 500 MW PWR)
- Olkiluoto (2 x 880 MW BWR) - *license renewal ongoing*

Under construction

- Olkiluoto (1600 MW EPR) - *operating license phase, start of operation in 2018*

Decision-in-principle

- Hanhikivi (1200 MW PWR) - *construction license phase*

Proportion of nuclear power of the electricity production in Finland is ca 27%.

Nuclear waste management

- Operating waste storages and final repositories at Olkiluoto and Loviisa
- Spent fuel interim storages at Olkiluoto and Loviisa
- Spent fuel repository by Posiva in Olkiluoto - *under construction since 2016.*

SAFIR2018 General objectives

- Development and maintenance of expertise

  Public research based on actual research needs offers an excellent environment for educating new experts.

- Development and renewal of research infrastructure

  The programme also supports the development of research infrastructure so that the analysis, measurement and testing equipment remain up-to-date.

- International and high level research

  Nearly all SAFIR2018 projects have real international co-operation.

  The results of SAFIR2014 (2011-2014) were reported in over 1000 research reports, journal articles and conference papers.

SAFIR2018 Vision

Mission

National nuclear power plant safety research develops and creates expertise, experimental facilities as well as computational and assessment methods for solving future safety issues.

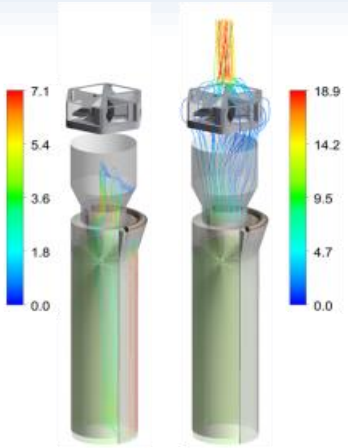
Vision of SAFIR2018

The SAFIR2018 research community is a vigilant, internationally recognised and strongly networked competence pool that carries out research on topics relevant to the safe use of Finnish nuclear power plants on a high scientific level and with modern methods and experimental facilities.

SAFIR2018 Research Areas

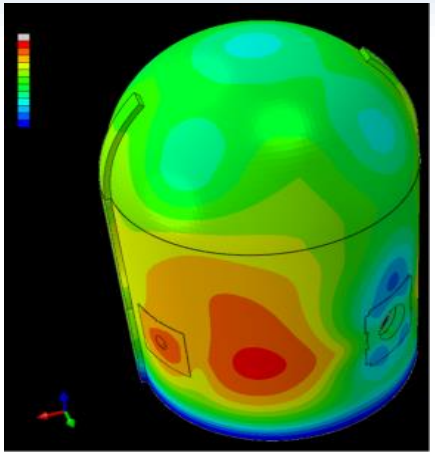
Plant safety and systems engineering

- Overall safety throughout the life cycle of nuclear power plants
- Operational resilience
- Management principles and safety culture
- PRA and Defence-in-Depth (DiD)
- Safety assessment of automation (I&C) and electric systems
- Extreme weather conditions.



Reactor safety

- Experimental and computational methods for ensuring the safety requirements
- Thermal-hydraulic problems, CFD methods
- Reactor core safety analyses
- Fuel behaviour studies, reactor dynamics
- Severe accidents and fission product transport
- Uncertainty and sensitivity analyses.



Structural safety and materials

- Support of the long-term and reliable use of nuclear power plants
- Integrity of barriers and material issues
- Aging phenomena of structures and equipment
- Experimental and numerical methods for external event assessment
- Fire risk evaluation.

SAFIR2018 Programme Management

MANAGEMENT BOARD

- Responsible of the programme as a whole, its results, and that it follows the nuclear energy act
- STUK (chair), Aalto, Fennovoima, Fortum, LUT, MEAE, SSM, Tekes, TVO, VTT

RESEARCH AREA STEERING GROUPS

- Planning of research, evaluation of research proposals, follow-up of the results and costs of the projects
- STUK (chair), Fennovoima, Fortum, TVO

REFERENCE GROUPS

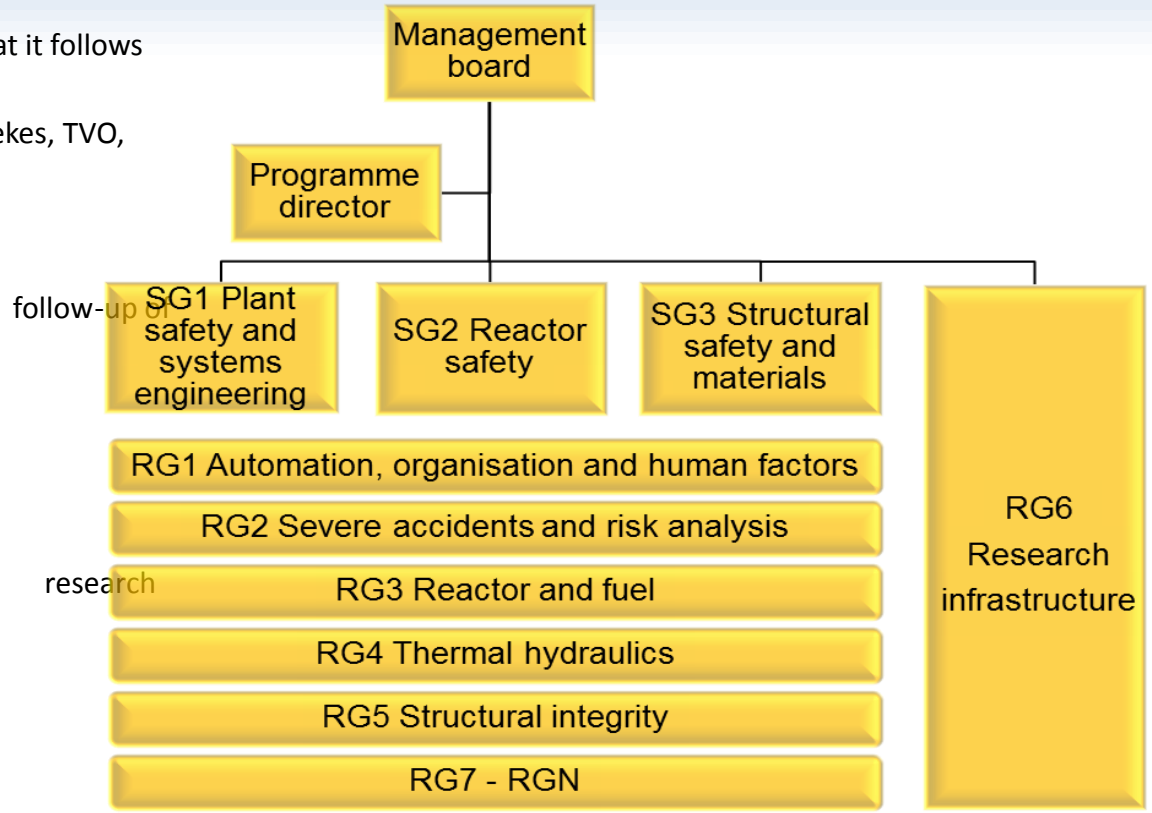
- Scientific steering of research projects in the defined areas
- Reference groups have projects from one or several research areas.
- STUK, utilities, research organisations, other experts

PROJECTS

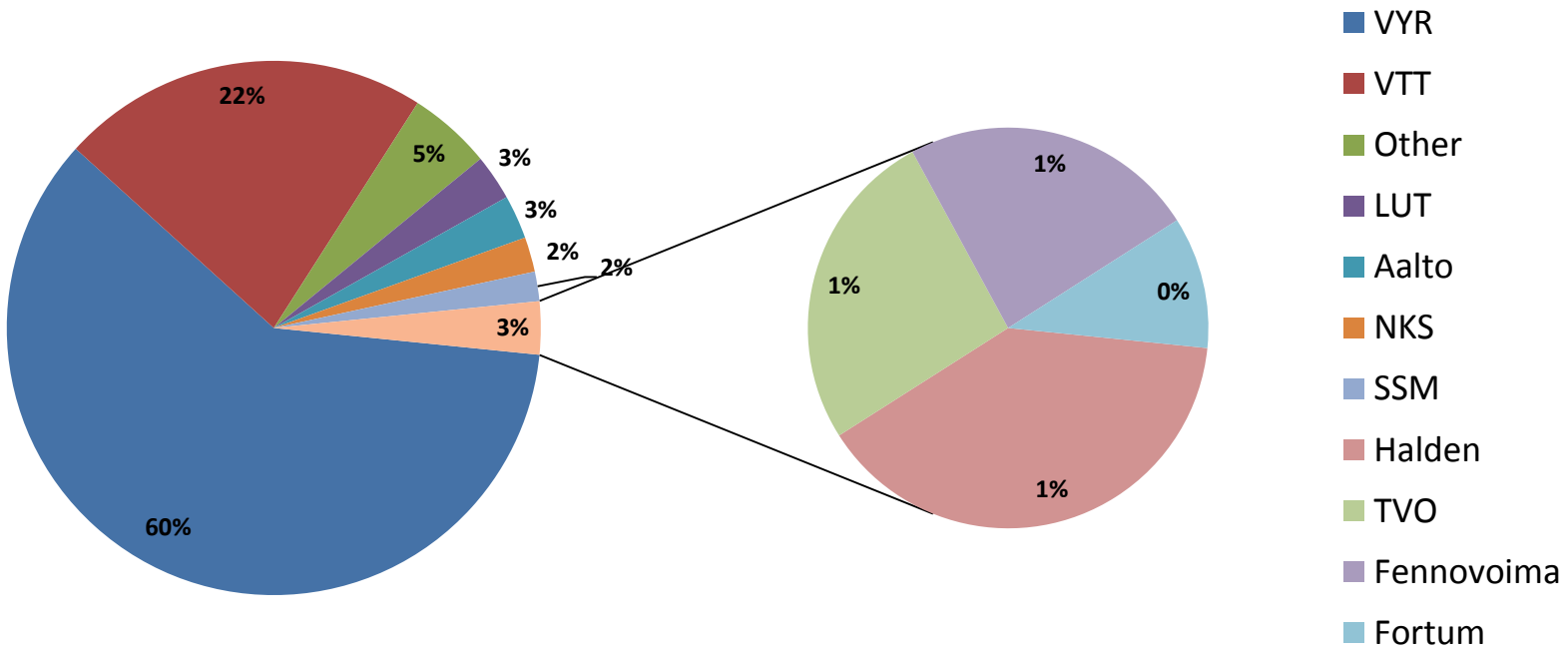
- Every project is guided by one reference group.
- Project manager is responsible of the project as a whole.
- Researchers from one or more research organisations.

ADMINISTRATION

- Programme director and project coordinator



SAFIR2018 Total funding in 2015-2016 was 15,5 M€



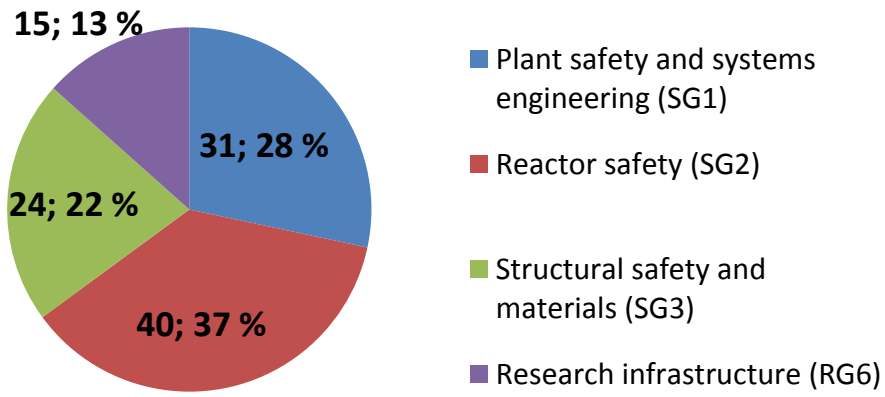
The main funding organisations were the Finnish State Nuclear Waste Management Fund (VYR) with 9,3 M€ and VTT with 3,5 M€.

SAFIR2018 Projects in 2015-2016 and 2017

28 projects annually in 2015-2016:

- SG1 Plant safety and systems engineering
- SG2 Reactor safety
- SG3 Structural safety and materials.
- RG6 Research infrastructure

112 person years in 2015-2016



Project year 2017

Planned total funding is 6,4 M€ and volume 41 person years.

Research in 29 projects is guided by six reference groups:

- RG1 Automation, organisation and human factors (SG1; 4 projects)
- RG2 Severe accidents and risk analysis (SG1, SG2, SG3; 7 projects)
- RG3 Reactor and fuel (SG2; 5 projects)
- RG4 Thermal hydraulics (SG2; 4 projects)
- RG5 Structural integrity (SG3; 6 projects)
- RG6 Research infrastructure (3 projects)

RG1 - Automation, organisation and human factors

Four projects in 2017:

- CORE - Crafting operational resilience in nuclear domain (SG1) – *VTT, Finnish Institute of Occupational Health (FIOH)*
- ESSI - Electric Systems and Safety in Finnish NPP (SG1) – *VTT, Aalto*
- MAPS - Management principles and safety culture in complex projects (SG1) – *VTT, Aalto University, University of Oulu, University of Jyväskylä*
- SAUNA - Integrated safety assessment and justification of nuclear power plant automation (SG1) – *VTT, Aalto , Finnish Software Measurement Association (FISMA), Risk Pilot, IntoWorks*

RG2 - Severe accidents and risk analysis

Seven projects in 2017:

- EXWE - Extreme weather and nuclear power plants (SG1) – *Finnish Meteorological Institute (FMI)*
- GENXFIN - Safety of new reactor technologies (SG1) – *VTT*
- PRAMEA - Probabilistic risk assessment method development and applications (SG1) – *VTT, Aalto University, Risk Pilot*
- CASA - Comprehensive analysis of severe accidents (SG2) – *VTT*
- CATFIS - Chemistry and transport of fission products (SG2) – *VTT*
- ERNEST – Experimental and numerical methods for external event assessment improving safety (SG3) – *VTT* (ESPIACS and NEST combined in 2016)
- FIRED - Fire risk evaluation and defence-in-depth (SG3) – *VTT, Aalto University*

Finished projects:

- ESPIACS - Experimental studies on projectile impacts against concrete structures (SG3) – *VTT*
- NEST - Numerical methods for external event assessment improving safety (SG3) – *VTT*

RG3 - Reactor and fuel

Five projects in 2017:

- KATVE - Nuclear Criticality and Safety Analyses Preparedness at VTT (SG2) – *VTT*
- MONSOON - Development of a Monte Carlo based calculation sequence for reactor core safety analyses (SG2) – *VTT*
- PANCHO - Physics and Chemistry of Nuclear Fuel (SG2) – *VTT*
- SADE - Safety analyses for dynamical events (SG2) – *VTT*
- USVA - Uncertainty and sensitivity analyses for reactor safety (SG2) – *VTT, Aalto University*

Finished projects:

- NEPAL15 - Neutronics, burnup and nuclear fuel (SG2) – *Aalto University*

RG4 - Thermal hydraulics

Four projects in 2017:

- COVA - Comprehensive and systematic validation of independent safety analysis tools (SG2) – *VTT*
- INSTAB - Couplings and instabilities in reactor systems (SG2) – *Lappeenranta University of Technology*
- INTEGRA - Integral and separate effects tests on thermal-hydraulic problems in reactors (SG2) – *Lappeenranta University of Technology, VTT*
- NURESA - Development and validation of CFD methods for nuclear reactor safety assessment (SG2) – *VTT, Aalto University, Lappeenranta University of Technology*

RG5 - Structural integrity

Six projects in 2017:

- COMRADE - Condition monitoring, thermal and radiation degradation of polymers inside NPP containments (SG3) – *VTT, RISE (SP)*
- FOUND - Analysis of fatigue and other cumulative ageing to extend lifetime (SG3) – *VTT, Aalto University*
- LOST - Long term operation aspects of structural integrity (SG3) – *VTT*
- MOCCA - Mitigation of cracking through advanced water chemistry (SG3) – *VTT*
- THELMA - Thermal ageing and EAC research for plant life management (SG3) – *VTT, Aalto University*
- WANDA - Non-destructive examination of NPP primary circuit components and concrete infrastructure (SG3) – *VTT, Aalto University*

RG6 - Research infrastructure

Three projects in 2017:

- INFRAL - Development of thermal-hydraulic infrastructure at LUT – *Lappeenranta University of Technology*
- JHR - JHR collaboration & Melodie follow-up – *VTT*
- RADLAB - Radiological laboratory commissioning – *VTT*

SAFIR2018 Results 2015-2016

The results of the projects after two years research work have been reported in **SAFIR2018 Interim Report** that is available on SAFIR2018 website http://safir2018.vtt.fi/

The projects of the programme have produced **552 publications** during 2015-2016:

- 89 scientific articles
- 121 conference papers
- 216 research reports (SAFIR2018 research organisations)
- 126 other publications (theses, reports of other organisations, other)

17 higher academic degrees were obtained:

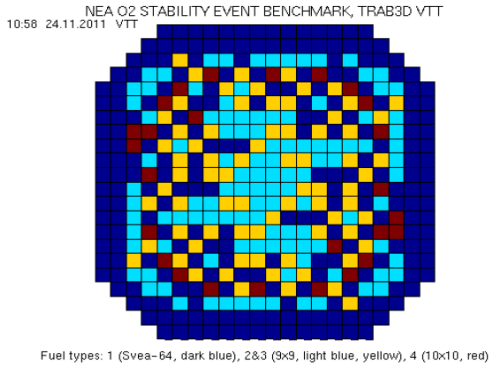
- 6 Doctors
- 11 Master's degrees.

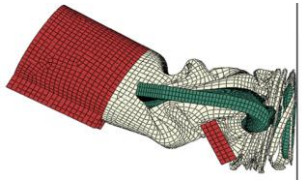
International Co-operation in SAFIR2018

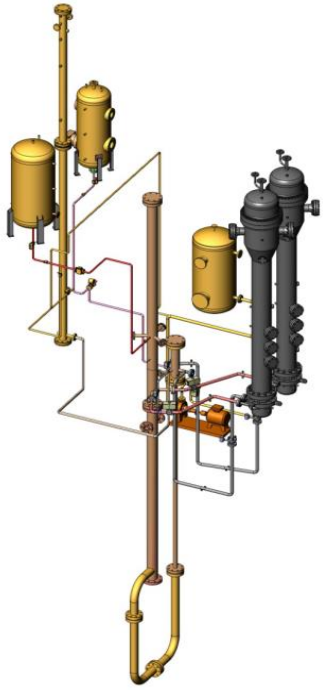
Almost all projects have international contacts

- OECD NEA projects and working groups, Halden project co-operation, AER, USNRC
- EU networks and projects, Euratom, NUGENIA
- Co-operation with universities and research institutes
- Co-operation with nuclear industry and safety authorities
- Nordic co-operation: NKS, NORTHNET, Energiforsk, BG, RISE Research Institutes of Sweden (SP), Risk Pilot, Swedish NPP´s (Vattenfall, Ringhals, Forsmark, Barsebäck), SSM

SAFIR2014 was evaluated in 2014 by an international expert group lead by prof. Mike Weightman. The evaluation report can be found on SAFIR2014 website http://safir2014.vtt.fi







MoU between SAFIR2018 and NUGENIA

Memorandum of Understanding between Ministry of Economic Affairs and Employment of Finland governing SAFIR2018 and the Nuclear Generation II & III Association NUGENIA on scientific and technical co-operation in the area of nuclear safety research, was signed at NUGENIA+ Final Seminar, 29.8.2016, Helsinki, Finland.

http://safir2018.vtt.fi

KYT Programme

KYT2018 - Finnish Research Programme on Nuclear Waste Management

Kari Rasilainen
VTT Technical Research Centre of Finland

KYT2018 starting points 1

- Research period 2015-2018
- Annual budget
  - Around 2 M€ in 2015
  - Around 3 M€ in 2016-2018 (increase due to VTT Centre for Nuclear Safety)
- Funding from State Nuclear Waste Management Fund (VYR) into which nuclear waste producers pay annually 0,13 % of their assessed liability[2] respectively (0,08 % in 2015 and 0,13 % in 2016-2018)
  - Research organisations can also direct own funding in their projects

[2]http://www.finlex.fi/en/laki/kaannokset/1987/en19870990.pdf

KYT2018 starting points 2: NWM environment when KYT2018 was prepared

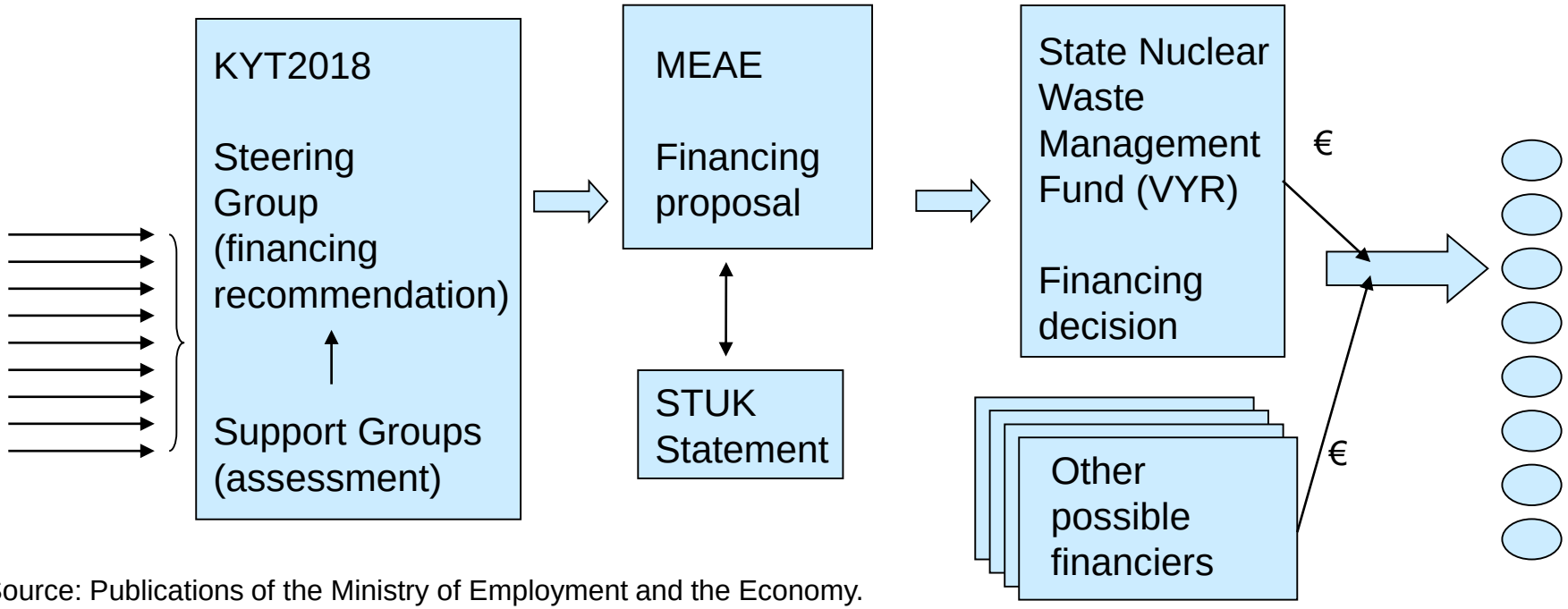
- Construction Licence application for Posiva's spent fuel disposal facility 28.12.2012
- Nuclear power decisions in Finland
  - OL3 Operating Licence application during next research period
  - OL4, FV1 Construction Licence application during research period?
  - FiR1 decommissioning being prepared, EIA started in 2013
- VTT Centre for Nuclear Safety
- Nuclear waste events abroad
  - Sweden: SKB's Construction Licence application 3/2011
  - USA: Blue Ribbon Commission final report 2012 on America's nuclear future <= Yucca Mountain was abandoned 2010
  - EU: IGD-TP (Implementing Geological Disposal - Technology Platform)

KYT2018 aims

- Basic aim is to produce high quality research results to be used by Finnish nuclear authorities
  - STUK: Radiation and Nuclear Safety Authority, Finland
  - TEM: Ministry of Employment and the Economy, from 2017 Ministry of Economic Affairs and Employment (MEAE)
- Nationally central research topics
- Topics directly related to the respective nuclear waste management duties of waste producers or authorities do not belong to KYT2018
- The results of the research programme are public and thus available for all participants
- The long-term aim of KYT2018 is, for its part, to
  - Maintain national knowhow in nuclear waste management
  - Promote collaboration between authorities, nuclear industry and scientists

Decision making in KYT2018 about project proposals

Project proposals	Assessment	Financing proposal	Financing decision	Projects to be financed
(October)	(Nov.- Dec.)	(January)	(March)	



Source: Publications of the Ministry of Employment and the Economy. Energy and the Climate 51/2014

KYT2018 assessment criteria of project proposals

- Relevance and usability of results are assessed against research needs
- Networking with other actors in the field, KYT2018 seeks well-integrated joint projects
- Training and scientific merits
  - New experts
  - New expertise
- Efficiency shown in previous KYT or other projects
- Realism in cost and work amount estimates

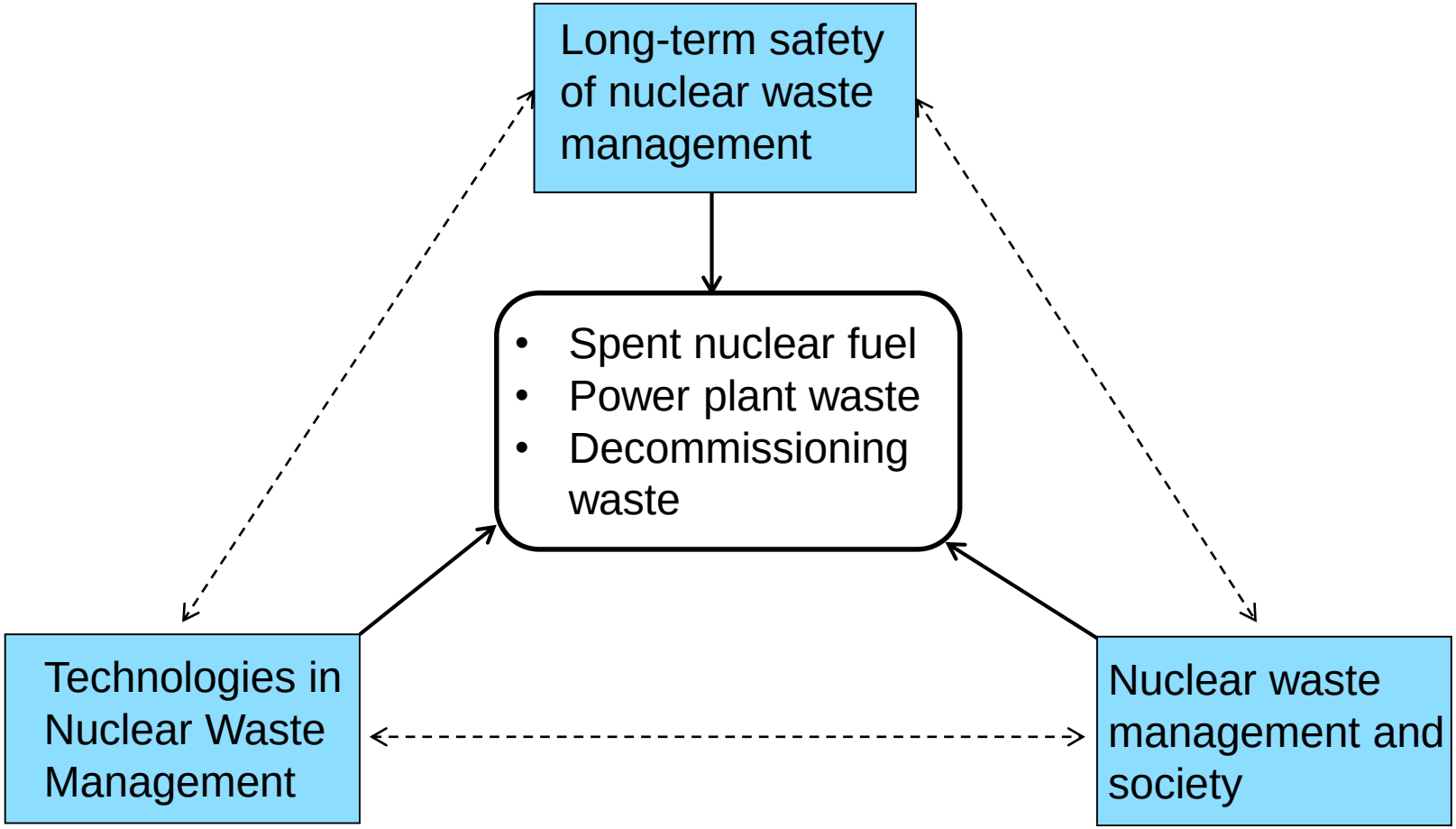
KYT2018 types of projects

- 1 year project
- Longer term project
- Coordinated project (established in KYT2014 due to recommendations in KYT2010 international review)
  - Actually a small research programme
  - Several organisations in the research consortium
  - Project has a named leader

KYT2018 management

- Steering Group
  - MEAE (Ministry of Economic Affairs and Employment) appoints
  - Strategic lines of the research programme
    - Can propose topical focus areas for MEAE in the annual call for project proposals
    - Makes a recommendation for MEAE of projects to be funded
- Support Groups (I, II and III)
  - Appointed by the Steering Group
  - Assess the contents of project proposals, follow up and guidance of the projects receiving funding
  - I: Buffer, backfill and canister, II: Safety assessment and innovations and III: Society and Man
- Coordinator
  - Management of the research programme
- Website
  - http://kyt2018.vtt.fi/

KYT2018 Research topics

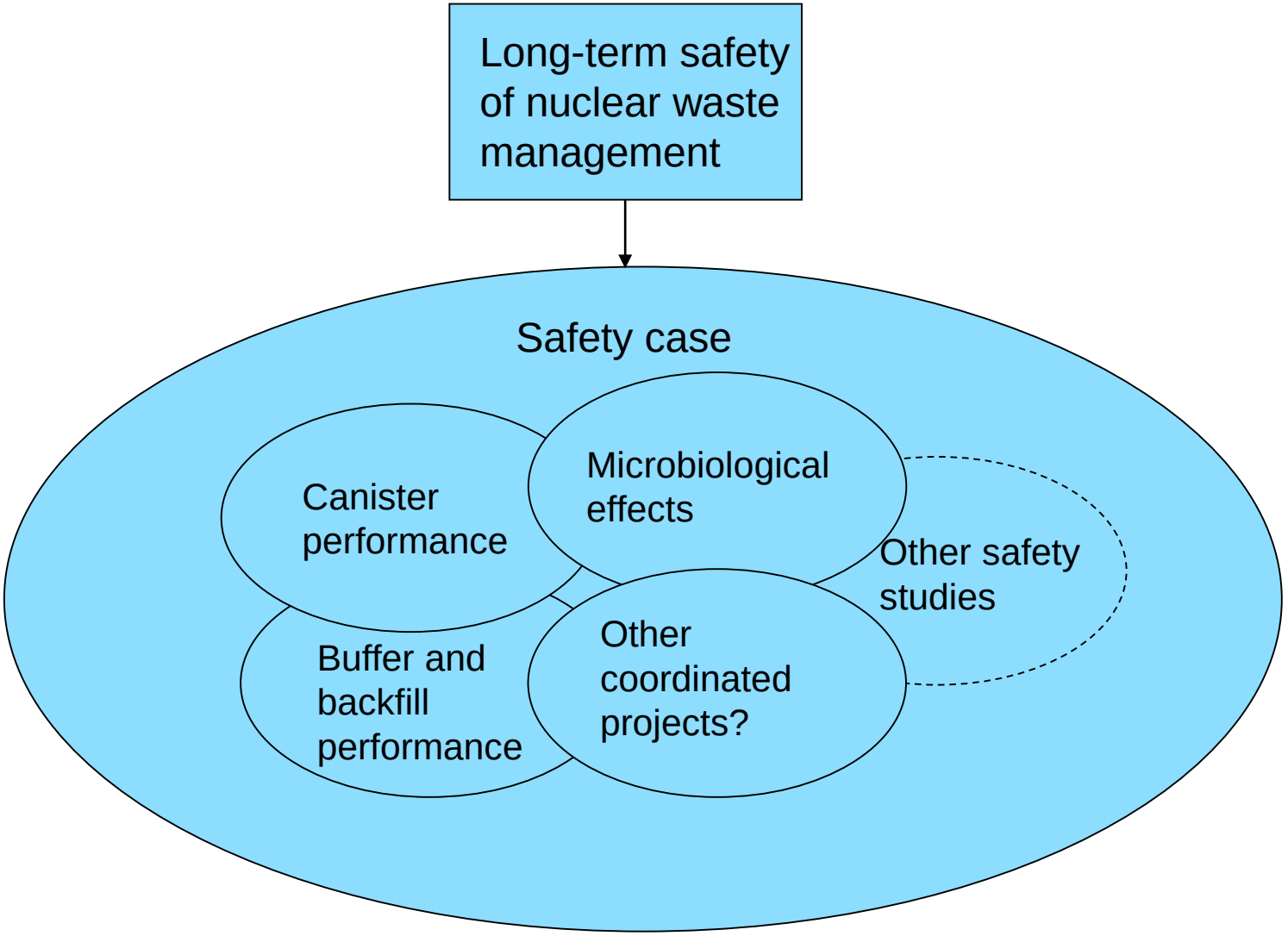


Technologies in nuclear waste management

Possible research subjects are e.g.:

- Reprocessing, Nuclide partitioning and transmutation (P&T)
- Retrievability of the geological disposal and alternative implementation (e.g. deep bore holes)
- Storage alternatives, e.g. dry storage, other long-term storage
- Potential new solutions in low and medium level waste management, e.g. shallow land disposal of very low level waste, or disposal of new type waste, and reducing the amount of waste
- New solutions for implementing decommissioning, e.g. characterization and waste treatment methods of metal and concrete waste
- Development of alternative barrier material (e.g. canister material)
- Development of the evaluation methods of the costs in nuclear waste management

KYT2018 Research topics 2



Whole ellipse:
Coordinated project:
Dashed line ellipse:
single project

Safety research in nuclear waste management : Safety Case (coordinated)

Gathers together all factors affecting the long term safety of nuclear waste disposal. Possible research topics are e.g.:

- The recognition of safety functions and the way in which scenarios are formed
- Alternative conceptual models and interpretations
- Development of methods for uncertainty analysis
- New sources of methodological information (safety assessment type of work outside nuclear waste research (e.g. Safety case work done in national nuclear safety program SAFIR 2018)
- Presentation of safety case for wider audiences (principles, methods, and limitations of Safety Case)
- The analysis of the evolution of the repository right after the disposal facility has been closed.

Safety research in nuclear waste management : Buffer and backfill performance (coordinated)

Mass flows related to Safety Case context to and from canister through buffer, and buffer-canister-microbes coupling. Possible research topics are e.g.:

- Research concerning buffer and backfill performance
  - Modelling and experiments
- Development of THM and THC modelling lines and their integration
- Connection between material properties and performance
- Possible safety related detailed subjects

Safety research in nuclear waste management : Canister performance (coordinated)

Canister lifetime related to Safety Case context, i.e. when does the release of nuclides start; how does undamaged canister limit the release of nuclides; and buffer-canister-microbes coupling. Possible research topics are e.g.:

- Long-term corrosion resistance of canister including microbial effects to corrosion
- Mechanical properties and their changes
  - Properties of the friction stir welded seam
  - Canister inner parts
- Effects of external loads on the canister (buffer swelling pressure, pressure changes due to glacial events

Safety research in nuclear waste management : Microbiological effects (coordinated)

Safety Case related context of microbial effects, i.e. buffer-canister-microbes coupling, the subsequent microbial effects on engineering barrier system materials, and on the transport of radionuclides. Possible research topics are e.g.:

- Sampling representativeness
- Estimating microbial activity in final disposal conditions
- How microbes affect on the performance of the release barriers
- Microbial activity in low and medium level waste disposal

Safety research in nuclear waste management : Other safety related studies

Possible topics are e.g.:

- Long-term behaviour of concrete structures in final disposal conditions
- Studies related to the conclusion of tests simulating the final disposal conditions of operating waste
- The impact of spent fuel properties on the safety of final disposal, in particular the impacts of an increase in the burnup level and the final disposal of new fuel types
- The behaviour of C-14 in final disposal (spent fuel, operating waste, decommissioning waste)
- Bedrock research as regards the safety of final disposal, and the research to ensure the quality of the bedrock
- Biosphere research as regards the safety of final disposal
- The modelling of the closure of repository (e.g. tunnels) and the assessment of their performance.

Social science studies related to nuclear waste management

Besides technical know-how nuclear waste management needs political and wider acceptance in society. Possible research topics are e.g.:

- Ethical and public debate
- Issues related to long time scales e.g. the closed repository and the long-term preservation of the knowledge
- Generation of nuclear energy.

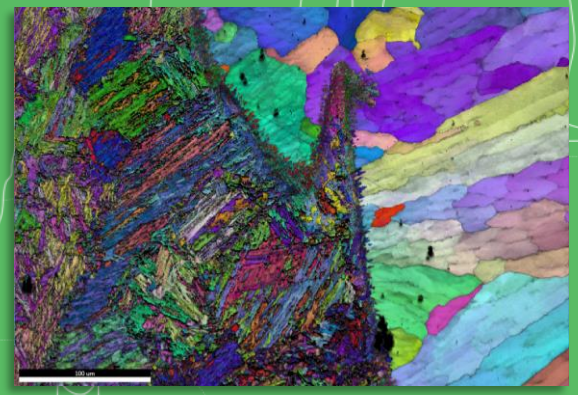
KYT2018 collaboration

- Thematic seminars
- Common seminars with SAFIR programme if needed
- Other research programmes
    - Scientific collaboration
- YTERA project of the Academy of Finland
    - Graduate School for nuclear technology and radiochemistry
- EU
- International expert organisations, e.g. OECD NEA

KYT2018 summary

- Based on Nuclear Energy Act
- Research period 2015-2018
- Budget 2 M€/a (2015) -> 3 M€/a (2016-2018)
- Call of project proposals annually
- Different kind of project types
- Framework programme (in English): https://www.tem.fi/files/41406/TEMjul_51_2014_web_12112014.pdf
- More information at website (http://kyt2018.vtt.fi/)


TECHNOLOGY FOR BUSINESS



Additional information regarding SAFIR2018 programme projects

CASA - Comprehensive Analysis of Severe Accidents

Background and objective

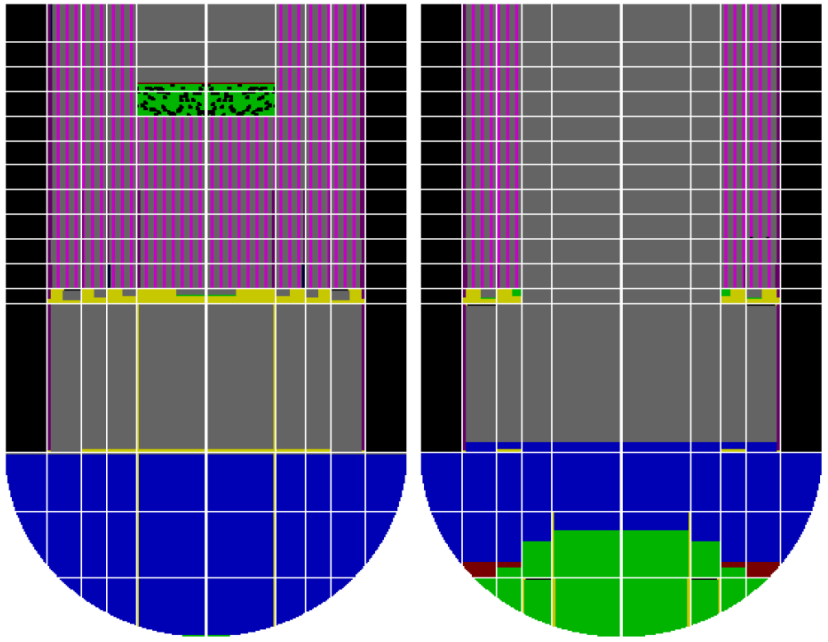
Despite of nearly 40 years of research in the area of severe accidents there are still plenty of uncertain issues. This is partly because large scale experiments with real materials are extremely difficult, if not impossible, to execute. Information obtained from separate effect tests has to be linked together by simulations. This project focuses on enhancing simulation expertise and also tools bringing together a large spectrum of phenomena related to the thermal hydraulics of severe accidents. Analyses are extended evaluating the environmental consequences of a hypothetical severe accident.

Results exploitation and effect on safety

Knowledge of the different phenomena and awareness of the remaining uncertainties, as well as their management
strategies, forms the basis for decision making concerning severe accident management. Performed safety analyses, gained expertise and verified simulation methods are useful for Finnish authorities and power utilities immediately after the results are presented.

Resources

- Project manager: Anna Nieminen, VTT
- VTT
- 2015-2016: 40 pm and 508 k€
- 2017: 13 pm and 214 k€



State of the Fukushima Dai-ichi Unit 3 reactor at 43 h 34 min and 45 h after the earthquake as analysed with MELCOR.

Back

CATFIS – Chemistry and transport of fission products

Background and objective

CATFIS project is focused on reducing the uncertainties associated with estimating the behaviour and speciation of fission products in a severe accident. The objective is to experimentally study the chemistry and transport of fission products, especially iodine and ruthenium, in primary circuit and containment conditions. Another objective is to study the formation of air radiolysis products and their impact on FPs, as well as, on sump pH.

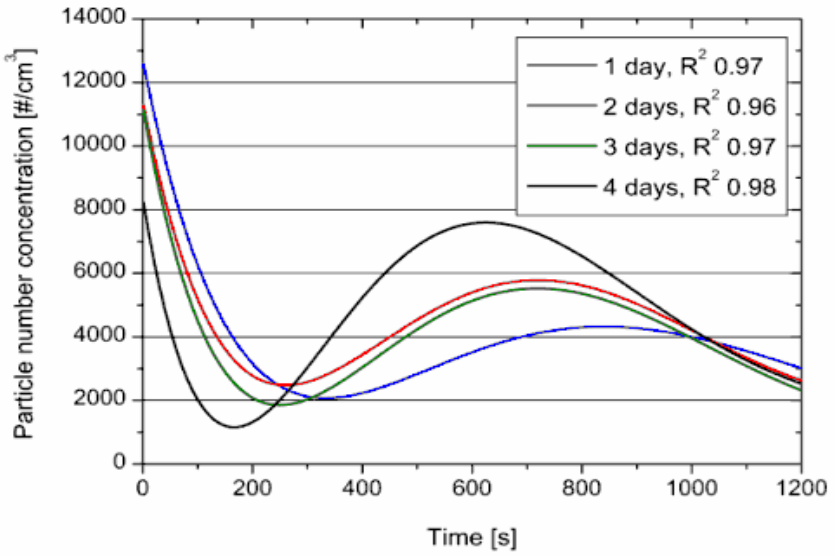
As a result, new models based on the experimental data will also be derived. The models of phenomena, which could not be previously considered in the accident analysis, can be included in SA analysis codes.

Results exploitation and effect on safety

The experimental data can be used , e.g., by the nuclear power companies and the radiation and nuclear safety authority for PSA level 2 analysis of the existing nuclear power plants. A complete experimental database will be finalized by the end of 2018.

Resources

- Project manager: Teemu Kärkelä, VTT
- Collaboration with IRSN, JRC-ITU, Chalmers, NUGENIA
- 2015-2016: 30 pm and 420 k€
- 2017: 8 pm and 143 k€



The number concentration of the formed IOx particles after the exposure of gaseous CH_3I precursor to beta radiation in an oxygen atmosphere at 20 °C. The irradiation period ranged from 1 day to 4 days.

Back

COMRADE - Condition monitoring, thermal and radiation degradation of polymers inside NPP containments

Background and objective

Polymers are widely used inside NPP containments as sealants, paint coatings, cable insulators and jacketing materials, lubricants and greases. These polymers are aged during their lifetime by heat, radiation and moisture. Available tools and knowledge for setting an acceptance criteria defining the remaining lifetime and condition of different components is currently lacking. Also procedures measuring component condition by the means of non-destructive methods, do not exist. The main objective is to evaluate the effect of different stressors (heat, radiation and dose rate) on polymer materials used inside NPP containments during normal service life, service failures and severe accidents. Further studies are made on material properties of different components and how they can be correlated with their functional property in order to create and improve condition monitoring methods for different components.

Results exploitation and effect on safety

The project will provide improved condition monitoring techniques to plant operators and better understanding how to evaluate the life time of different components during normal service life, service failures and severe accidents. Ageing management and thus overall safety is improved as definition of acceptance criteria for different components becomes more reliable.

Test bench used in testing the tightness of sealants. Functional property of sealants is tightness which is correlated to the condition of an O-ring thus creating a calibration curve. These curves are further used to estimate remaining lifetime of the component in question.

Resources

- Project manager: Konsta Sipilä, VTT
- VTT, RISE (SP), Energiforsk, SSM
- 2016: 9 pm and 194 k€
- 2017: 8 pm and 188 k€

Back

CORE – Crafting Operational Resilience in Nuclear Domain

Background and objective

Aim is to improve safe operation of nuclear power plants by developing guidance, training interventions, and other practical solutions that promote resilience for the three general defence levels of prevention, preparation, and consequence management. More specifically, the aim is to 1) develop new tools for human factors safety analysis, 2) promote reflectivity in operator learning, 3) investigate the effects of multitasking, challenging diagnostic problems and acute stress in simulated accident situations and 4) develop guidance for the coordination of activities in emergency exercises.

Results exploitation and effect on safety

The project is targeted to develop operational practices that promote nuclear safety in different levels of defence and that can be utilized by design organizations, nuclear power plant utilities and regulatory bodies. The objective is the immediate exploitation of project results.

Resources

- Project manager: Jari Laarni, VTT
- VTT Technical Research Centre of Finland, Finnish Institute of Occupational Health (FIOH)
- 2015-2016: 58 pm and 657 k€; 2017: 19 pm and 235 k€

(www.tvo.fi)

CORE's focus is on human factors of operator and maintenance tasks

Back

COVA – Comprehensive and systematic validation of independent safety analysis tools

Background and objective

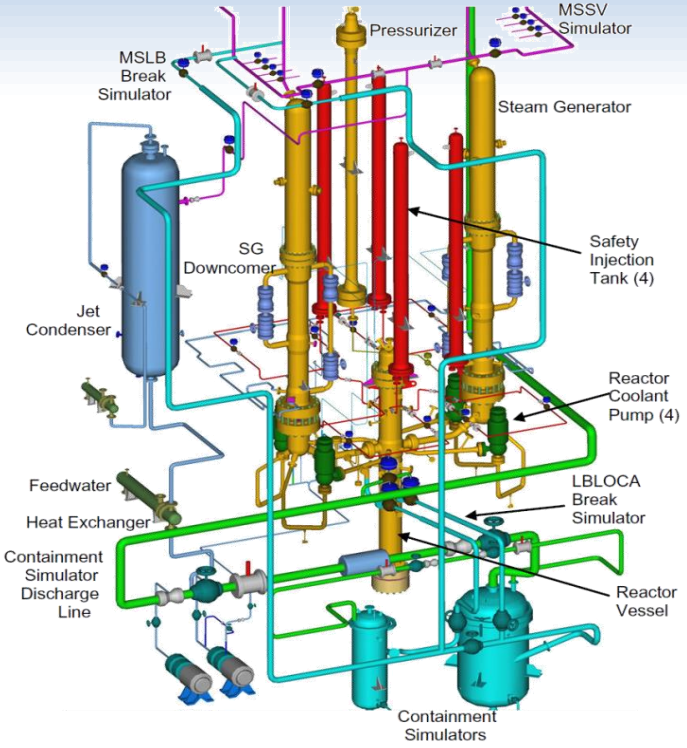
Apros is a process simulation software developed in cooperation between VTT and Fortum. It is currently used in safety analysis work both at the regulatory side and by Finnish utilities Fortum and TVO. In COVA the state of Apros validation is critically assessed by comparing the list of validation cases with OECD/NEA validation matrices. A list of essential validation cases is identified and re-analysed to bring the validation base up to date. In suitable cases, the level of uncertainty in the calculations is determined. The TRACE code, by U.S. NRC, is used alongside Apros, permitting code-to-code comparison.

The project also includes calculation of new validation cases that extend the code's validity range to new passive safety systems. Following and participation in multiple international research programs is included in the project.

Results exploitation and effect on safety

The project will strengthen Apros as a safety analysis tool. It will also enhance competence transfer from senior experts to new experts.

The project promotes international networking and cooperation through participation in international research projects such as the U.S. NRC CAMP programme and projects coordinated by OECD/NEA.



ATLAS facility, operated by KAERI, is a new thermal-hydraulic integral test facility for advanced PWRs. OECD/NEA ATLAS project is one the international cooperation projects included in COVA. (image: KAERI)

Resources

- Project manager: Seppo Hillberg, VTT
- VTT Technical Research Centre of Finland Ltd
- 2015-2016: 45 pm and 584 k€;
- 2017: 19 pm and 249 k€

Back

ERNEST – Experimental and numerical methods for external event assessment improving safety

Background and objective

Aircraft crash is one possible external hazard that a structure can undergo. 9/11 terrorist attacks showed that even deliberate large passenger aircraft crashes are possible. Resistance against this type of a crash is especially important for the structures that house a large number of people or for which a failure is otherwise disastrous like a nuclear power plant (NPP) reactor building.

This resistance is demonstrated with predictive models which have to be validated before use in order to rely on the results. Experimental data obtained from tests in which similar phenomena arise is needed for this purpose. To satisfy these needs, VTT has carried out three impact test series for concrete structures, funded and designed together with its numerous foreign and domestic partners. VTT has also developed its computational capabilities for analysing such scenarios. This testing activity and subsequent development and validation of computational capabilities will be continued within ERNEST project.

Results exploitation and effect on safety

The project will generate experimental data on the phenomena that arise in an airplane crash against a concrete structure like a NPP reactor building. The project will also improve reliability of the computational capabilities that VTT uses when analysing such scenarios.

A wall-floor-wall reinforced concrete structure, impacted with a soft projectile to study propagation and damping of vibration, and its numerical model.

Resources

- Project manager: Ari Vepsä, VTT
- VTT Technical Research Centre of Finland Ltd
- 2016: 5 pm and 90 k€
- 2017: 6 pm and 115 k€

Back

ESPIACS – Experimental Studies on Projectile Impacts Against Concrete Structures

Background and objective

Aircraft crash against civil structures is one possible external hazard that a structure can undergo. 9/11 terrorist attacks showed that even deliberate large passenger aircraft crashes are possible. Resistance against this type of a crash is especially important for the structures that house a large number of people or for which a failure is otherwise disastrous like a nuclear power plant (NPP) reactor building.

This resistance is demonstrated with predictive models which have to be validated before use in order to rely on the results. Experimental data obtained from tests in which similar phenomena arise is needed for this purpose. To satisfy this need, VTT has carried out three impact test series for concrete structures, funded and designed together with its numerous foreign and domestic partners. Despite extensive testing, there are still some open questions for which answers will be sought in ESPIACS-project.

Results exploitation and effect on safety

The project will generate experimental data on the phenomena that arise in an airplane crash against a concrete structure like a NPP reactor building. The generated data is intended for validation of predictive models which can be used for assessment of safety in a real life case.

A wall-floor-wall reinforced concrete structure, impacted with a soft projectile to study propagation and damping of vibration.

Resources

- Project manager: Ari Vepsä, VTT
- VTT Technical Research Centre of Finland Ltd
- 2015: 3 person months and 44 k€

Back

ESSI – Electric Systems and Safety in Finnish NPP

Background and objective

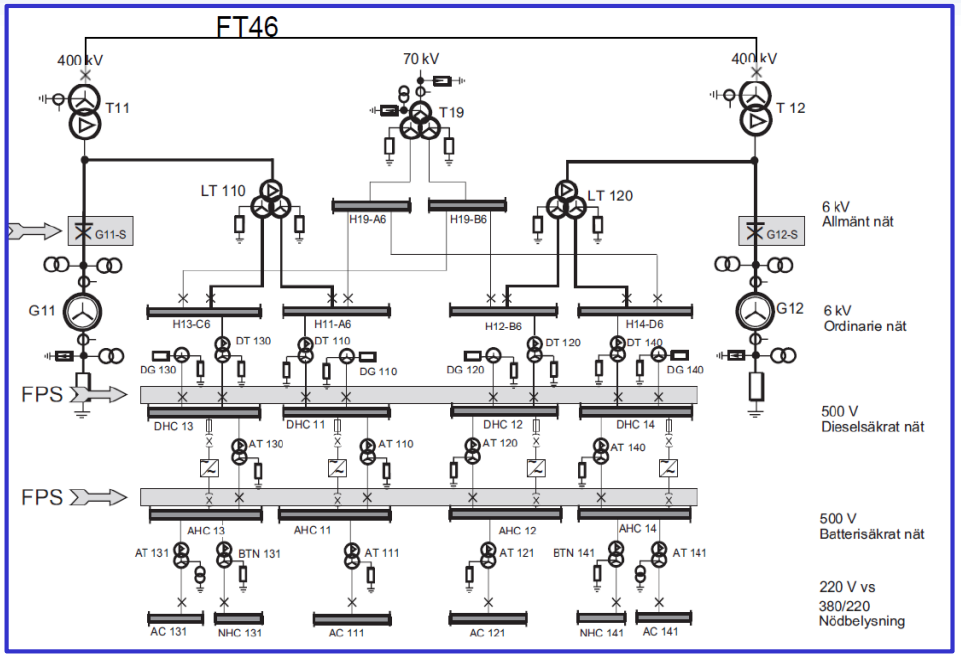
ESSI project examines disturbances and common cause faults which can cause the loss of in-site electrical system in NPP. The objectives of research are to examine the possible common cause fault impacts of open phase condition (OPC) and large lightning strikes in Finnish NPP electrical systems. Also the risks of adaptive operation of NPP in load following mode will be examined.

Results exploitation and effect on safety

OPC related research will be exploited by developing early detection solutions for unbalance condition in the NPP electric systems. Another important issue is to provide NPP operation personnel understanding about the time criticality of the OPC situation and possible means of mitigating the situation by operation decisions.

The lightning research will be utilized in improving the lightning overvoltage protection and grounding arrangements of the NPP electric, automation and control systems.

The research regarding adaptive operation of nuclear power plant can be exploited to setting the technological limits of adaptive control in today's nuclear power plants with regard to electrical systems in order to avoid the increase of disturbances in power plant.



A general schematic electrical diagram of a nuclear power plant

Resources

- Project manager: Seppo Hänninen, VTT
- VTT, Aalto University
- 2017: 11 pm and 130 k€;

Back

EXWE - Extreme weather and nuclear power plants

Background and objective

Extreme weather and sea level events affect the design principles of nuclear power plants and might pose external threats to the plants. In addition, geomagnetic effects of extreme solar storms may reduce the reliability of the external power transmission grid.

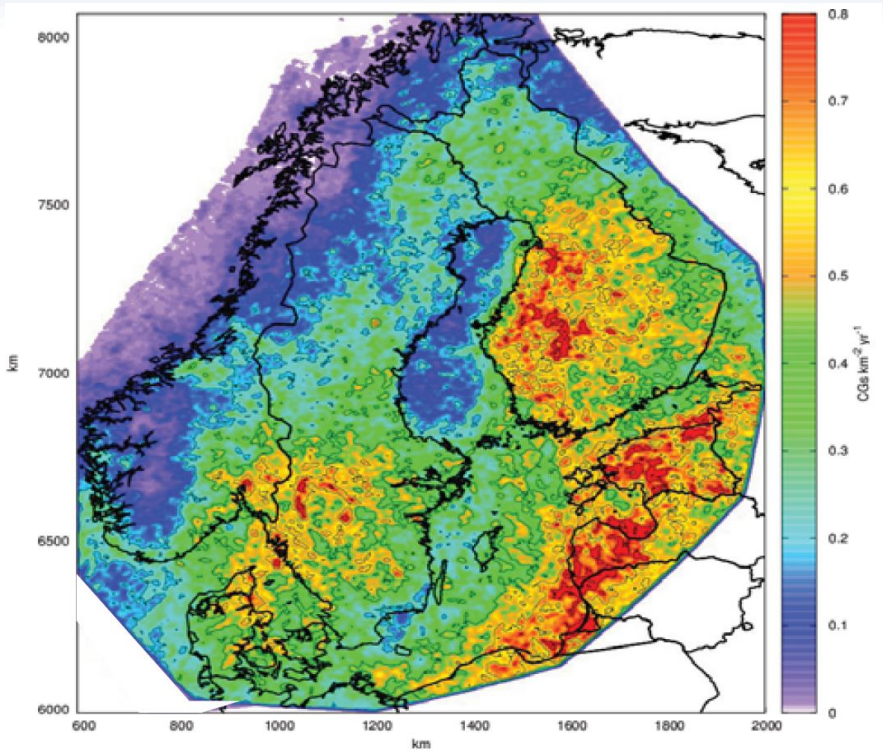
The aim is to enhance scientific understanding of the environmental conditions of the NPPs' sites and to predict how they may change. The work is focused on four topics:
1) extreme weather incidents, 2) extreme sea level events,
3) solar storm occurrence & effects, and 4) atmospheric dispersion modelling of accidental releases.

Results exploitation and effect on safety

The results (available from 2016 onwards) can be used to improve the design of future NPP units and the safety of existing units against the effects of nature phenomena. The end-users are 1) the power companies designing and running the power plants and 2) the nuclear safety authorities defining the safety regulations for NPP constructions and operations.

Resources

- Project manager: Kirsti Jylhä, FMI
- Finnish Meteorological Institute (FMI)
- 2015-2016: 76 pm and 650 k€; 2017: 20 pm and 200 k€



Thunderstorm measurements can be used as a source of information for extreme convective weather cases. The figure shows the average annual number of cloud-to-ground lightning flashes per km^2 in 2002-2013. EXWE involves mainly detailed analysis of measured and model-simulated data, but also modelling runs.

Back

FIRED - Fire Risk Evaluation and Defence-in-Depth

Background and objective

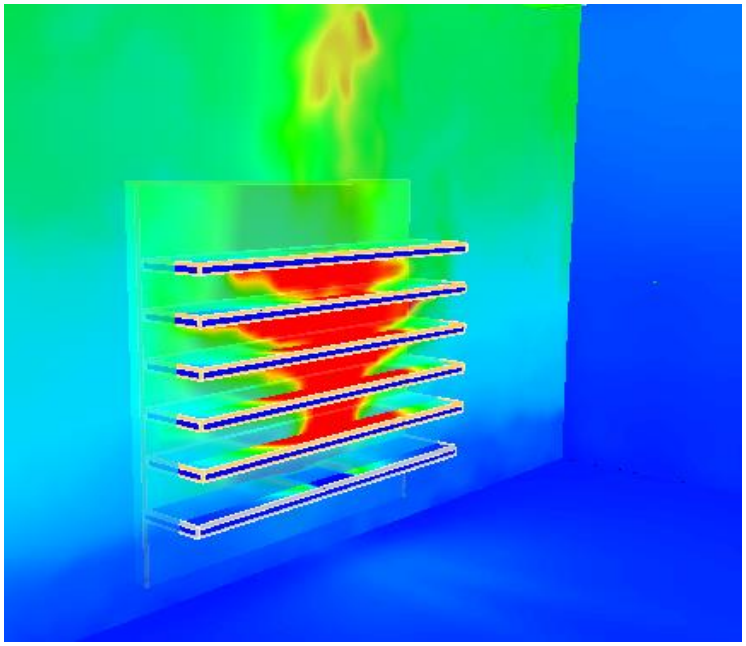
Computational tools enable reliable and accurate evaluation of the fire safety in NPPs. The tools have improved significantly over the past years, but still improvement in some areas, maintenance, and validation is needed. The work in FIRED will be focused on four specific topics: evaluating fire risks during cable life cycle, assessing fire-barrier performance, tool and method development, and participation to an international experimental program OECD/NEA PRISME2. Most of the work involves modelling, but experiments will be also performed to support and validate the models.

Results exploitation and effect on safety

The results of FIRED will be exploited in all levels: all tasks increase knowledge and support education of experts. Improved tools may be openly used by all fire safety engineers, and especially the results of fire-barrier assessment can be directly applied by authorities and utilities. Utilities will directly benefit from the large scale experimental results, and their use in model validation will benefit everyone. Most of the results can be exploited in 2-5 years, and beyond.

Resources

- Project manager: Anna Matala, VTT
- Organisations: VTT, Aalto University
- 2015-2016: 36 pm and 415 k€; 2017: 16 pm and 201 k€



Modelling cable fires, especially flame retardant and aged cables, is one of the main topics in FIRED.

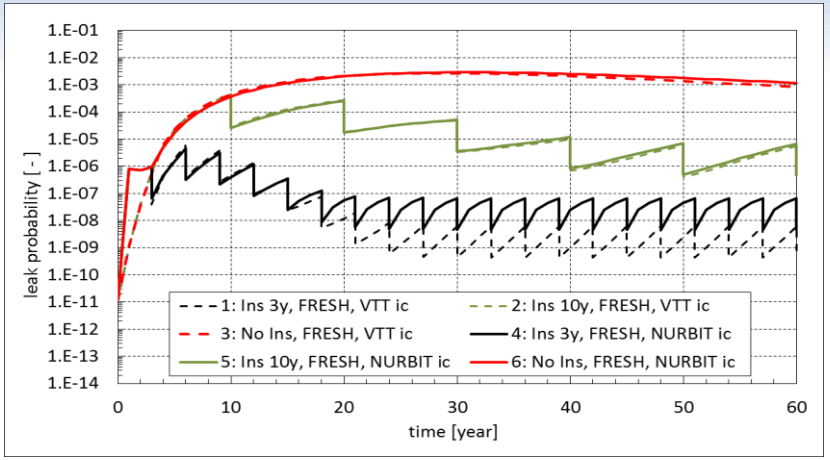
Back

FOUND – Analysis of Fatigue and Other Cumulative Ageing to Extend Lifetime

Background and objective

Project FOUND concerns cross-disciplinary assessment of ageing mechanisms for safe management and extension of operational plant lifetime. It develops deterministic, probabilistic and risk informed approaches in computational and experimental analyses with education of new experts.

The project focuses on: Probabilistic structural safety assessment of NPP piping systems; Susceptibility of BWR RPV internals to degradation mechanisms, Fatigue usage of primary circuit with emphasis on environmental effects and transferability; Fatigue and crack growth caused by thermal loads; Development of RI-ISI methodologies; Development of analysis methods for NPP piping systems and Residual stress relaxation in BWR NPPs.



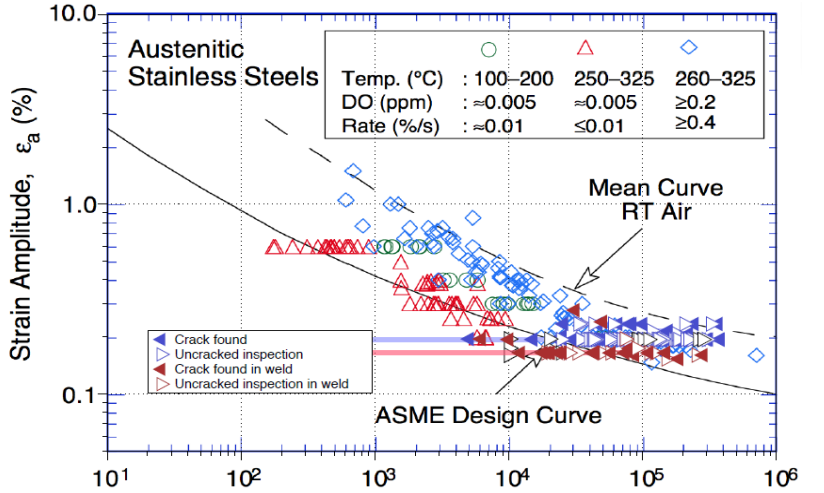
Example leak probability results for a initial flaw in pipe and welding residual stress load.

Results exploitation and effect on safety

FOUND provides new experimental capabilities and more accurate computational lifetime and risk assessment applications for NPPs. The main results will be available from 2017 onwards.

Resources

- Project manager: Juha Kuutti, VTT
- Organisations: VTT, Aalto University
- 2015-2016: 68 pm and 951 k€; 2017: 20 pm and 325 k€



Experimental-numerical thermal fatigue lifetime data for austenitic stainless steel in water.

Back

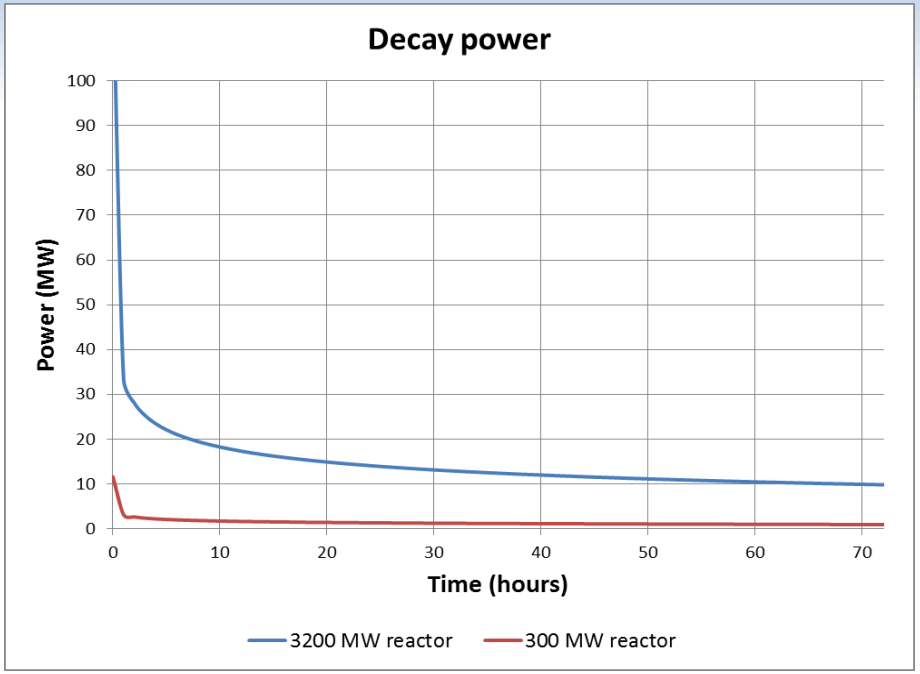
GENXFIN – Safety of new reactor technologies

Background and objective

The main mission of the GENXFIN project is to improve scientific and technologic expertise in the field of new nuclear energy technologies and related processes through international collaboration. The main objective is to coordinate participation in various international working groups and information dissemination on interested parties. This year an essential part of the project is to get familiar with the licensing of innovative Small Modular Reactor (SMR) concepts which is interesting from a national perspective. Research on new reactor technologies has an educational role in Finland but it is also a platform for technology development.

Results exploitation and effect on safety

The project results will assist the safety authorities to prepare for possible future applications on new reactor concepts. They can also be exploited by possible coming licensees. Further, the results can be utilized in development of current codes, as application of these on new systems may reveal possibilities for improvement. A major part of the project is information dissemination that involves all national stakeholders. Many of the new developments for the new reactor technologies can be applied in current reactors and those under construction within 5 years. The mission is to enable new safety features through enhanced technology transfer, innovative process development, and materials engineering.



Smaller power makes SMR severe accident easier to manage than that of a large plant.

Resources

- Project manager: Jarno Kolehmainen, VTT
- Participants: VTT, Fortum (in-kind)
- 2016: 7 pm and 112 k€
- 2017: 5 pm and 94 k€

Back

INFRAL – Development of thermal-hydraulic infrastructure at LUT

Background and objective

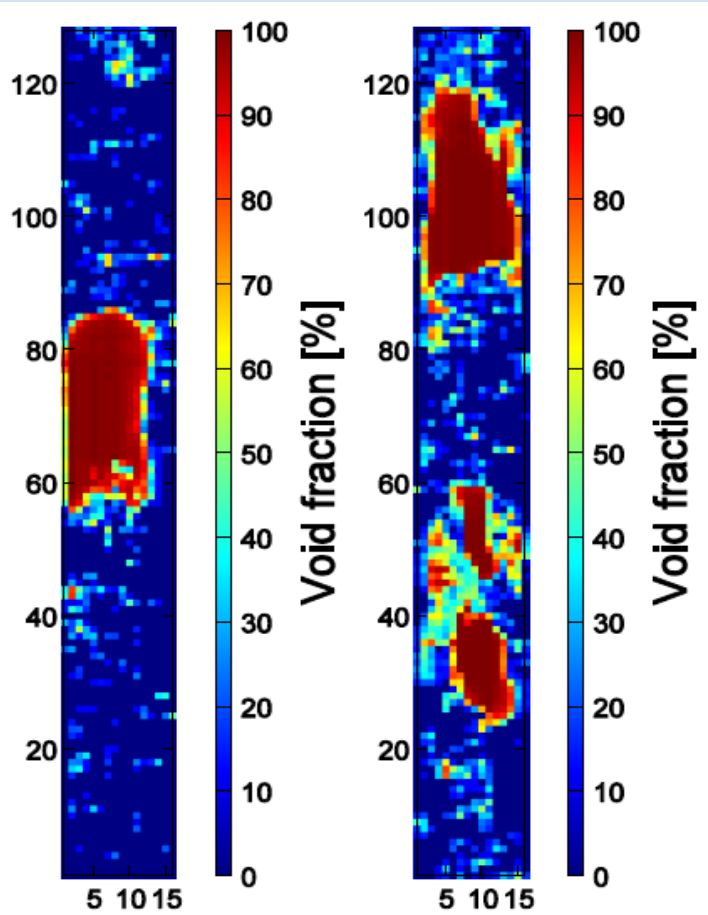
The up-to-date experimental research infrastructure is essential for the modern nuclear safety analyses. The goal of the INFRAL project is to ensure the availability of infrastructures and research teams capable to design, construct and operate test facilities representing the physics of nuclear safety related phenomena with sufficient accuracy. Adopting and testing new, advanced measuring techniques enables to produce high quality test data for the development and validation of modern computational tools.

Results exploitation and effect on safety

It is foreseen that the results from all activities performed in the project can be widely applied to experimental research performed in LUT and in Finland. The measurement techniques acquired, tested and developed in the project are available for SAFIR and other projects, conducting tests at LUT laboratories. Ultimate goal is to enhance nuclear safety by providing the means for measuring the code validation data of new level of quality.

Resources

- Project manager: Joonas Telkkä, LUT
- Lappeenranta University of Technology (LUT)
- 2015-2016: 44 pm and 627 k€; 2017: 15 pm and 264 k€



Two examples of instantaneous void fraction distributions measured with the Axial Wire-Mesh Sensor (AXE), Air-Water experiments in the HIPE test facility

Back

INSTAB - Couplings and instabilities in reactor systems

Background and objective

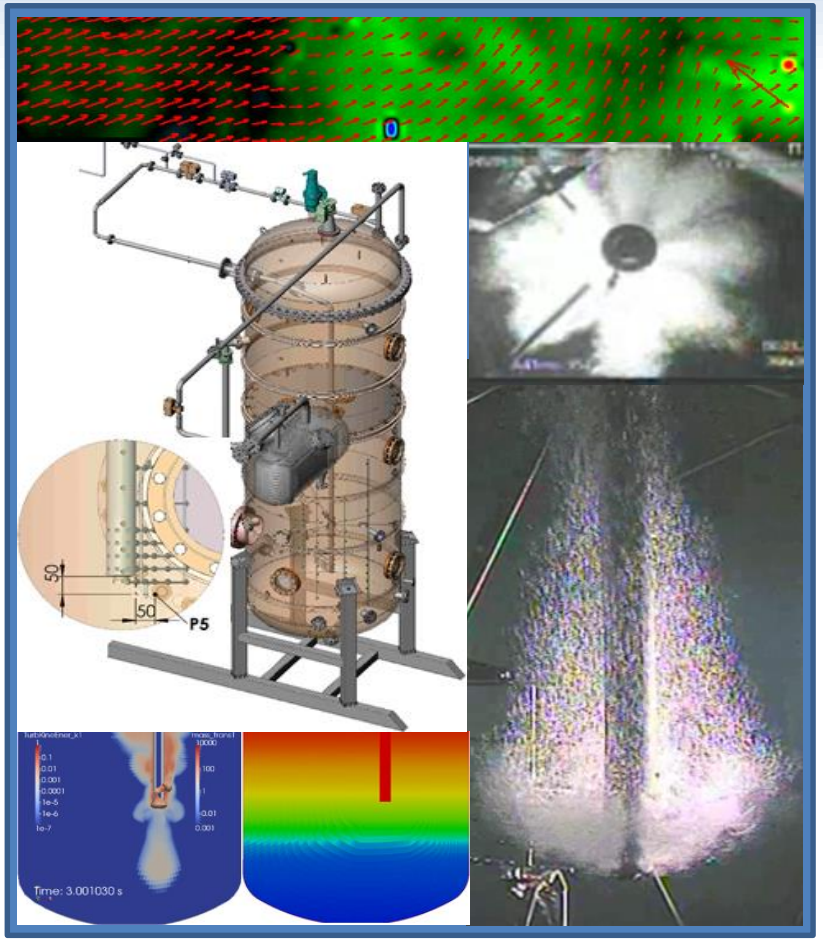
The INSTAB project aims to increase understanding of the phenomena related to BWR pressure suppression function to enhance capabilities to analyze Nordic BWR containments under transient and accident conditions. Experiments in the PPOOLEX facility for example with spray nozzles and SRV spargers provide high quality measurement data which can be used to improve the analytical tools used in the safety analyses of nuclear power plant systems.

Results exploitation and effect on safety

The main benefit of project will come through improved calculation models of CFD and system codes. The project outcome will allow the end users i.e. power utilities, safety authorities and research organizations to analyze the risks related to different scenarios of safety importance in the drywell and wetwell compartments of a Nordic BWR. Improved and validated calculation models can be expected to be implemented in the simulation tools from 2016 onwards.

Resources

- Project manager: Markku Puustinen, LUT
- Lappeenranta University of Technology (LUT)
- 2015-2016: 34 pm and 380 k€; 2017: 14 pm and 162 k€



INSTAB focuses on phenomena related to BWR containment pressure suppression function and pressure suppression pool operation.

Back

INTEGRA - Integral and separate effects tests on thermal-hydraulic problems in reactors

Background and objective

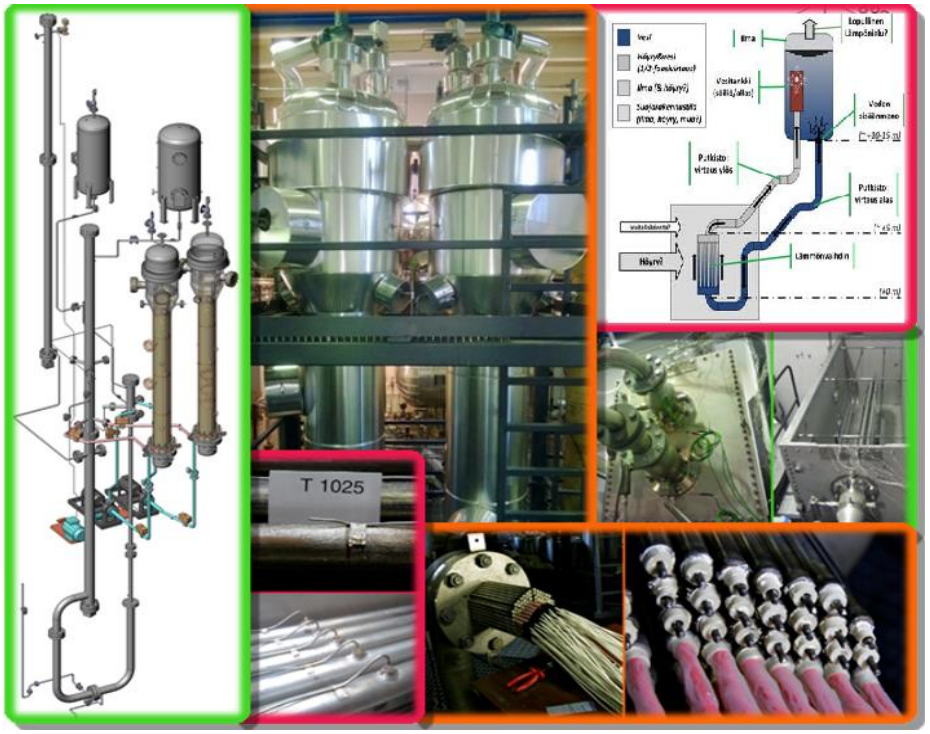
The objective is to improve the understanding of thermal hydraulic system behavior by performing integral and separate effects tests. Data will be used in the development and validation of computer codes for the safety analyses of nuclear power plants.

Results exploitation and effect on safety

The PWR PACTEL facility is used for tests within the OECD/NEA PKL Phase 3 and 4 project and on system behavior due to a pump trip, accumulator injection and inadvertent valve openings. The knowledge and database can be used for further analyses and to transfer the data to a plant scale. Limits of passive heat removal systems are reviewed and studied experimentally. The results are available (from 2016) to test, validate and ensure the computational capabilities in plant analyses and severe accident situations.

Resources

- Project manager: Vesa Riikonen, LUT
- Lappeenranta University of Technology (LUT), VTT
- 2015-2016: 58 pm and 682 k€
- 2017: 16 pm and 357 k€



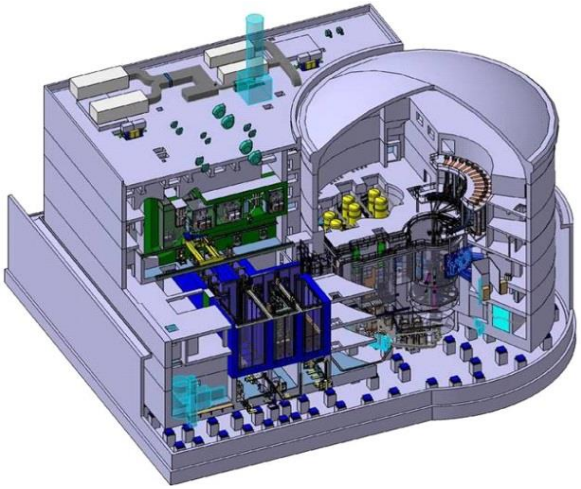
INTEGRA focus is on topical safety issues, exploiting integral and separate effect test facilities like PWR PACTEL and passive safety system facility.

Back

JHR – JHR collaboration and Melodie follow-up

Background and objective

Finland is participating in the construction of the Jules Horowitz Reactor (JHR) with a 2 % in-kind contribution, which includes both Underwater and Hot-cell Gamma spectrometry and X-ray radiography (UGXR and HGXR) systems as well as a Mechanical Loading Device for Irradiation Experiments (MeLoDIE). The participation in three working groups (WG), founded to plan the JHR experimental devices and determine experimental needs, brings knowledge on nuclear fuel and irradiated materials research as well as on the preparation and execution of in-core experiments to Finland.



Jules Horowitz Reactor

Results exploitation and effect on safety

In addition to bringing out our own interests and needs, the WG discussion about experimental needs and possibilities is useful when making decisions about the participation and collaboration in the future experiments. The results of WG work will be available immediately, and the information will be specified as the work progresses. The Melodie in-core experiment, carried out in Osiris reactor, will provide information on the new technologies used in the device and their suitability to the reactor environment. The experiment will act as a predecessor to future experiments in JHR. Furthermore, the Melodie experiment will provide irradiation creep data.

Resources

- Project manager: Santtu Huotilainen, VTT
- 2015-2016: 4 pm and 70 k€; 2017: 2 pm and 29 k€

Back

KATVE - Nuclear Criticality and Safety Analyses Preparedness at VTT

Background and objective

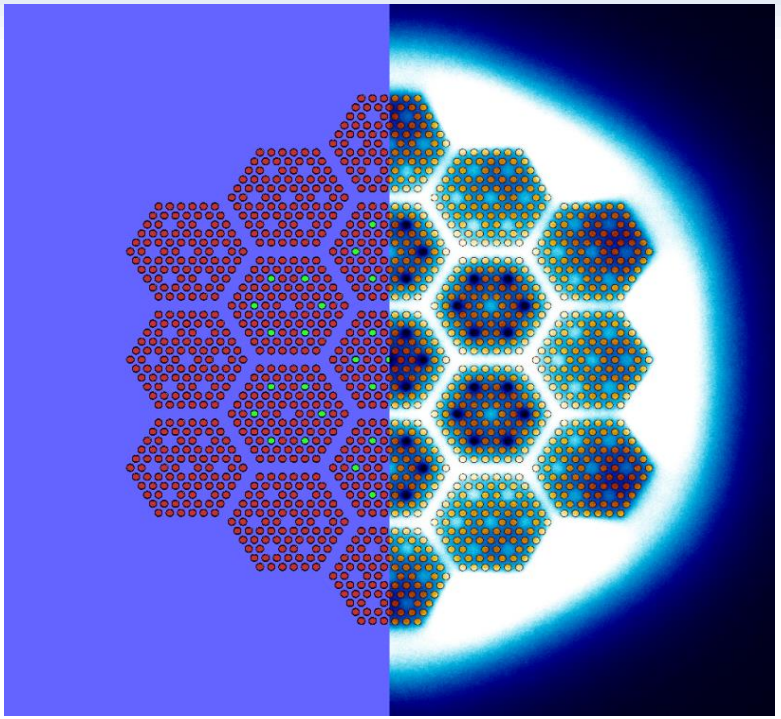
The motivation of this project is to have a readily available capability to perform analyses for the authorities and utilities in criticality safety, radiation shielding and activation analyses. Calculation systems including source terms are also developed for coolability of storage facilities. The capability to perform such analyses requires competent staff, appropriate, well validated tools, and knowledge of standards and requirements.

Results exploitation and effect on safety

The emphasis in KATVE is to develop methods, tools and knowledge in the fields mentioned above. The target of the work is to bring the knowledge and the tools to a level that meets the requirements of international standards and guidelines. Having competent staff and good tools is essential in assuring a high level in nuclear safety analyses.

Resources

- Project manager: Pauli Juutilainen, VTT
- VTT Technical Research Centre of Finland
- 2015-2016: 36 pm and 410 k€; 2017: 11 pm and 200 k€



The Serpent geometry (left) and thermal flux to fission rate plot (right) for one of the ZR6M cases. This is a case in the criticality safety validation package that is one of the main tasks in the criticality safety work in KATVE.

Back

LOST - Long term operation aspects of structural integrity

Background and objective

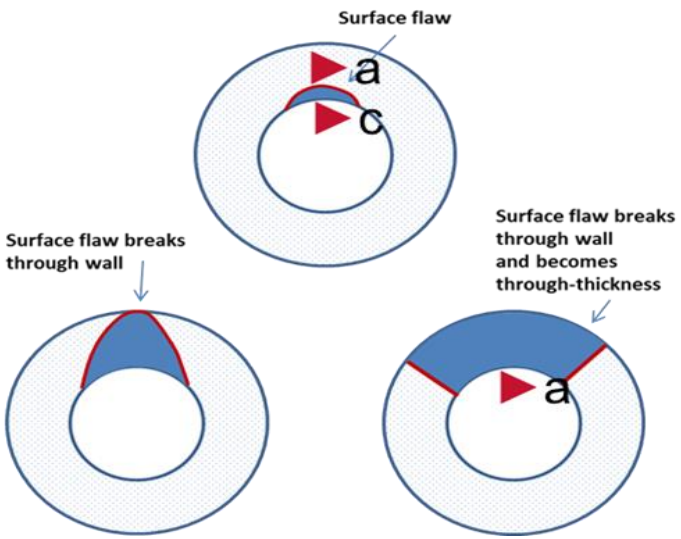
A systematic ageing management procedure is the basis for justifying the safe long term operation (LTO) of nuclear power plants. One fundamental part in this process is to demonstrate the structural integrity of the NPP components such as pipes, welds and valves. The required safety margins are determined by considering various loading conditions, postulated defects as well as degradation and ageing mechanisms. This project focuses on the determination of acceptable defect sizes with respect to the required safety margins in dissimilar metal welds (DMW) and pipes. Both experimental and numerical work is done.

Results exploitation and effect on safety

The results can be used for structural integrity assessment and fracture mechanical analysis of the reactor circuit in NPPs by safety authorities and nuclear power plant end users. Improved structural integrity assessment can also be applied in design of new power plants to ensure the necessary safety. The results can be used immediately after completion of the project.

Resources

- Project manager: Sebastian Lindqvist, VTT
- VTT Technical Research Centre of Finland
- 2015-2016: 322 pm and 21 k€; 2017: 18 pm and 307 k€



A surface flaw developing to a through-thickness flaw. The acceptable defect size has to be determined to ensure structural safety.

Back

MAPS - Management principles and safety culture in complex projects

Background and objective

MAPS aims at enhancing nuclear safety by supporting high quality execution of complex projects in the nuclear industry. The objectives are threefold: (1) to identify the generic safety principles of managing complex projects in the nuclear industry; (2) to clarify the cultural phenomena and their influence on safety culture and safety, and (3) to facilitate management and safety culture in projects by providing practical tools and guidance on e.g. facilitating communication, organizing decision making in unexpected situations, encouraging openness, and distributing knowledge and lessons learned.

Results exploitation and effect on safety

The results of MAPS will be beneficial for all actors in the network: the regulator, the power companies, suppliers and subcontractors. Good quality and smooth execution of complex project activities contribute to the defence in depth.

Resources

- Project manager: Nadezhda Gotcheva, VTT
- VTT, Aalto University, University of Oulu, University of Jyväskylä
- 2015-2016: 40 pm and 488 k€; 2017: 15 pm and 199 k€

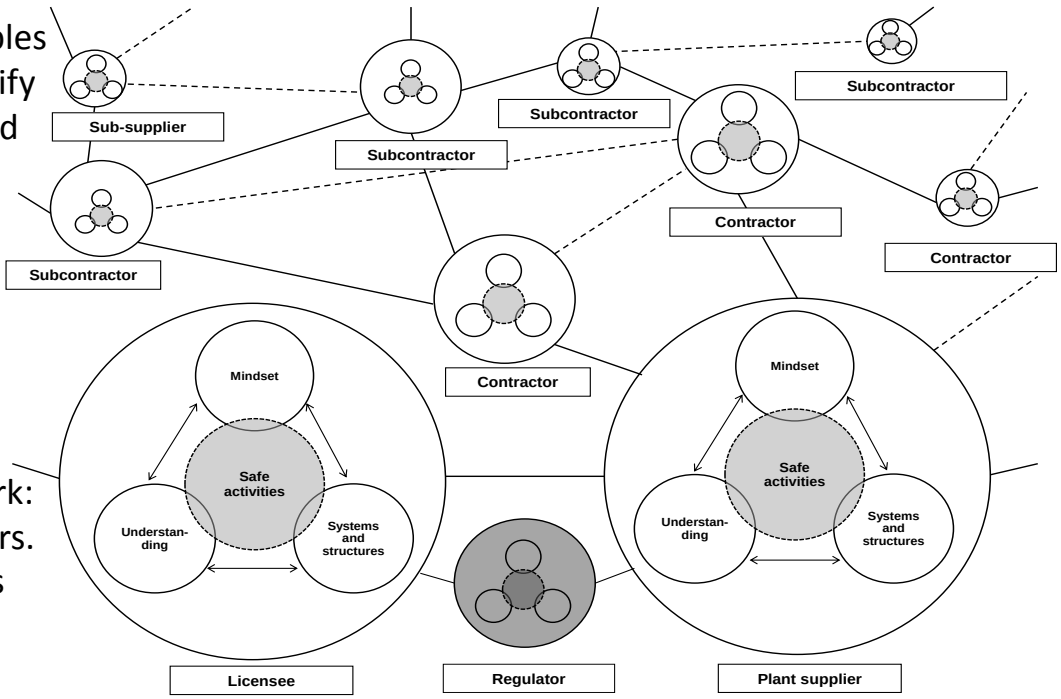


Figure 1. The interactions within the project network influence the alignment of cultural features between the actors and thus their safety culture and safety (adapted from Gotcheva et al., 2012).

Back

MOCCA - Mitigation of cracking through advanced water chemistry

Background and objective

Corrosion problems in nuclear power plants are caused by interaction of coolant water with the construction materials. The objective of this project is to identify alternative water chemistry regimes through which corrosion problems can be minimized.

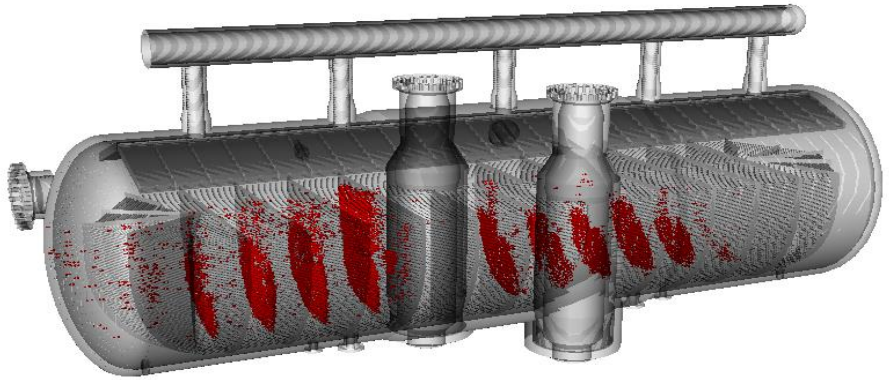
In 2015 the focus is on water chemistry options minimizing the formation of magnetite (Fe_3O_4) oxide particles which, if deposited into SGs can cause enrichment of impurities and stress corrosion cracking (SCC).

Results exploitation and effect on safety

The results will be applied by the chemistry personnel of operating power plants in designing improved plant chemistry practises. The expected effect on safety is minimising the number of corrosion induced SG tube failures and prolongation of safe lifetime of SGs.

Resources

- Project manager: Timo Saario, VTT
- VTT Technical Research Centre of Finland
- 2015-2016: 15 pm and 244 k€; 2017: 8 pm and 136 k€



Steam generator of Loviisa NPP showing the location of magnetite oxide particle clusters concentrating into tube/tube support structure crevices and on the hot leg side (courtesy of Fortum).

Back

MONSOON – Development of a Monte Carlo based calculation sequence for reactor core safety analyses

Background and objective

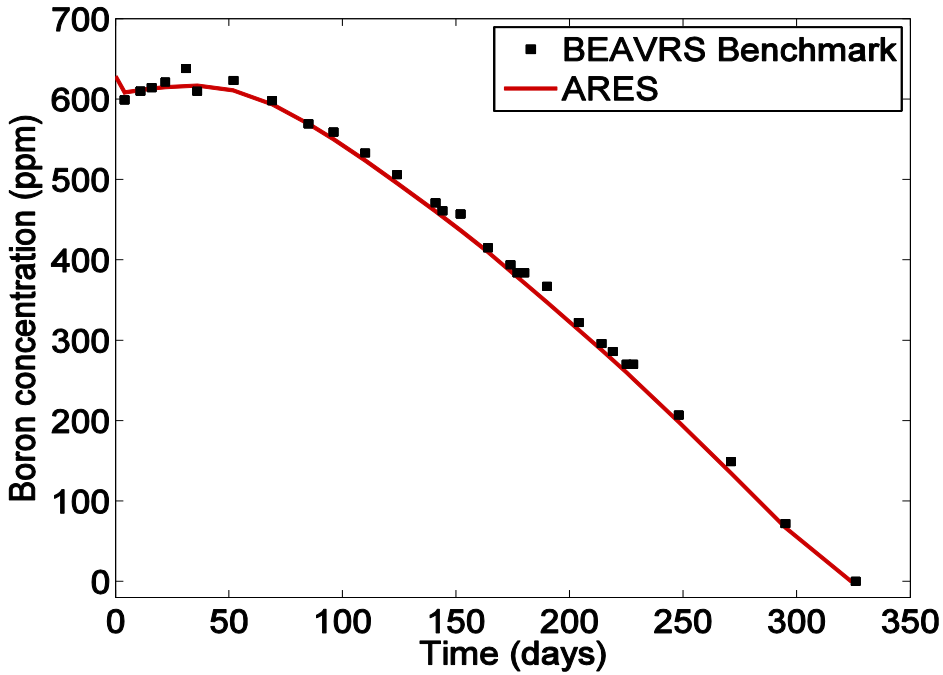
The project continues the development of the Serpent Monte Carlo code, started at VTT in 2004, and funded from the previous SAFIR research programmes. The work in the MONSOON project is focused on advanced methods for spatial homogenization, i.e., the production of input parameters for deterministic fuel cycle and transient core simulator codes. Another major goal is to develop Serpent from a viable into a practical and extensively validated tool for routine tasks in spatial homogenization.

Results exploitation and effect on safety

Serpent, together with the fuel cycle and transient simulator codes developed at VTT and STUK, provide a complete and independent calculation system for the safety analyses of Finnish power reactors.

Resources

- Project manager: Jaakko Leppänen, VTT
- VTT Technical Research Centre of Finland
- 2015-2016: 23 pm and 275 k€; 2017: 12 pm and 146 k€



Boron let-down curve in a 1000 MWe Westinghouse PWR calculated using the Serpent-ARES code sequence, compared with measured data (MIT BEAVRS Benchmark)

Back

NEPAL15 – Neutronics, burnup and nuclear fuel

Background and objective

NEPAL15 continues our research on **burnup calculation methodology** and **mesoscopic modelling of nuclear fuel**, started in the NEPAL project (2011-14). One of our scientists works as a postdoc at ORNL and develops burnup calculation methods of mutual interest. In the nuclear fuel task, one of our scientists introduces a physics student into the subject and supervises his/her Bachelor's thesis.

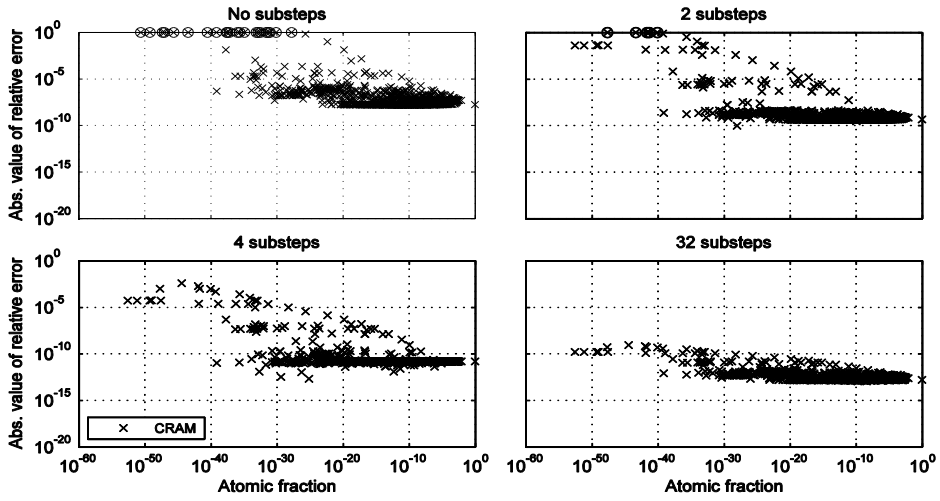
Results exploitation and effect on safety

The results of NEPAL15 can be defined primarily as new calculation methods and scientific publications documenting them. Moreover, the new expertise in the field and the new experts themselves are important deliverables of NEPAL15.

The burnup methods are implemented in Serpent that is distributed by VTT to dozens of organizations. The mesoscopic fuel model is closer to basic research.

Resources

- Project manager: Jarmo Ala-Heikkilä, Aalto University
- Aalto University School of Science, Dept of Applied Physics
- 2015: 10 person months and 96 k€



Relative errors for individual nuclides after a single depletion step of 100 days with different numbers of substeps. Initial concentrations are all zero, but U-235 has an order 6 polynomial source term (feed rate).

Back

NEST - Numerical methods for external event assessment improving safety

Background and objective

The decisions to build new nuclear power plants (NPP) in Finland, and especially the positioning of one NPP in a new location, called for the need to assess the seismic hazard and the potential effect of earthquakes on plant safety requirements and design criteria for new installations.

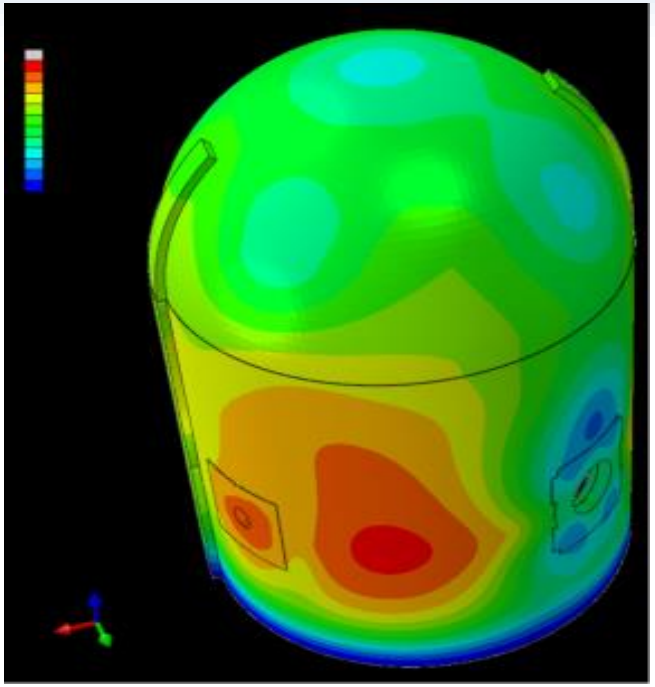
Also, it is required (Government Decree 733/2008) that the nuclear plant design takes into account large airliner crashes, as well as resulting fires and explosions.

Results exploitation and effect on safety

Methods and modelling techniques developed and validated in this project can directly be applied in safety assessment and design analyses. Results obtained within these studies are useful for safety authorities and utilities in structural safety assessment of NPPs.

Resources

- Project manager: Arja Saarenheimo, VTT
- ÅF-Consult Oy, The University of Uppsala, University of Helsinki – Institute of Seismology, Aalto University, Geological Survey of Denmark and Greenland
- 2015: 22 person months and 334 k€



Deformation of pre-stressed concrete containment under high internal pressure

Back

NURESA - Development and Validation of CFD Methods for Nuclear Reactor Safety Assessment

Background and objective

Computational Fluid Dynamics (CFD) methods are developed and validated for Nuclear Reactor Safety (NRS) assessment:

- Participation in benchmarks on mixing and stratification
- Modelling of spray experiments performed with PPOOLEX
- Development and validation of OpenFOAM code

Results exploitation and effect on safety

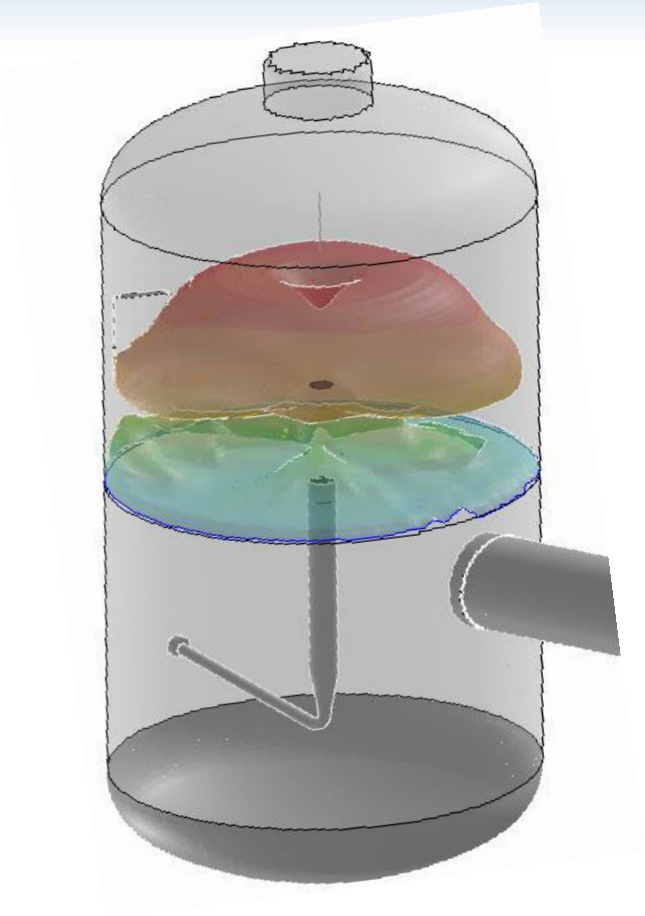
Benchmarks on mixing and stratification provide validation of the CFD methods and information on the uncertainties of the analysis.

Development and validation of spray models and calculation of PPOOLEX experiments at LUT provides improved understanding of the pressure suppression function of the BWR containment.

Validated, transparent, publicly available OpenFOAM solvers will become available for NRS assessment.

Resources

- Project manager: Timo Pättikangas, VTT
- VTT, Aalto University, LUT, Fortum
- 2015-2016: 35 pm and 494 k€; 2017: 17 pm and 234 k€



CFD calculation of an experiment performed with the PANDA facility. The erosion of helium stratification by vertical jet is calculated.

Back

PANCHO – Physics and chemistry of nuclear fuel

Background and objective

Work in PANCHO consists of development of FINIX fuel behaviour module, investigations of fuel behaviour in accident scenarios and research into areas such as chemical properties of the fuel pellet and mechanical behaviour of the cladding.

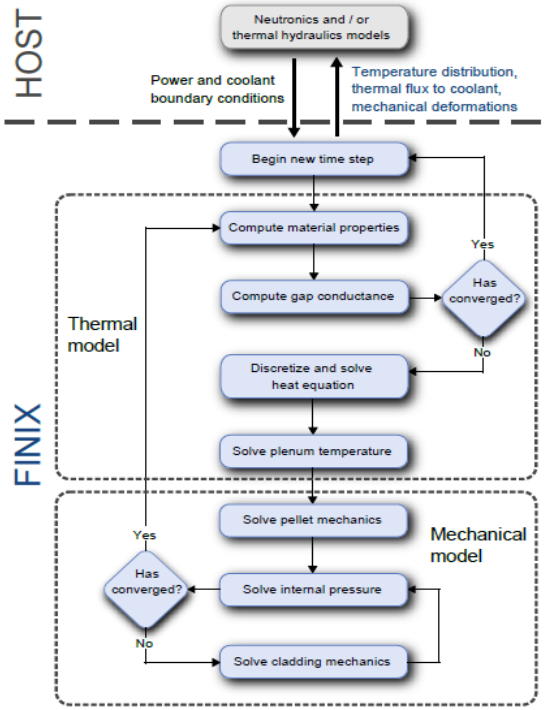
Most of the work will be modelling as the experimental data is obtained through the participation in international research programmes such as Halden Joint Programme. There is also some experimental work performed in PANCHO in the form of cladding mechanical tests and fuel leaching.

Results exploitation and effect on safety

As nuclear fuel provides the first safety barriers against the spread of fission products the understanding of its behaviour is important for the nuclear safety. The applicability of FINIX will be extended to LOCA conditions and base irradiation. New models will be introduced for improved description of cladding creep and fuel mechanical behaviour. Codes used for safety analysis of Finnish reactors will be further validated.

Resources

- Project manager: Ville Tulkki, VTT
- VTT Technical Research Centre of Finland
- 2015-2016: 52 pm and 618 k€; 2017: 18 pm 259 k€



Flowchart of FINIX thermomechanical solution

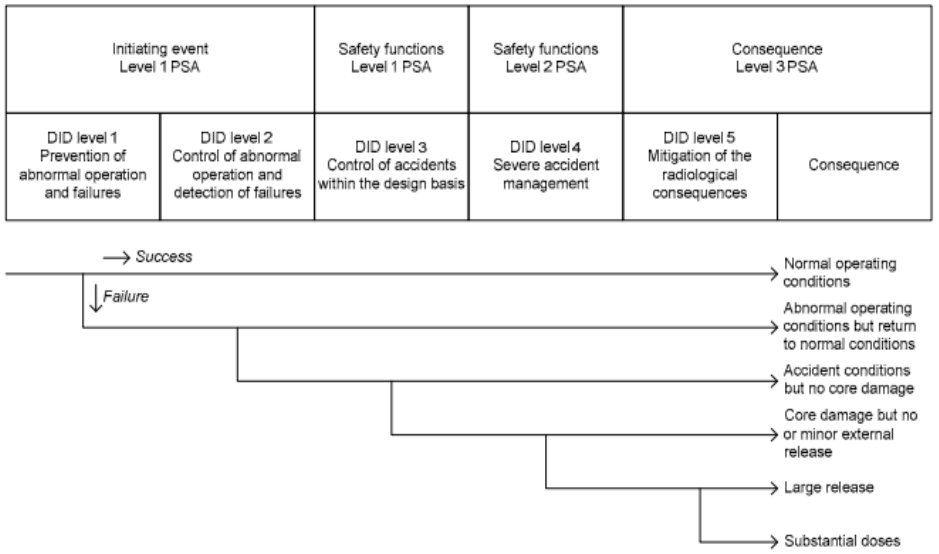
Back

PRAMEA – Probabilistic risk assessment method development and applications

Background and objective

PRA is the field of quantifying risks in terms of probabilities, evaluating the contribution of different subsystems, processes etc. to total system risk, and assessing the uncertainty related to the analyses. Construction of new nuclear power plants, and the modernization of existing ones, poses challenges to PRA.

PRAMEA will cover the important issues in probabilistic risk/safety assessment of nuclear power plants. The human reliability analysis of digitalized control rooms will reveal whether changes to existing HRA practices are necessary, and if so, what they are. Multi-unit PRA will consider plant-wide safety issues common to all units on site. State-of-the-art software will be developed for the analysis of serious accidents. In consequence analysis, methods for assessing pathways will be developed.



Connection between defense-in-depth layers and PSA levels

Results exploitation and effect on safety

HRA results will be utilized in plant PRA when digitalized control rooms are taken into use. PRA software will replace outdated programs.

Resources

- Project manager: Ilkka Karanta, VTT
- VTT, Risk Pilot, Aalto University
- 2015-2016: 61 pm and 746 k€; 2017: 24 pm and 328 k€

Back

RADLAB – Radiological laboratory commissioning

Background and objective

Renewal of the hot cell infrastructure is central feature of the VTT Centre for Nuclear Safety (CNS) in Otaniemi. The project involves efforts in four main areas:

- hot cell design, fabrication and commissioning
- hot laboratory equipment procurement and nuclearization
- design, fabrication and installation of self-built research facilities
- design, fabrication and installation of self-built materials handling and storage facilities.

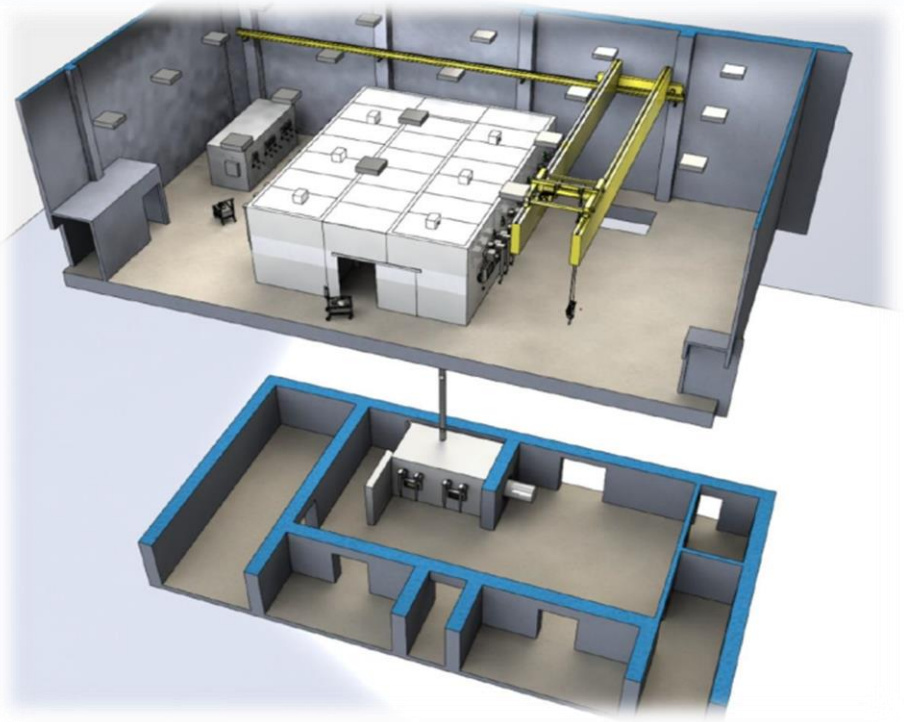
Management of the hot cell renewal as a part of the overall infrastructure construction, commissioning and ramp-up of operations is coordinated in part as a task of this project.

Results exploitation and effect on safety

The VTT CNS and its hot cell facility is a national infrastructure hosted by VTT. Aimed at research and testing of radioactive materials, it helps fulfil the national requirements for independent competences supporting nuclear power plants.

Resources

- Project manager: Wade Karlsen, VTT
- VTT Technical Research Centre of Finland
- 2015-2016: 108 pm and 1757 k€; 2017: 47 pm and 703 k€



The hot cells will be designed, fabricated and installed in collaboration with Isotope Technologies Dresden, GmbH.

Back

SADE – Safety analyses for dynamical events

Background and objective

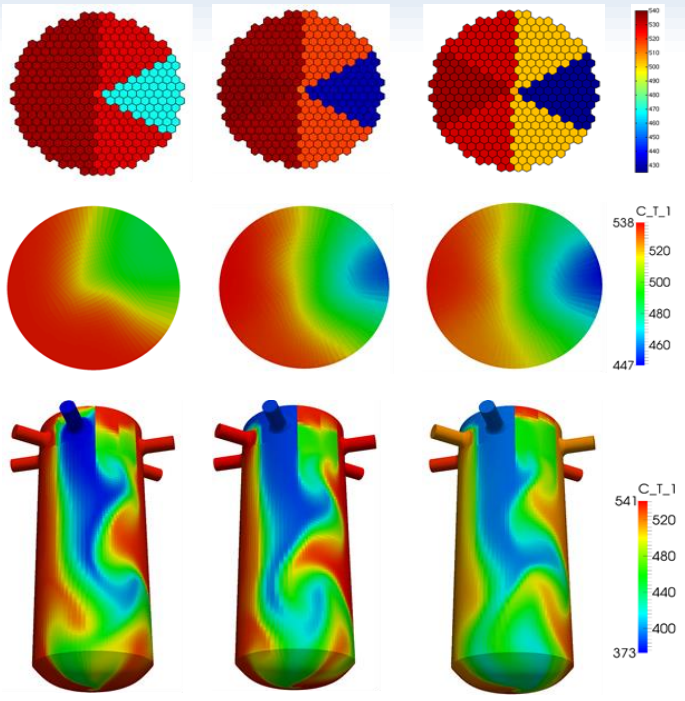
The main idea is to improve VTT's modelling capabilities by coupled use of the CFD-type thermal-hydraulics solver PORFLO and the reactor dynamics codes HEXTRAN and TRAB3D. Alongside the coupling with CFD-solver, a new type of coupling between HEXTRAN and system code SMABRE is done and the neutronics modelling is improved. The goal is to have a tool set, which is more accurate and still fast and robust enough for practical safety analysis.

Results exploitation and effect on safety

Objective is that by the end of the project we have calculated several transients and accidents relevant from safety analyses point of view with the developed computational tool set of coupled neutronics, system codes and real 3D thermal hydraulics. New coupling between HEXTRAN and SMABRE for VVER-reactors will be available for safety analyses already during the SAFIR2018 program. Own code and in-depth understanding of it enables the best possible expertise on safety analyses.

Resources

- Project manager: Ville Sahlberg, VTT
- VTT Technical Research Centre of Finland
- 2015-2016: 23 pm and 257 k€; 2017: 7 pm and 93 k€



Coolant temperature in VVER-440 RPV and in core inlet after connection of a cold, isolated loop. Uppermost distributions are calculated by HEXTRAN-SMABRE, others with one-directional coupling between HEXTRAN-SMABRE and PORFLO.

Back

SAUNA - Integrated safety assessment and justification of nuclear power plant automation

Background and objective

Licensing of NPP digital automation systems has been a major challenge. State-of-the-art safety **assessment** methods have not been effectively put to use, and safety **justification** has focused more on the need to submit documents such as SARs, less on structured representation.

SAUNA will develop an integrated, model-based approach for assessing and demonstrating the safety of automation design. Plant safety is assessed by evaluating, e.g., the product, the design processes, and safety culture. Through shared, formal information models, and model-driven safety demonstration, SAUNA promotes the use of Systems Engineering practices.

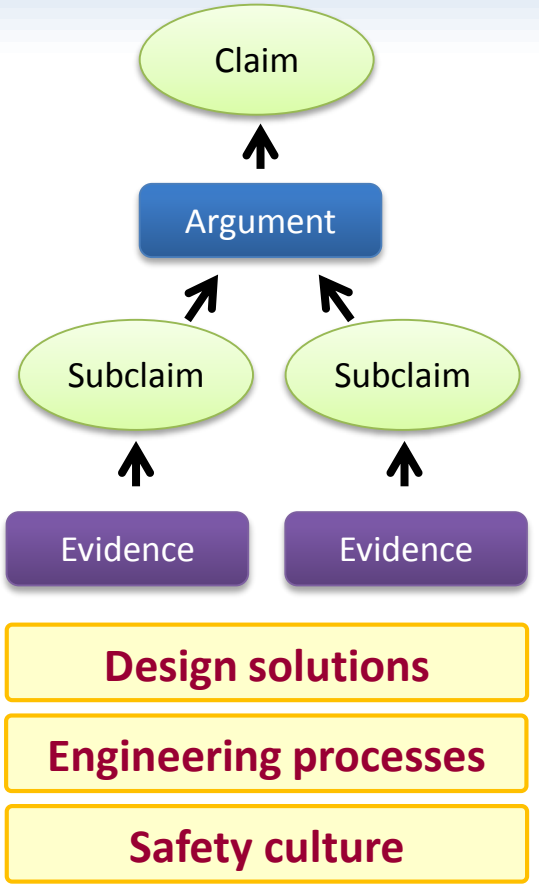
Results exploitation and effect on safety

Methods, practices, information models, and tools developed in SAUNA will promote safe and efficient plant operation, and also support cost-effective licensing and implementation of NPP automation.

Selected assessment methods and (possibly) tools – particularly for analysing **Defence-in-Depth** issues – will also be developed.

Resources

- Project manager: Antti Pakonen, VTT
- VTT, Aalto University, Risk Pilot AB, FiSMA ry, IntoWorks Oy
- 2015-2016: 86 pm and 1033 k€; 2017: 27 pm and 349 k€



Demonstration of plant safety calls for multidisciplinary assessment, and a structured way to represent safety claims.

Back

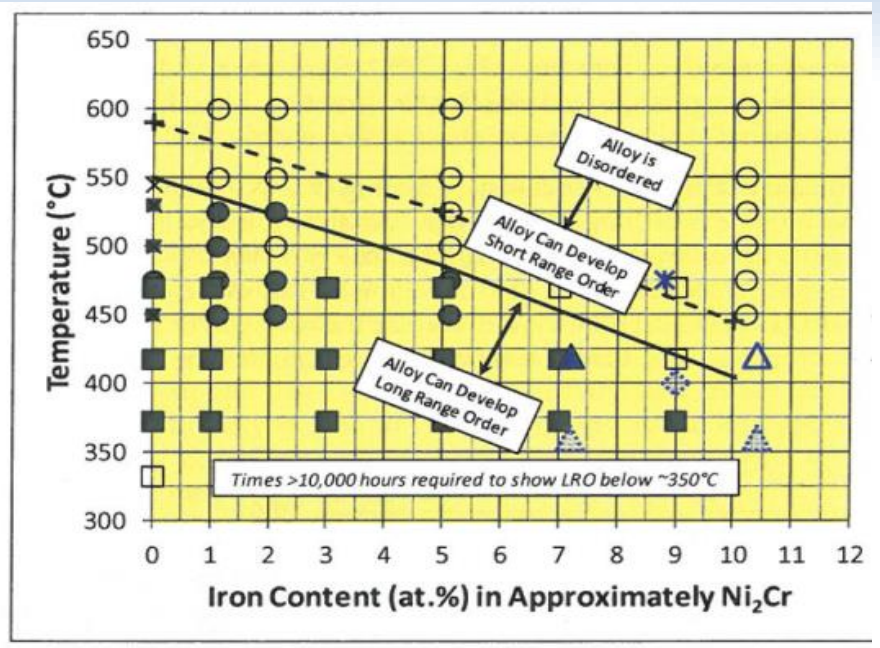
THELMA – Thermal ageing and EAC research for plant life management

Background and objective

THELMA deals with nuclear materials behaviour in LWR environments with special focus on determination of thermal ageing in austenitic primary circuit materials and precursors for environmentally assisted cracking (EAC) initiation to be used for plant life management and failure analyses. Educating new experts in the field of nuclear materials is of high priority in the project.

Results exploitation and effect on safety

The project will deliver data on thermal ageing of stainless steel weld metals, which can be used in ageing management. It will also produce novel data on thermal ageing / long range ordering of nickel-based Alloy 690, which will be very important for life time management. The objective of the EU-project INCEFA, reported to THELMA, is to develop an European consensus on corrosion fatigue assessment. New experts are educated in an advance course on nuclear materials. The Yong Generation also performs most of the THELMA-work.



Effect of iron on the development of ageing / long range order.

Resources

- Project manager: Principal scientist Ulla Ehrnstén, VTT
- VTT and Aalto Univeristy
- 2015-2016: 45 pm and 636 k€; 2017: 16 pm and 234 k€

Back

USVA - Uncertainty and sensitivity analyses for reactor safety

Background and objective

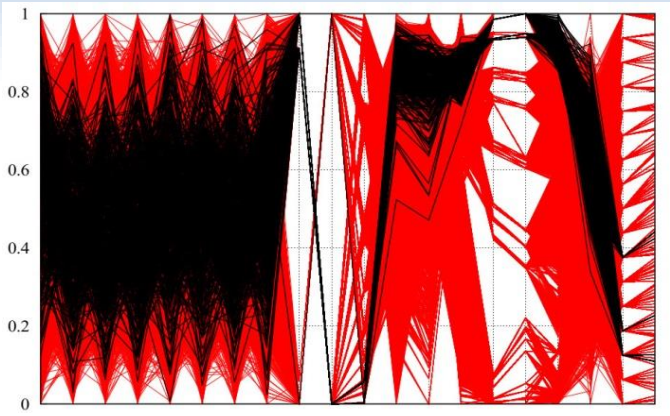
USVA develops methods and practices in uncertainty and sensitivity analyses in reactor safety. Established methods for the analysis of calculation sequences or multi-physics simulations are in need of development. Thus the major goal of USVA is to identify and develop methods for analyses involving more than one simulation code.

Results exploitation and effect on safety

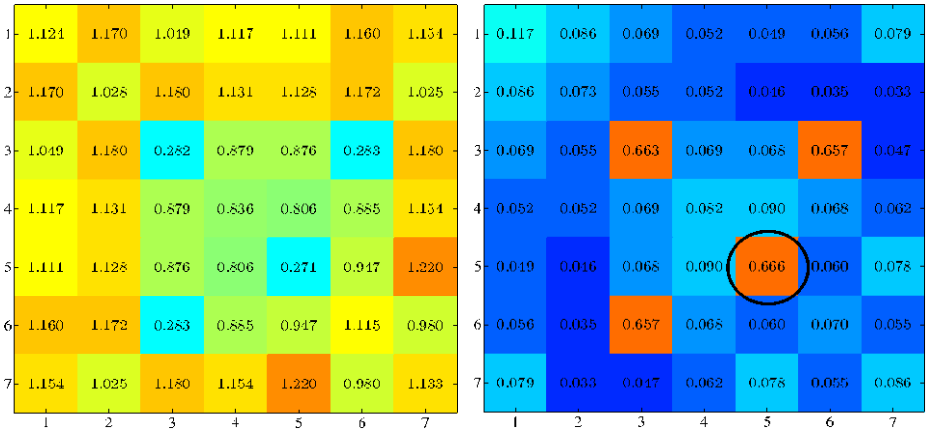
Uncertainty and sensitivity analyses are required to accompany deterministic safety analyses, the former in best-estimate plus uncertainty analyses, and the latter in conservative analyses. By the end of the project, the methods developed in USVA are expected to be used in safety analysis tools. In addition, the knowledge gained from the analyses of multi-physics simulations and calculation sequences can be used in estimating the impact of the uncertainties of an individual model on the whole calculation package.

Resources

- Project manager: Ville Valtavirta, VTT
- VTT, Aalto
- 2015-2016: 36 pm and 355 k€; 2017: 9 pm and 115 k€



Cobweb visualization of the most significant factors affecting clad strain in a LB-LOCA (from SIMULATE-APROS-FRAPCON-FRAPTRAN-GENFLO code sequence).



Pin-powers and their relative uncertainties (%) due to nuclear data uncertainty for a BWR fuel assembly as calculated by VTT-modified CASMO-4.

Back

WANDA – NDE of NPP primary circuit components and concrete infrastructure

Background and objective

Research in WANDA is conducted in the area of Non-destructive Examination (NDE) of NPP components and concrete walls.

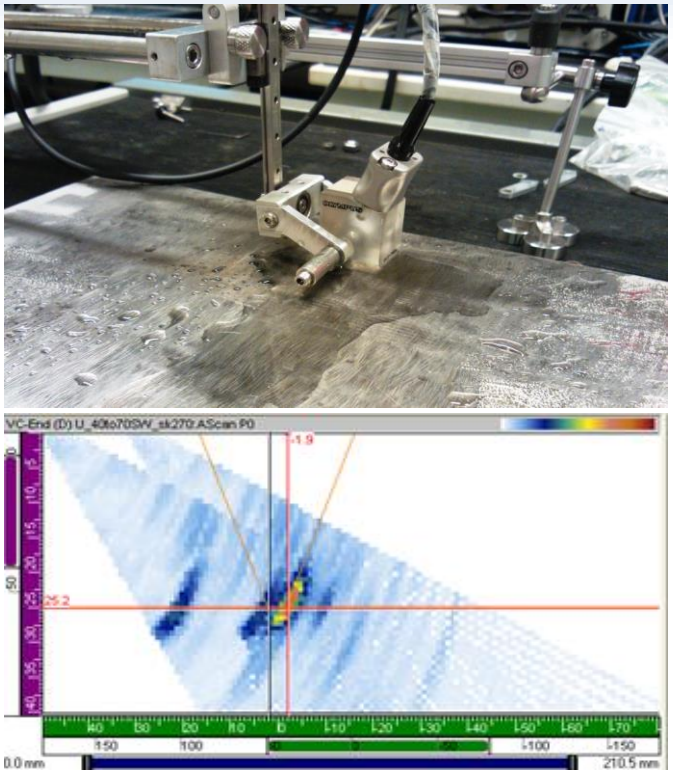
In-service inspections (ISI) demonstrates the structural integrity of the components and materials of the NPP. NDE plays an important role in the ISI. Objective of WANDA is the development of the non-destructive testing techniques (NDT) towards more reliable inspections. NDT methods used for metal components are ultrasonic applications and simulation, eddy current and radiography. The NDE Methods for the concrete inspection will be explored in more detail.

Results exploitation and effect on safety

The research in WANDA is enhancing the inspection procedures and methods. More reliable and efficient NDE inspections promote the safety of nuclear power plants. The results gained in WANDA increases the knowledge of the NDT methods used in the ISI.

Resources

- Project manager: Tuomas Koskinen, VTT
- VTT and Aalto University
- 2015-2016: 28 pm and 438 k€; 2017: 10 pm and 160 k€



Ultrasonic testing of a weld. Crack indication with ultrasonic phase array technique.

Back