
# NKS-R STATUS REPORT

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# 1 Overall status summary

This report provides a short overview of the status of the NKS-R programme.

All contracts from the Call for Proposals (CfP) 2018 were signed by the end of March and the six activities are now ongoing according to plan.

Two activities from from CfP 2017 are completed (NORDEC and SC_AIM) and the NKS reports have been published, see below. A report from VTT SPARC in 2016 has been published in addition to the final report that was delivered in August 2017. LUT has submitted four reports that will be included as appendices to a main report for COPSAR that is expected in June. Reports from SPARC and FIREBAN are expected in June/July. Delays have been reported from HYBRID and WRANC.

Summaries of the acitivites with status updates are presented in Chapter 2 (2017 activities) and Chapter 3 (2018 activities).

## 1.1 Published NKS reports

The following reports have been published within the NKS reports series since the last board meeting in January.

| Report nr | Project | Report Title | Published |
|---|---|---|---|
| NKS-404 | NORDEC | *Challenges and opportunities for improving Nordic nuclear decommissioning* | 2 Feb 2018 |
| NKS-405 | SC_AIM | *Safety culture assurance and improvement methods in complex projects* | 2 Feb 2018 |
| NKS-408 | SPARC* | *Phenomena Threatening Containment Integrity and Evaluating Source Term Characteristics* | 8 Jun 2018 |

*) The final report NKS-408 contains the contributions from VTT in 2016 that were missing in the SPARC final report NKS-395 that was published in August 2017.

LUT has submitted four reports describing the experimental work that has been performed in the COPSAR activity in 2017. These reports will be included as appendices to a main report that will be completed as soon as the contributions from KTH and VTT are available (expected publication in June).

| Project | Partner | Report Title | To be published |
|---|---|---|---|
| COPSAR | LUT | *PPOOLEX Spray Tests on Mixing Effects in Condensation Pool* | As appendix in June |
| COPSAR | LUT | *Mixing Test in PPOOLEX with Sparger in Centre Position* | As appendix in June |
| COPSAR | LUT | *General Description of SEF-POOL Test Rig* | As appendix in June |
| COPSAR | LUT | *Characterizing Tests in SEF-POOL Facility* | As appendix in June |

## 1.2 Seminars and publications in 2018

| Project | Seminar date |
|---|---|
| FIREBAN | Workshop for PRA Integration – November 2018 |
| NORDEC | Open workshop in Lillehammer – December 2018 |

## 1.3 Young scientist travel support

A request for travel support has been received from Tiina Lavonen – Research Scientist at VTT (30 y.o.) M.Sc. planning for Ph.D.

"*VTT is currently preparing for the decommissioning of FIR1 (TRIGA type) research reactor and we have done and are currently doing the characterization analysis for research reactor waste and construction materials. My part has been to analyze the original composition of different materials from FIR1 with HR ICP-MS. I would like to participate in ICP conference, Nordic Plasma Conference (10-13 June in Loen, Norway) and do a poster about our characterization analysis with HR ICP-MS.*"

# 2 Summary and status of activities initiated in 2017

Seven activities were were initiated in CfP 2017 (Table 1). Five of the activities were continued activities and two were new (NORDEC and WRANC). Two activities are completed (NORDEC and SC_AIM) and one is partly delivered (COPSAR).Final reports from COPSAR, SPARC and FIREBAN are expected to be delivered in June/July. Delays have reported from HYBRID and WRANC with expected deliveries later in 2018.

Summaries of the activities are presented in the following sections.

**Table 1. NKS-R 2017 activities**

| Acronym | Activity title | First invoice | Second invoice | Report number | Expected Delivery |
|---|---|---|---|---|---|
| COPSAR | *Containment Pressure Suppression Systems Analysis for Boiling Water Reactors* | √ | | | June[a] |
| FIREBAN | *Determination of fire barriers's reliability for fire risk assessment in NPP* | 4/5 | | | July |
| HYBRID | *Development of hybrid neutron transport methods and data visualization tools* | 1/2 | | | Dec |
| NORDEC | *Challenges and opportunities for improving Nordic nuclear decommissioning* | 5/9 | 4/9 | NKS-404 | Done |
| SC_AIM | *Safety culture assurance and improvement methods in complex projects* | √ | √ | NKS-405 | Done |
| SPARC | *Scenarios and Phenomena Affecting Risk of Containment Failure and Release Characteristics* | √ | | | June |
| WRANC | *Warm Pre-Stressing – Validation of the relevance of the main mechanisms behind Warm Pre-Stressing in assessment of nuclear components* | 2/3 | | | Sep/Oct |

a) Four reports were received from LUT in March. The reports will be included as appendices to a single main report for COPSAR.

## 2.1 COPSAR

*Containment Pressure Suppression Systems Analysis for Boiling Water Reactors*

**Research Area:** Thermal Hydraulics

**Summary**

Thermal hydraulics experiments on the behaviour of a safety relief sparger (SRV) and a containment spray system are carried out at the PPOOLEX facility at Lappeenranta University of Technology (LUT). The effectiveness of mixing a thermally stratified water pool due to injection through a sparger is studied. Modelling work is done at VTT Technical Research Centre of Finland Ltd (VTT) and at Kungliga Tekniska Högskolan (KTH).

**Activity leader:** Markku Puustinen, Lappeenranta University of Technology (LUT)
**Funded organizations:** LUT, VTT, KTH
**Funding:** 493 kDKK

**Status:** Partly delivered, final report expected in June 2018. Contributions have been received from LUT, see below.

### 2.1.1 Reported work from LUT

LUT has submitted four reports describing the experimental work that has been performed. These reports will be included as appendices to a main report that will be completed as soon as the contributions from KTH and VTT are available. The reports from LUT are summarized below.

a) **Report Title:** *PPOOLEX Spray Tests on Mixing Effects in Condensation Pool*

**Authors:** Lauri Pyy, Tatu Hovi, Markku Puustinen, Antti Räsänen, Eetu Kotro

**Abstract:** This report summarizes the results of the spray tests carried out in the PPOOLEX facility at LUT. The main purpose of the tests was to study mixing of a thermally stratified pool with the help of spray injection from above. An additional goal was to obtain data, particularly PIV measurement data, for improving simulation models related to spray operation in CFD and system codes as well as to contribute to the development of the EMS and EHS models by KTH.
The initial temperature difference between the bottom and the top layer of the pool before the initiation of spray injection varied from 29 °C to 32 °C.
First, the cold spray water penetrated the water surface causing mixing in the top layers. Then an internal circulation process took place in the pool at the elevation of the thermocline between the cold and warm water as the cold and therefore more dense sprayed water pushed its way downwards. Most of the pool water volume mixed during the tests as the downwards penetrating mixing process continued. However, the tests were terminated before complete mixing of the pool was achieved.
For the analysis of the PIV results, all the tests could be separated to three phases. In first phase, the movement of the particles is minor, the whole particle ensemble moves in unison, and there are indications that there is no mixing involved. In the second phase, the optical environment does not suit to PIV measurement at all. The last phase starts after the mixing has occurred in the PIV measurement area and the optical environment enables PIV to be executed to some extent in a normal manner by averaging velocity fields. However, the dynamical characteristics of the flow makes the analysis of the results difficult.

**Keywords:** condensation pool, spray, mixing
**Publication date:** Received in March, to be published as appendix to main report in June 2018.

b) **Report Title:** *Mixing Test in PPOOLEX with Sparger in Centre Position*

**Authors:** Markku Puustinen, Jani Laine, Antti Räsänen, Eetu Kotro, Kimmo Tielinen

**Abstract:** This report summarizes the results of the sparger pipe test (SPA-CT1) carried out in the PPOOLEX facility at LUT in 2017. The test facility is a closed stainless steel vessel divided into two compartments, drywell and wetwell. Steam was blown through the vertical DN65 sparger pipe to the condensation pool filled with sub-cooled water.

The main objective of the test was to study how the change of the sparger pipe position to the pool centre affects the stratification/erosion/mixing behaviour during steam discharge via the sparger pipe. Particularly, the effect on the elevation and thickness of the thermocline between the cold and warm water volumes and on the temperature profile of the pool were of interest. The SPA-T8R test done earlier with the sparger pipe away from the pool centre acted as a reference case. A secondary

goal was to obtain data for the development of the EMS and EHS models to be implemented in GOTHIC code by KTH.

The general behaviour during the stratification/erosion/mixing phases is almost identical in the new sparger test and in the earlier reference test. The initial uniform temperature profile first changes to a stratified situation and eventually back to an almost uniform and mixed situation at the end of the final mixing phase. During the erosion phase the thermocline moves slowly downwards and the thickness of the transition region seems to be almost the same in both tests.

The moving of the sparger pipe to the centre axis of the pool seems to have only a slight effect on the elevation of the thermocline as well as on the temperature profile in the pool.

**Keywords:** condensation pool, mixing, sparger
**Publication date:** Received in March, to be published as appendix to main report in June 2018.

c) **Report Title:** *General Description of SEF-POOL Test Rig*

**Authors:** Kimmo Tielinen, Antti Räsänen, Eetu Kotro, Ilkka Saure

**Abstract:** The SEF-POOL test facility has been designed together by KTH and LUT. It has been constructed by the Nuclear Engineering research group at LUT. The work has been part of the SAFIR2018/INSTAB and NKS/COPSAR projects.

The EHS and EMS models have been proposed by KTH for simulation of steam injection into a pool filled with sub-cooled water. The models have been implemented in the GOTHIC code and validated against the PPOOLEX experiments with blowdown pipes.

Now the concepts of the EHS and EMS models are being extended to SRV spargers and validation has been carried out against PANDA and PPOOLEX experiments done with a model of a SRV sparger. This validation effort has shown that the injection angle, total momentum, and momentum profile have a large effect on the pool behaviour. Uncertainty on these parameters exists and therefore the SEF-POOL separate effect test facility has been constructed at LUT in order to measure/define the effective momentum and reduce the uncertainty of the simulations.

This report provides a facility description of the SEF-POOL test rig. The report presents the basic requirements and design principles of the facility. The geometry and the main operational parameters as well as the installed instrumentation are introduced. The appendixes include figures to supplement the SEF-POOL geometry and instrumentation presented in the main text. The flexibility of the facility provides appropriate possibilities to extend the facility set-up according to the future research needs.

**Keywords:** sparger, condensation pool, effective momentum
**Publication date:** Received in March, to be published as appendix to main report in June 2018.

d) **Report Title:** *Characterizing Tests in SEF-POOL Facility*

**Authors:** Markku Puustinen, Jani Laine, Antti Räsänen, Eetu Kotro, Kimmo Tielinen

**Abstract:** The SEF-POOL test facility has been designed together by KTH and LUT. It has been constructed by the Nuclear Engineering research group at LUT and it will be used for the validation of the EHS and EMS models proposed by KTH for simulation of steam injection into a pool filled with sub-cooled water. The models have been validated against the PPOOLEX experiments with blowdown pipes and are now being extended to SRV spargers.

This report presents the key observations from the preliminary/characterizing tests conducted with the SEF POOL facility. Steam-to-water and water-to-water injections have been done. One test has been done with water injection into an empty pool. The main goal has been to test different options for the force measurement and to provide data for KTH for preliminary comparison of theoretical effective momentum with values calculated based on directly measured force.

The tests revealed that some modifications to the facility are needed. Most importantly, the arrangement for the direct force measurement was changed.

A quick analysis by KTH showed that the steam momentum can be roughly predicted by the theoretical estimate and the frequencies obtained with the fast pressure transducer correlate well with the correlations proposed in the literature. A strong temperature dependence, i.e. larger momentum as the pool temperature increases, was noticed.

Lower pressure inside the propulsion volume than the ambient pressure in the pool resulted to a lower force measurement than the true jet momentum. LUT and KTH will continue working on the design to solve this issue so that the actual tests to be used for the validation of the EMS model can be carried out in 2018.

**Keywords:** sparger, condensation pool, effective momentum
**Publication date:** Received in March, to be published as appendix to main report in June 2018.

## 2.2 FIREBAN

*Determination of fire barriers's reliability for fire risk assessment in NPP*

**Research Area:** Risk Analysis & Probabilistic Methods

**Summary**
The scope of the project is to investigate and assess the reliability of fire barriers in NPP during realistic fire scenarios to support the plant-scale risk assessment. The objective is to establish data and methods to determine the conditional probabilities for failure of fire barrier. Statistics, literature review, calculation and specific unique designed fire tests will be used as methods. The next steps in the process are the final definition of criteria for reliability and also further calculation supported by fire tests.

**Activity leader:** Patrick van Hees, Lund University
**Funded organizations:** LU, VTT, AAU, DBI, RAB
**Funding:** 393 kDKK

**Status:** Delay in the second-year report has occurred but the report is expected to be delivered by 1 July.

## 2.3 HYBRID

*Development of hybrid neutron transport methods and data visualization tools*

**Research Area**: Reactor Physics

**Summary**
The purpose of the present project in neutron transport modelling is to combine both probabilistic and deterministic approaches in order to obtain fast running methods (thanks to the deterministic route) and accurate results (thanks to the probabilistic route). The so-called response matrix method was the method investigated in the first phase of the project undertaken in 2016 with NKS support. This method was originally derived in the early seventies in a pure deterministic sense. In this project, the computation of the collision probabilities required for applying the method is carried out using a probabilistic solver instead.

The outcome is enhanced visualization tools. This requires the construction of an adequate data management system with visualization capabilities. In sum, the technology is supporting the efficient development of reactor core simulations, useable first for research purposes by Chalmers, and later by commercial companies.

In 2017, the project will involve 2 MSc students under the supervision of senior scientists, and make use of the complementary expertise from Chalmers University of Technology (deterministic neutron transport), the Technical Research Centre of Finland - VTT (probabilistic neutron transport), and the Institute for Energy Technology - IFE (visualization tools).

**Activity leader:** Christophe Demazière, Chalmers University of Technology
**Funded organizations:** Chalmers, IFE
**Funding:** 493 kDKK

**Status:** Delays - some reports are expected in the early fall of 2018. The activity will be completed in December 2018.

1) *The technical work at Chalmers and VTT is completed. The final report for their part of the project will be prepared and delivered to NKS in the early fall of 2018.*

2) *IFE has not been able to identify a suitable student for a Masters or Bachelors project. Alternatives to student participation are currently being considered involving resources from another project where relevant development work is being done. If knowledge from another project can be transferred to HYBRID, then IFE is confident that it will be able to submit a completed report by December 2018.*

**Summary of the situation concerning the development of a hybrid neutron transport solver (Chalmers and VTT)**

Work performed
*Since the last status report submitted on December 14th, 2017, the focus of the work was put on:*

- *Reducing the computational cost of the calculations of the probabilities in the hybrid method.*
- *Extending the methodology to systems containing more regions.*

- *Calculating the solution for a larger system (4 fuel assemblies of 17x17 PWR design) from Monte Carlo.*
- *Calculating the solution for a larger system (4 fuel assemblies 0f 17x17 PWR design) using the hybrid method.*

Achieved milestones

*Concerning the development of a hybrid neutron transport solver, the following milestones have been achieved as of May 30th, 2017:*

- *A revised procedure to estimate from Serpent the probabilities required in the response matrix method was developed. The goal of this revision was to lower the computational cost associated to the computation of the probabilities, so that larger system with more regions could be considered. More specifically, the probability for neutrons emitted from a fuel region to first interact in a fuel region was reduced, all other aspects being kept identical, from 30 min to 9 min. The procedure to estimate the probabilities when neutrons were emitted from the moderator was also improved.*
- *A larger system containing more regions and corresponding to 4 fuel assemblies of a 17x17 PWR design was developed. The emphasis for the choice of this system was to have more regions for each local problem in the matrix response, so that a larger system could be modelled for the global problem in the matrix response.*
- *Calculations with a pure Monte Carlo approach were completed.*
- *Calculations with the hybrid method were completed, either using in each local problem 1 fuel cell or 2x2 fuel cells.*
- *Comparisons between the hybrid and pure Monte Carlo solutions are being finalized.*

**Summary of the situation on data storage and visualization (IFE)**

*The work at IFE was to focus on comparisons of different database solutions. This was planned as a project by a Masters or Bachelors project with the Østfold University College or the University of Oslo. Unfortunately, a suitable student could not be found.*

*The proposed work on visualization has been put on hold so this work can be conducted in parallel, and that we can better ensure that the NKS project can be completed in its entirety, or terminated without cost to NKS.*

*These delays have put back the completion of this project.*

*Alternatives to student participation are currently being considered. IFE is conducting several database related projects with synergies to this HYBRID project. This includes the transfer of HRP operational and experimental data to new data platforms. Some of the development work for these projects will have direct relevance for the proposed HYBRID project. It's being investigated if knowledge gained in these projects can be transferred to the HYBRID project. If this is possible then IFE is confident that it will be able to meet its commitments to this NKS project and submit a completed report by December 2018.*

## 2.4 NORDEC

*Challenges and opportunities for improving Nordic nuclear decommissioning*

**Research Area**: Decommissioning incl. decommissioning waste

**Summary**
In this project a study is conducted on how decommissioning is regulated, planned and performed in the Nordic countries, identify where the main challenges lie, collect best practices and share experiences between the Nordic participants. The contributions for this project comes from regulators, operators and contractors, thus having a wide span of stakeholder involvement. The Norwegian Radiation Protection Authority (NRPA), Swedish Radiation Safety Authority (SSM), Danish Health Authority (SIS), Finnish Radiation and Nuclear Safety Authority (STUK), the energy companies Fortum and Vattenfall, the consulting firm ÅF of Sweden, VTT Technical Research Center of Finland, and Institute For Energy Technology (IFE) in Norway are participating in the project. The project involves collecting experiences from completed and ongoing decommissioning-related activities in Sweden, Finland, Denmark and Norway. The experiences' evaluation aims to identify possible improvements in processes, methods and tools. The project is fostering collaboration among Nordic stakeholders through sharing of challenges and best practices.

**Activity leader:** István Szőke, Institute for Energy Technology
**Funded organizations:** IFE, NRPA, SSM, STUK, SIS, VTT, Vattenfall AB, Fortum, ÅF
**Funding:** 524 kDKK

**Status:** Completed in February 2018.

### 2.4.1 Final report NKS-404

**Report Title:** *Challenges and opportunities for improving Nordic nuclear decommissioning*
**Authors:** Espen Nystad, Grete Rindahl, Claire Taylor, István Szöke, Sizarta Sarshar

**Abstract:** The overall goal of the NorDec project has been to explore challenges related to how decommissioning regulation is applied, and how projects are planned and performed in the Nordic countries, as well as collect best practices and share experiences between the Nordic stakeholders. The contributions for this project came from a wide range of stakeholders, including regulators, operators and contractors, and via the use of questionnaires, interviews and a workshop. The most frequently reported decommissioning challenges were: 1) Developing and maintaining competence and motivation; 2) Regulatory oversight and decision making; and 3) Safe and effective waste characterization and clearance. Workshop participants discussed around identified challenges and possible solutions enabling organisations to build up suitable competence for overcoming these issues. This report presents the results from the project.

**Keywords:** Decommissioning, regulation, challenges, lessons learned
**Publication date:** 2 Febr 2018
**ISBN** 978-87-7893-492-5

## 2.5 SC_AIM

*Safety culture assurance and improvement methods in complex projects*

**Research Area:** Organisational Issues and Safety Culture

**Summary**
The activity aims to increase understanding on how to improve nuclear safety culture in complex project settings (e.g. in the presence of multiple organizations interacting, diverse background of personnel, etc.). The practical goals of the projects are to identify and specify methods to improve and facilitate safety culture in complex projects and to identify and specify methods to assure safety culture in complex projects.

**Activity leader:** Kaupo Viitanen, VTT Technical Research Centre of Finland
**Funded organizations:** VTT, KTH
**Funding:** 279 kDKK

**Status:** Completed in February 2018.

### 2.5.1 Final report NKS-405

**Report Title:** *Safety Culture Assurance and Improvement Methods in Complex Projects – Final Report from the NKS-R SC_AIM*
**Authors:** Kaupo Viitanen, Nadezhda Gotcheva, Carl Rollenhagen, Teemu Reiman

**Abstract:** A good safety culture is an essential ingredient for ensuring nuclear safety. The predominant approaches for safety culture improvement are based on the assumption of stable and relatively homogeneous organizations, which often does not apply to contemporary project-oriented and turbulent environments. This research activity aims to provide guidance for methodical safety culture change in complex nuclear industry projects, and how to utilize existing safety culture tools or create new ones to support this effort. A set of twelve principles of safety culture change were developed that summarize the essential good practices of leading safety culture change. The principles are based on up-to-date practical experience and theories in the fields of systems thinking, organizational management and safety science. The principles are related to the generic characteristics of safety-critical project environments to illustrate their relevance in the context of complex projects. We propose that these principles are instrumental in leading safety culture activities in an informed manner, and to avoid mechanistic or superficial methods. Guidelines for the implementation of safety culture ambassadors were developed on the basis of the empirical work carried out in the Nordic nuclear power industry. Safety culture ambassadors group is novel method for safety culture improvement which aims to support the development of good safety culture by involving safety-conscious individuals from different parts of the company in safety culture activities. The guidelines can be utilized as a reference for practitioners in the nuclear power industry aiming to implement the method.

**Keywords:** Safety culture, safety culture improvement, project management, organizational change
**Publication date:** 02 Febr 2018
**ISBN** 978-87-7893-493-2

## 2.6 SPARC

*Scenarios and Phenomena Affecting Risk of Containment Failure and Release Characteristics*

**Research Area:** Severe Accidents

**Summary**
A robust severe accident management strategy is paramount for minimizing the environmental impact in the case of a severe accident involving melting of a reactor core. Both physical phenomena (deterministic) and accident scenarios (stochastic) are sources of uncertainties in the assessment of effectiveness of the accident mitigation. Adequate approaches are necessary in order to address both deterministic (epistemic) and stochastic (aleatory) sources of uncertainty in a consistent manner.

The goal of the project is to develop approaches and data for addressing the effects of scenarios and phenomena on the risk of containment failure and characteristics of release in case of a severe accident. There are 4 work packages that provide tightly coupled with each other activities.

**Activity leader:** Pavel Kudinov, Royal Institute of Technology (KTH)
**Funded organizations:** KTH, LRC, VTT
**Funding:** 524 kDKK

**Status:** Final report expected in June 2018. A report (NKS-408) has been published containing material that was not íncluded in the SPARC final report for 2016 (NKS-395) from last year.

### 2.6.1 Final report NKS-408 (From SPARC 2016)

**Report Title:** *Phenomena Threatening Containment Integrity and Evaluating Source Term Characteristics*
**Authors:** Veikko Taivassalo, Eveliina Takasuo, Magnus Strandberg, Tero Tyrväinen, Ilkka Karanta, Anna Nieminen

**Abstract:** To assess phenomena threatening the BWR containment integrity more reliably, long-term debris bed coolability and possibility of hydrogen explosions to occur were analysed deterministically. When comparing VTT's MEWA results on the debris bed post-dryout temperature to KTH's DECOSIM results, a good agreement was achieved while the temperatures continued to increase, but the stabilized temperatures differed notably. Hydrogen explosions are possible in the containment only if the inertion is lost. This is most probable during the shutdown or start-up. In addition, factors affecting source term characteristics, i.e. release temperature, altitude and probability were considered for different accident scenarios to further develop the methods and tools for PRA. Source term release height is usually the height of the location where the reactor building leaks or the height of the chimney if release is controlled. The temperature of release from containment is in most cases close to 100 oC but the temperature of radionuclides can potentially change during their migration in the reactor building.

**Keywords:** Debris bed coolability, MEWA, hydrogen explosions, MELCOR, source term, PRA, FinPSA
**Publication date:** 08 Jun 2018
**ISBN** 978-87-7893-497-0

## 2.7 WRANC

*Warm Pre-Stressing – Validation of the relevance of the main mechanisms behind Warm Pre-Stressing in assessment of nuclear components*

**Research Area:** Plant Life Management and Extension

**Summary**
The embrittlement of the RPV due to extended operation can lead to difficulties in demonstrating safe operation beyond 40 years when using traditional assessment methods. Therefore, utilizing the beneficial WPS (Warm Pre-Stressing) effect in assessments is an important possibility for demonstrating continued safe operation beyond 40 years of the RPV.

The WPS effect is the increase of the apparent brittle fracture toughness for a ferritic component when pre-loaded at a temperature in the ductile upper shelf region and then cooled to the brittle lower shelf region of the material fracture toughness transition curve. The WPS effect can be attributed to four main mechanisms. These mechanisms have different impact, depending on the pre-load level and load path. All the mechanisms are related to plastic straining at pre-load.

**Activity leader:** Tobias Bolinder, Inspecta Technology AB
**Funded organizations:** Inspecta, KTH, SINTEF
**Funding:** 393 kDKK

**Status:** Delays – Final report expected in September/October 2018. Awaiting final measurements from SINTEF.

# 3 Summary and status of activities initiated in 2018

Six activities were approved funding in CfP 2018. Four of these are continuing activities and two are new (SITRON and SYNTAGMA). BREDA-RPV started in 2016 but did not apply for funding in CfP 2017. All contracts were signed before the end of March.

An overview of the 2018 NKS-R activities is presented below in Table 2.

A request for status updates of ongoing activities were sent to the Activity Leaders on May 7. The status of all activities are summarized in the sections below.

**Table 2. NKS-R 2018 activities**

| Activity | Title | Leader | Partners | NKS number | Contract number | Total funding kDKK | Partner funding kDKK | Contract received |
|---|---|---|---|---|---|---|---|---|
| BREDA-RPV | Barsebäck RPV trepan studies | KTH | KTH | NKS_R_2016_118 | AFT/NKS-R(18)118/1 | 500 | 150 | 2018-02-21 |
| | | | VTT | | | | 250 | |
| | | | CTH | | | | 100 | |
| FIREBAN | Determination of fire barriers's reliability for fire risk assessment in NPP. | LU | LU | NKS_R_2016_119 | AFT/NKS-R(18)119/2 | 450 | 104,9 | 2018-02-13 |
| | | | VTT | | | | 104,9 | |
| | | | AAU | | | | 104,9 | |
| | | | DBI | | | | 104,9 | |
| | | | RAB | | | | 30,4 | |
| SITRON | SITe Risk Of Nuclear installations | Risk Pilot (Fi) | Risk Pilot | NKS_R_2018_125 | AFT/NKS-R(18)125/3 | 600 | 100 | 2018-02-02 |
| | | | LRC | | | | 100 | |
| | | | VTT | | | | 100 | |
| | | | IFE | | | | 300 | |
| SPARC | Scenarios and Phenomena Affecting Risk of Containment Failure and Release Characteristics | KTH | KTH | NKS_R_2016_122 | AFT/NKS-R(18)122/4 | 600 | 255 | 2018-03-28 |
| | | | VTT | | | | 224 | |
| | | | LRC | | | | 121 | |
| SYNTAGMA | Synthetic ground motions to support the Fennoscandian GMPEs | VTT | VTT | NKS_R_2018_126 | AFT/NKS-R(18)126/5 | 600 | 277 | 2018-02-14 |
| | | | UU | | | | 46 | |
| | | | GEUS | | | | 46 | |
| | | | CTH | | | | 231 | |
| NORDEC | Challenges and opportunities for improving Nordic nuclear decommissioning | IFE | IFE | NKS_R_2017_123 | AFT/NKS-R(18)123/6 | 250 | 175 | 2018-02-19 |
| | | | NRPA | | | | 6,25 | |
| | | | SSM | | | | 6,25 | |
| | | | STUK | | | | 6,25 | |
| | | | SIS | | | | 6,25 | |
| | | | VTT | | | | 12,5 | |
| | | | Vattenfall | | | | 12,5 | |
| | | | Fortum | | | | 12,5 | |
| | | | ÅF | | | | 12,5 | |

## 3.1 BREDA-RPV

*Barsebäck RPV trepan studies*

**Research Area:** Plant Life Management and Extension

**Summary**

Irradiation induced ageing of the weld material of the reactor pressure vessel (RPV) is a limiting factor from a long-term operation perspective. The closed Barsebäck 2 reactor gives an opportunity to harvest samples from the RPV, which was manufactured and welded with the same technique and high amounts of nickel and manganese as most Nordic RPVs. A test program to analyze the as-aged material properties has been prepared within the NKS-R activity BREDA-RPV.

In 2016 base line testing was performed at VTT on un-irradiated material retrieved from the original testing of the reactor pressure vessel. In addition, a feasibility study on harvesting of material from the reactor pressure vessel at Barsebäck was presented in the end of 2016 as a collaboration between the present project group and Ringhals AB, who will act as contact point for

the trepan extraction. The microstructural features of un-irradiated material was mapped for several specimens laying the foundation for continued studies on irradiated materials.

The activity in 2018 starts by studies of the mechanical properties of an accelerated surveillance capsule as well as material from a standard surveillance capsule from the RPV of Barsebäck 2. The main deliverable is a literature review on the feasibility to utilize specimens with high degree of constrain, i.e. very small test specimen, to study the effects of irradiation on the mechanical properties. This is a preparation for testing of material from the reactor pressure vessel itself, which will be available in the end of 2018. It further contains an enhanced microstructural evolution of RPV weld materials containing high levels of nickel and manganese to study the build-up of agglomerates that are in part responsible for irradiation hardening of these alloys. This study includes Light Optical, Scanning Electron, Transmission Electron and Atom Probe Microscopy at CTH and VTT. The issue is also relevant to the Finnish new-build project in Hanhikivi since the base metal in that RPV has a similar composition.

**Activity leader:** Pål Efsing, Royal Institute of Technology
**Funded organizations:** KTH, VTT, CTH
**Funding:** 500 kDKK

**Milestones**

| **Tasks, milestones and deliverables until 2018-12-31** | **Date** |
|---|---|
| Microstructural analysis of un-irradiated archive material using Transmission Electron Microscopy/TEM - VTT | 2018-09-30 |
| Literature review and coupled Finite Element Analysis on constraint effects on mechanical test samples and actual Reactor Pressure Vessels – VTT/KTH | 2018-11-30 |
| Microstructural study of low temperature heat treated material using Atom Probe Tomography/APT - CTH | 2018-11-30 |
| Summary report on mechanical testing on long term thermally aged material, fracture mechanical properties - KTH | 2018-10-31 |

**Status: Work progressing according to plan (May 30)**

*Material sampling from the reactor pressure vessel (RPV) of Barsebäck 2 has been conducted during the spring of 2018. Material was harvested from both the irradiated beltline region and from the RPV head, which has seen insignificant irradiation but relevant reactor temperature. Furthermore, a number of archive samples has been retrieved in order to allow for baseline testing. This tesing is going to be conducted as a separate work package by the Swedish Nuclear Power Plants as an in-kind contribution to the current NKS project. Surveillance specimens from the active program from Barsebäck 2 have been identified and will be transported to VTT for mechanical testing.*

*Since the material has not been avaible yet fror atom probe studies on active samples from Barsebäck, the work scope at Chalmers has been pushed into the fall for practical reasons.*

*Fracture mechanical testing of thermally aged surrogate material, similar weld material as used for the Barsebäck RPV harvested from a retired component from Ringhals, has shown that the effect of thermal ageing on the weld material used in the RPVs manufactured by Uddcomb, i.e. with high nickel and magnesium content, can be significant. At least for ageing temperatures at 345 °C, as is the case for the pressurizer of a pressurized water reactor (PWR) unit.*

*In this context, work has proceeded regarding the effect of constraint on mechanical properties. A draft version of the literature report is available for internal review and commenting, and plans are made to investigate the effect using Finite Element (FE) modelling tools.*

*The hardness test accompanied by post irradiation heat treatment, in order to isolate the effects that influence the irradiation induced hardening, has been postponed to the fall due to the commissioning of the new hot-cell laboratory at VTT in Finland.*

*The microstructure of unirradiated RPV material was characterized in 2017 using light optical microscopy and scanning electron microscopy (SEM). The characterization has been continued on irradiated weld metal in 2018 using field emission gun transmission electron microscopy (FEG-TEM) and SEM. The focus has been on secondary particles. Totally six slices were cut from the weld metal in one of the mechanical test specimens, and TEM-foils were prepared. The weld metal contains Al-Si-oxides with some Ca, Mn and Ti. The size is smaller than 1 μm. The weld metal contains even smaller Cr-Mo carbides. Both are typical for RPV weld metals. The average size of the round oxides was determined to be 240 nm, being between 40 and 992 nm, based on 60 particles using TEM. The size distribution was also determined using SEM. The average size was then 276 nm, being between 62 and 784 nm, based on 60 particles. The results can be explained through the higher resolution of TEM, resulting in a smaller average size, and larger area when using SEM. Further investigations are ongoing, and the results will be compiled in a report later in 2018. The results and gained insights will be used when characterizing the same material in irradiated condition in 2019.*

## 3.2 FIREBAN

*Determination of fire barriers' reliability for fire risk assessment in NPP.*

**Research Area:** Risk Analysis & Probabilistic Methods

**Summary**
The scope of the project is to investigate and assess the reliability of fire barriers in NPP during realistic fire scenarios to support the plant-scale risk assessment.
The objective is to establish data and methods to determine the conditional probabilities for failure of fire barrier. The Methods used will be statistics, literature review, calculation and specific unique designed fire tests.

The scientific merit of the activitiy will be the establishment of a link between exisiting data on fire barriers and and probablistic fire design in NPP. The technical merit of the project is the possiblity to allow users to better determine the overall probablity of loss of compartmentation between redundant systems in case of different fire scenarios.
This is an important risk analysis for nuclear power plants, as it has been shown that the loss of compartmentation has severe consequences for a safe reactor shut down process.

**Activity leader:** Patrick van Hees, Lund University
**Funded organizations:** LU, VTT, AAU, DBI, RAB
**Funding:** 450 kDKK

**Content of the project**
The project major core of activity is the development of methods for barrier failure assessment, divided into the following work packages:

**Work package 1: State-of-the-art for fire barrier reliability assessment**
The first work package will collect the state of the art on methods and experiences to determine the reliability of fire barriers. The result of this work package will be an overview of the need for possible further development and the requirements for additional data both as input data for the PSA models.

**Work package 2: Risk-based assessment of barrier performance**
In this work package, we will determine the relationship between the standard-fire based fire resistance classification and the failure risk under real fire conditions and real protection objectives.

**Work package 3: Reliability determination**
This work will contain four major routes of determination:

**Work package 4: Dissemination of results**
Results from the project will be reported in scientific journals and at conferences. A small workshop for interested parties will be organised at the end of project.The co-operation with other national projects, such as the SAFIR2018 programme in Finland, will also take place in this work package.

**Work package 5: Management**
For the management of the project, we include activities such as communication with partners, meeting organisation, economical follow up and progress follow up.

**Milestones**

| **Tasks, milestones and deliverables until 2018-12-31** | **Date** |
|---|---|
| Determination of reliability by different methods as input data for PSA (MS4)<br>Uncertainty propagation analysis from model/parameter uncertainty to risk estimate (MS5) | 2018-04-01 |
| Workshop for PRA Integration (D3) | 2018-11-01 |
| Final report | 2018-12-31 |

**Status: Work progressing according to plan (June 15)**

Update provided by Topi Sikanen, VTT:

- *Aalto continues the development of 3D heat transfer module in FDS with the aim of predicting the cold side temperature of Fire Barriers in large scale fire tests*
- *VTT works on modelling the behaviour of building products based on small scale tests.*

- *VTT disseminates results to utilities and authorities through the national SAFIR2018 programme.*
- *DBI, LTH and Ringhals are preparing fire resistance tests to validate the models developed at DBI, Aalto and LTH. One of the test set-up will also to contain a specific deficiency from a fire barrier in a nuclear power plant. Ringhals will provide this data.*
- *Test are scheduled after the summer.*
- *DBI and LTH continue cooperating in the development of models for predicting the fire resistance of fire barriers and publications were made.*

## 3.3 SITRON

*SITe Risk Of Nuclear installations*

**Research Area:** Risk Analysis & Probabilistic Methods

**Summary**
The importance of multi-unit Probabilistic Safety Assessment (PSA) has increased after the Fukushima Daiichi accident in March 2011. The major part of nuclear power sites house more than one nuclear power plant unit (NPP) and other nuclear facilities such as a spent fuel pool storage. Currently, multi-unit risks have not been accounted for adequately in risk assessments, but the multi-unit PSA is intensively discussed internationally.

The objective of the project is to search feasible approaches to assess the site level risk. This objective concerns with safety goals, risk criteria and PSA applications for a multi-unit site. Multi-unit risk assessment is not only limited to reactors but also other relevant sources for radioactive release such as spent fuel pools and storages. The second objective with the project is to develop methods to assess the risk for multi-unit scenarios. This objective concerns with analysis methods to consider the dependencies between the units. Pilot studies will be carried out to test and to demonstrate the proposed approach. The third objective is to develop applications for site risk analysis. In this respect, SITRON will study the role of Technical Support Centre (TSC) in multi-unit scenarios. The project will also follow the international development in this field.

**Activity leader:** Jan-Erik Holmberg, Risk Pilot Finland
**Funded organizations:** Risk Pilot (Fi), LRC, VTT, IFE
**Funding:** 600 kDKK

**Milestones**

| **Tasks, milestones and deliverables until 2018-12-31** | **Date** |
|---|---|
| Kick-off meeting for 2018 activities | 2018/02 |
| 2018 mid-term meeting | 2018/06 |
| Conference paper (ESREL) | 2018/06 |
| Conference paper (PSAM) | 2018/09 |
| Final seminar | 2018/11 |
| Working reports for each working package | 2018/12 |
| **Final report** | 2019/01 |

**Status: Work progressing according to plan (21 May)**

SITRON project status

| Task | Status |
|---|---|
| WP2: A work report on site level PSA methods | *Outline prepared* |
| WP3: A work report on guidelines for site level PSA model management | *Outline prepared* |
| WP4: Pilot studies are continued and finalized with emphasis on level 2 PSA scenarios | *Pilot studies initiated, outline of the pilot study report agreed* |
| WP5: Literature review on the assessment of the role of technical support centre | *Literature review initiated* |
| WP5: Questionnaire to utilities | *Questionnaire prepared and submitted to utilities* |
| WP6: Internal project meetings to coordinate WP activities | *Four Skype meetings organised* |
| WP6: Working meeting with stakeholders (Spring 2018) | *Organised April 12, 2018* |
| WP6: Progress reporting to the financiers | *Status reports (May 2018) submitted to SAFIR, Nordic PSA Group and NKS* |
| WP6: Presentation of the project achievements in international conferences | *Papers submitted to ESREL2018 (June 2018) and PSAM14 (September 2018). Abstract submitted to OECD/NEA WGRISK workshop (July 2018). All accepted.* |
| WP6: Organisation of a Nordic workshop on site level PSA | *Not initiated* |
| WP6: A summary report to be published in NKS report series | *Not initiated* |

Overall progress 30%

## 3.4 SPARC

*Scenarios and Phenomena Affecting Risk of Containment Failure and Release Characteristics*

**Research Area:** Severe Accidents

**Summary**
A robust severe accident management strategy is paramount for minimizing the environmental impact in the case of a severe accident involving melting of a reactor core. Both physical phenomena (deterministic) and accident scenarios (stochastic) are sources of uncertainties in the assessment of effectiveness of the accident mitigation. Adequate approaches are necessary in order to address both deterministic (epistemic) and stochastic (aleatory) sources of uncertainty in a consistent manner.

KTH, VTT and LRC have been active in addressing phenomenological and scenario uncertainties in severe accidents in the framework of national programs such as APRI-MSWI, SAFIR, NPSAG, NKS-DECOSE and NKS-DPSA, European FP7 and Horizon2020 projects SARNET, SAFEST, CESAM, IVMR and in direct collaboration with nuclear power utilities and regulators.

The goal of the project is to develop approaches and data for addressing the effects of scenarios and phenomena on the risk of containment failure and characteristics of release in case of a severe accident. There are 4 work packages that provide tightly coupled with each other activities;
WP1: Development and application of risk oriented accident analysis framework (ROAAM+) for prediction of conditional containment failure probability for a Nordic type BWR (KTH).
WP2: Development of the methods for coupling of Integrated Deterministic Probabilistic Safety Analysis tools such as ROAAM+ developed by KTH with PSA in general and PSA-L2 in particular (LRC).
WP3: Deterministic modelling of core degradation, melt relocation, vessel failure, debris spreading, coolability and threats for the containment integrity (VTT).
WP4: Analysis of the factors that affect the energy (temperature), altitude and probability of the release in PSA-L2 (VTT). The input is from KTH, LRC and VTT analysis in WP1, WP2 and WP3.

**Activity leader:** Weimin Ma, Royal Institute of Technology
**Funded organizations:** KTH, VTT, LRC
**Funding:** 600 kDKK

**Milestones**

| **Tasks, milestones and deliverables until 2018-12-31** | **Date** |
|---|---|
| 1) WP1 Report on experiments and modeling development for analysis of severe accident phenomena in Nordic BWR (KTH) | 31.01.2019 |
| 2) WP2 Report on development of demonstration case for integration of the data generated by integrated deterministic-probabilistic safety analysis into PSA (LRC) | 31.01.2019 |
| 3) WP3 Report on analysis of debris bed coolability (VTT) | 31.01.2019 |
| 4) WP4 Report on PSA-L2 analysis of important factors for severe accident phenomena and release characteristics (VTT) | 31.01.2019 |
| **Final report** | 31.01.2019 |

**Status: Work progressing according to plan (May 30)**

*The work plan of the SPARC activity has been fulfilled by around 50%, with involvement and contributions of many researchers at KTH, VTT and LRC, including young students and engineers. The research efforts will be enhanced and spreading to the entire activity space during next 6 months.*

More details about the progress of the SPARC 2018 activity is found in Appendix A.

## 3.5 SYNTAGMA

*Synthetic ground motions to support the Fennoscandian GMPEs*

**Research Area:** Risk Analysis & Probabilistic Methods

**Summary**
In recent years earthquake source modelling methods have been developed, partly in NKS projects, to substantiate the expected earthquake ground motion in the ranges where empirical observations are not available in Fennoscandia. These ranges are, at the higher end of observed magnitudes and higher (Mw>4.0) and at distances closer than those available from instrumental recordings (0<d<40km). These ranges are very important contributor to the hazard, with de-aggregation showing well above 50% of the seismic hazard contribution from this interval.

The benchmark model results obtained in the NKS project AddGROUND highlighted shortcomings of the currently used Fennoscandian ground motion models (GMPEs) in probabilistic seismic hazard assessment (PSHA), and triggered the need to update these GMPEs. The update is proposed to be carried out in the Finnish Research Programme on Nuclear Power Plant Safety (SAFIR 2018).

As a complementary activity to the GMPE update in the SAFIR program, we propose that in the NKS framework we use the previously developed modelling method (Fülöp et al, 2017) to generate larger data set of synthetic ground motions. This is the logical extension of the earlier work, resulting in a practically usable synthetic data set. The two proposed studies reinforce each other – the analysis of measurement data in the SAFIR project is extended by the synthetic data generated in the NKS project, which in turn is validated by the measurements.

In addition to the technical outcome, this project also aims to establish and maintain a network of experts focused on diffuse seismicity areas of the Nordic Countries and further enhance the cooperation between VTT and Uppsala University in the area of earthquake source modelling. The project outcomes will support STUK and SSM, providing background information for the safety assessments of nuclear plants. The activity proposed here would be paired with the EVOGY project in SAFIR 2018 and be supervised from within that Ad-Hoc group, with participation from STUK, SSM, TVO, FORTUM and FENNOVOIMA.

**Activity leader:** Ludovic Fülöp, VTT Technical Research Centre of Finland
**Funded organizations:** VTT, UU, GEUS, CTH
**Funding:** 600 kDKK

**Milestones**

| **Tasks, milestones and deliverables until 2018-12-31** | **Date** |
|---|---|
| M.1. Establishing of 20 fault rupture cases to be modelled (4.0<Mw<5.5) | 02.2018 |
| M.2. Fault modelling in 3DEC finished. Fault slips extracted | 05.2018 |
| M.3. Slip data transferred. COMPSYN models ready to run | 06.2018 |
| M.4. COMPSYN modelling finished. Ground motion extracted for points in the distance range 0<d<30km | 10.2018 |
| D.1. Data analysed. One paper drafted | 11.2018 |
| **Final report** | 12.2018 |

**Status: Work progressing according to plan (June 7)**

*From the start of the year 2018 Milestones 1 and 2 have been achieved in SYNTAGMA (bold underline in the table below). The preparation for creating the COMPSYN models is ongoing.*

| | Date |
|---|---|
| **M.1. Establishing of 20 fault rupture cases to be modelled (4.0<Mw<5.5)** | **02.2018** |
| **M.2. Fault modelling in 3DEC finished. Fault slips extracted** | **05.2018** |
| **M.3. Slip data transferred.** COMPSYN models ready to run | 06.2018 |
| M.4. COMPSYN modelling finished. Ground motion extracted for points in the distance range 0<d<30km | 10.2018 |
| D.1. Data analysed. One paper drafted | 11.2018 |
| **Final report** | 12.2018 |

*Based on considerations related to the prevailing fault typologies in Fennoscandia, it was decided that the earthquake scenarios in Table 1 will be considered. The range of magnitudes, hypocentre depths and stress drops were taken into account.*

***Table 1.*** *Targeted earthquake scenarios*

| Depth (km) | Moment magnitude | Mechanism* | Stress drop (MPa) | Number of scenarios |
|---|---|---|---|---|
| 2 | 4 | RF, OB | 10 | 3 |
| 10 | 4, 5, 5.5 | RF, OB, SS | 10 | 9 |
| 10 | 5.5 | RF, OB, SS | 50 | 3 |
| 20 | 5.5 | RF, OB, SS | 10, 50 | 6 |

* "RF" = Reverse Faulting, "OB" = Oblique Faulting, "SS" = Strike-Slip Faulting

*Fault-ruptures for these scenarios were modelled in 3DEC. The 3DEC modelling is based on instantaneous rupture of the faults, once a pre-existing stress-state is postulated on the fault plane. Hence, the model result is only partly controlled and the model outcome will not completely conform to the targeted values.*

*As a major update to earlier work, the stress state promoting rupture in any random direction (rake and dip angle) can now be introduced in 3DEC. This allows modelling of more realistic ruptures, adjusted to the observed fault plane solutions In Fennoscandia.*
*The outcomes of the fault rupture models from 3DEC are given in the Table 2.*

*The slip patterns on the entire rupture area were archived and are now being transferred to COMSYN for reaching Milestone 3. Hence, the project is on schedule.*

***Table 2.*** *Fault rupture parameters based on 3DEC outcome*

| Mechanism* | Moment magnitude ($M_w$) | Seismic moment | Average Stress drop (MPa) | Average slip (m) | Peal slip velocity (m/s) | Rupture area ($km^2$) | Dip | Rake |
|---|---|---|---|---|---|---|---|---|
| RF | 4.3 | $3.9 \cdot 10^{15}$ | 9.7 | 0.11 | 1.7 | 1 | 30 | 80 |
| SS | 4.3 | $4.0 \cdot 10^{15}$ | 9.9 | 0.11 | 1.7 | 1 | 80 | 9.9 |
| OB | 4.3 | $3.8 \cdot 10^{15}$ | 9.5 | 0.11 | 1.7 | 1 | 45 | 46 |
| RF | 5.0 | $3.5 \cdot 10^{16}$ | 10 | 0.24 | 2.7 | 4.0 | 30 | 80 |
| SS | 5.0 | $3.4 \cdot 10^{16}$ | 10 | 0.23 | 2.6 | 4.0 | 80 | 9.8 |
| OB | 5.0 | $3.4 \cdot 10^{16}$ | 10 | 0.23 | 2.7 | 4.0 | 45 | 45 |
| RF | 5.5 | $2.0 \cdot 10^{17}$ | 12 | 0.45 | 3.8 | 12.3 | 30 | 80 |
| SS | 5.4 | $1.8 \cdot 10^{17}$ | 11 | 0.41 | 3.5 | 12.3 | 80 | 9.8 |
| OB | 5.4 | $1.8 \cdot 10^{17}$ | 11 | 0.41 | 3.7 | 12.3 | 45 | 46 |
| RF | 5.6 | $3.0 \cdot 10^{17}$ | 50 | 1.3 | 14 | 6.3 | 30 | 80 |
| SS | 5.6 | $3.0 \cdot 10^{17}$ | 48 | 1.3 | 13 | 6.3 | 80 | 9.9 |
| OB | 5.6 | $2.9 \cdot 10^{17}$ | 50 | 1.3 | 14 | 6.3 | 45 | 46 |

* “RF” = Reverse Faulting, “OB” = Oblique Faulting, “SS” = Strike-Slip Faulting

## 3.6 NORDEC

*Challenges and opportunities for improving Nordic nuclear decommissioning*

**Research Area**: Decommissioning incl. decommissioning waste

**Summary**

Approaching large-scale nuclear decommissioning projects in the Nordic countries makes it important for both regulators and operators to build new capabilities for handling up-coming challenges. Sweden has the most urgent need for building up large-scale national capability for Nuclear Power Plant (NPP) decommissioning in order to respond to national decisions resulting in shutdown plans for seven units in the country. Finland is preparing detailed plans for removing the active containment of the Otaniemi research reactor. Experience from decommissioning of research reactors lies primarily with Denmark, but there is also some experience in Sweden and Norway. All countries can benefit from a more mature and integrated approach to decommissioning that utilizes more thorough planning to identify the future needs of the organisation and makes it possible to plan for the resources needed to handle upcoming challenges.

The results of the survey in the previous phase of the project clearly identified a general need for informal platforms where Nordic countries can exchange more practical experience and work more closely together. Due to closer physical and cultural proximity and some similarities in national framework among these countries, such a forum would further facilitate development of national capabilities for nuclear decommissioning in these countries. It would be very advantageous to be able to continue Nordic exchange and communication also after the project is finalised.

The key Nordic general decommissioning challenge areas that the project has found to be the most important are the following:

- Developing and maintaining competence and motivation
- Regulatory decision-making and oversight
- Safe and effective waste characterization and clearance
- Planning and management of site modification and dismantling
- Collaboration and information sharing between stakeholders
- Establishing common legislation and guidance

In 2018 work meetings and workshops will be held to discuss the Nordic decommissioning challenges. Opportunities and models for establishing a platform enhancing Nordic collaboration will be discussed and new concepts related to the challenges will be presented. An open workshop is planned in Lillehammer in December 2018.

**Activity leader:** István Szőke, Institute for Energy Technology
**Funded organizations:** IFE, NRPA, SSM, STUK, SIS, VTT, Vattenfall AB, Fortum, ÅF
**Funding:** 250 kDKK

**Milestones**
**Tasks, milestones and deliverables until 2018-12-31**

T1: Work meetings (discussions)
- Video/phone discussions will be held with the project partners around the main Nordic decommissioning challenge areas identified in 2017.
- Opportunities and models for establishing a platform enhancing Nordic collaboration within the main Nordic decommissioning challenge areas will also be discussed.

T2: Workshop preparation
- Presentations will be prepared by the project partners with focus on opportunities for enhancing collaboration within main Nordic decommissioning challenge areas.
- Demonstrations will be prepared by the project partners presenting new concepts related to the main Nordic decommissioning challenge areas and collaboration of Nordic countries.
- Administrative and technical preparatory work for the workshop will also be done within this task.

T3: Workshop
- An open workshop will be held with the project partners and invitees. The workshop is planned to be held as a mini-workshop immediately following a larger international workshop organised by the project coordinator (Lillehammer, December 6-7).

T4: Reporting
- A final report, mainly consisting of presented material and summaries from the workshop, will be prepared.

**Status: Work progressing according to plan (June 4)**

*Based on the current work progress there are no foreseen issues that might cause major deviations from the deliverables promised in the work plan.*

***Current progress***

*The proposal for this project has been accepted with a funding from NKS limited to 250 kDKK. As a result, the original work plan has been limited. In line with the specific message from the NKS board, the new work plan is primarily focusing on the workshop mentioned in the proposal for the NORDEC activity in 2018.*

*According to the new work plan we focused on preparations for an NKS workshop addressing the key topics related to high priority needs for improving decommissioning in the Nordic countries. In order to achieve a good coordination between the NKS workshop and other workshops planned for 2018 by the project coordinator with strongly related focus areas, we decided to co-host the NKS workshop with two other events. This will ensure a good participation of international experts, facilitating application of international experience to Nordic challenges.*

***Next steps***

- *Work meeting(s) (via video/phone/e-mail) will be held with the participants of the project in order to plan/coordinate presentations on the key Nordic aspects identified in the 2017 phase of the project.*
- *An NKS Workshop will be held in Lillehammer, December 6-7, 2018 co-hosted with an OECD Halden Reactor Project, and an international workshop on "Application of advanced plant information systems for nuclear decommissioning and life-cycle management". See below for more information.*
- *A final report will be produced summarising the outcomes of the Workshop in December.*

Invitation

# OECD-HRP/NKS workshop on Challenges and opportunities for improving nuclear decommissioning in HRP member and Nordic countries

**December 6-7, 2018**

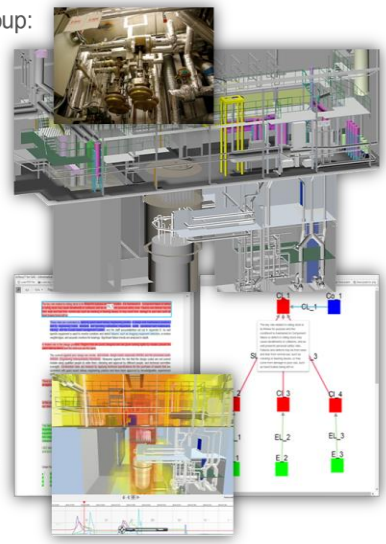
Hotel Scandic

**Lillehammer, Norway**

This workshop is organised within the OECD **H**alden **R**eactor **P**roject (www.ife.no/en/ife/halden/hrp/the-halden-reactor-project) and the Nordic Nuclear Safety Research Forum (www.nks.org/en/nksr/current_activities/nordec.htm). The workshop aims at bringing together a multidisciplinary group representing the professional community working on implementation and oversight of decommissioning for discussing opportunities and challenges for improving nuclear decommissioning in HRP member and Nordic countries. Special focus will be on bringing stakeholder organisations closer together through digitally enhanced innovative concepts. This workshop will also host the first meeting of a nuclear decommissioning advisory group to be launched by the OECD-HRP programme.

Examples for specific subjects to be addressed by the group:

- Collaborative development of guidance for practical application of regulation.
- Application of advanced information systems for demonstrating regulatory compliance.
- Joint development of case studies with digital support concepts.
- Establishing and testing digital experience based training methods.
- Joint development of e-Learning material for nuclear decommissioning.
- Interfacing big contractors with the regulators through digital safety demonstration methods.
- Collaborative testing of new decommissioning technologies using digital twins.



**3-5 December:** Within our series on "Digitalisation for nuclear decommissioning" an international workshop on **Application of advanced plant information systems for nuclear decommissioning and life-cycle management** will be held (www.ife.no/digidecom2018) at the same venue, providing the opportunity for interested participants to attend both events. (see also: www.ife.no/digidecom2019)

Organising committee: **digidecom@ife.no**

Chairman: I Szőke, Institute for Energy Technology, Norway

# 4 Overview of all NKS-R activities in 2010-2017

All activities started in 2016 and earlier have been finalised, see table below.

An activity is considered to be started at the time of the January board meeting, and ended when the final report has been delivered.

| Activity | NKS number | Started | Ended |
|---|---|---|---|
| Decom-sem | NKS_R_2010_83 | 01/2010 | 12/2010 |
| DIGREL | NKS_R_2010_86 | 01/2010 | 12/2010 |
| IACIP | NKS_R_2008_61 | 01/2010 | 12/2010 |
| INCOSE | NKS_R_2009_75 | 01/2010 | 05/2011 |
| MOSACA10 | NKS_R_2008_69 | 01/2010 | 01/2011 |
| NROI | NKS_R_2008_70 | 01/2010 | 04/2011 |
| POOL VTT | NKS_R_2007_58 | 01/2010 | 05/2011 |
| POOL KTH | NKS_R_2007_58 | 01/2010 | 06/2011 |
| POOL LUT | NKS_R_2007_58 | 01/2010 | 03/2011 |
| AIAS | NKS_R_2011_98 | 01/2011 | 12/2012 |
| DIGREL | NKS_R_2010_86 | 01/2011 | 01/2012 |
| ENPOOL | NKS_R_2011_90 | 01/2011 | 03/2012 |
| ENPOOL | NKS_R_2011_90 | 01/2011 | 05/2012 |
| ENPOOL | NKS_R_2011_90 | 01/2011 | 05/2012 |
| MoReMO | NKS_R_2011_95 | 01/2011 | 02/2012 |
| NOMAGE4 | NKS_R_2008_63 | 01/2011 | 11/2011 |
| POOLFIRE | NKS_R_2011_96 | 01/2011 | 02/2012 |
| SADE | NKS_R_2011_97 | 01/2011 | 03/2012 |
| RASTEP | NKS_R_2010_87 | 06/2011 | 09/2012 |
| AIAS | NKS_R_2011_98 | 01/2012 | 06/2013 |
| DECOSE | NKS_R_2012_100 | 01/2012 | 07/2013 |
| DIGREL | NKS_R_2010_86 | 01/2012 | 02/2013 |
| ENPOOL VTT | NKS_R_2011_90 | 01/2012 | 04/2013 |
| ENPOOL LUT | NKS_R_2011_90 | 01/2012 | 03/2013 |
| ENPOOL KTH | NKS_R_2011_90 | 01/2012 | 05/2013 |
| MoReMO | NKS_R_2011_95 | 01/2012 | 03/2013 |
| Nordic-Gen4 | NKS_R_2012_103 | 01/2012 | 11/2012 |
| POOLFIRE | NKS_R_2011_96 | 01/2012 | 02/2013 |
| RASTEP | NKS_R_2010_87 | 01/2012 | 10/2013 |
| SADE | NKS_R_2011_97 | 01/2012 | 03/2013 |
| Decom-sem | NKS_R_2013_106 | 01/2013 | 02/2014 |

| Activity | NKS number | Started | Ended |
|---|---|---|---|
| DECOSE | NKS_R_2012_100 | 01/2013 | 10/2014 |
| DIGREL | NKS_R_2010_86 | 01/2013 | 03/2014 |
| DPSA | NKS_R_2013_107 | 01/2013 | 07/2014 |
| ENPOOL | NKS_R_2011_90 | 01/2013 | 10/2014 |
| Exam HRA | NKS_R_2013_110 | 01/2013 | 03/2014 |
| HUMAX | NKS_R_2013_108 | 01/2013 | 02/2014 |
| L3PSA | NKS_R_2013_109 | 01/2013 | 03/2014 |
| POOLFIRE | NKS_R_2011_96 | 01/2013 | 12/2014 |
| SADE | NKS_R_2011_97 | 01/2013 | 02/2014 |
| ATR | NKS_R_2014_111 | 01/2014 | 06/2015 |
| DECOSE | NKS_R_2012_100 | 01/2014 | 07/2015 |
| DIGREL | NKS_R_2010_86 | 01/2014 | 02/2015 |
| DPSA | NKS_R_2013_107 | 01/2014 | 08/2015 |
| ENPOOL | NKS_R_2011_90 | 01/2014 | 07/2015 |
| HUMAX | NKS_R_2013_108 | 01/2014 | 01/2015 |
| L3PSA | NKS_R_2013_109 | 01/2014 | 04/2015 |
| Nordic-Gen4 | NKS_R_2012_103 | 01/2014 | 02/2015 |
| ProCom | NKS_R_2014_112 | 01/2014 | 03/2015 |
| ADdGROUND | NKS_R_2015_113 | 01/2015 | 04/2016 |
| ATR-2015 | NKS_R_2014_111 | 01/2015 | 06/2016 |
| COPSAR | NKS_R_2015_114 | 01/2015 | 08/2016 |
| DECOSE | NKS_R_2012_100 | 01/2015 | 10/2016 |
| L3PSA | NKS_R_2013_109 | 01/2015 | 11/2016 |
| LESUN | NKS_R_2015_115 | 01/2015 | 12/2015 |
| MODIG | NKS_R_2015_116 | 01/2015 | 03/2016 |
| PLANS | NKS_R_2015_117 | 01/2015 | 01/2016 |
| ADdGROUND | NKS_R_2015_113 | 01/2016 | 08/2017 |
| BREDA-RPV | NKS_R_2016_118 | 01/2016 | 03/2017 |
| COPSAR | NKS_R_2015_114 | 01/2016 | 08/2017 |
| FIREBAN | NKS_R_2016_119 | 01/2016 | 10/2017 |
| HYBRID | NKS_R_2016_120 | 01/2016 | 04/2017 |
| L3PSA | NKS_R_2013_109 | 01/2016 | 03/2017 |
| SC_AIM | NKS_R_2016_121 | 01/2016 | 01/2017 |
| SPARC | NKS_R_2016_122 | 01/2016 | 08/2017 |
| COPSAR | NKS_R_2015_114 | 01/2017 | ongoing |
| FIREBAN | NKS_R_2016_119 | 01/2017 | ongoing |
| HYBRID | NKS_R_2016_120 | 01/2017 | ongoing |

| Activity | NKS number | Started | Ended |
|---|---|---|---|
| NORDEC | NKS_R_2017_123 | 01/2017 | 02/2018 |
| SC_AIM | NKS_R_2016_121 | 01/2017 | 02/2018 |
| SPARC | NKS_R_2016_122 | 01/2017 | ongoing |
| WRANC | NKS_R_2017_124 | 01/2017 | ongoing |
| BREDA-RPV | NKS_R_2016_118 | 01/2018 | ongoing |
| FIREBAN | NKS_R_2016_119 | 01/2018 | ongoing |
| SPARC | NKS_R_2016_122 | 01/2018 | ongoing |
| NORDEC | NKS_R_2017_123 | 01/2018 | ongoing |
| SITRON | NKS_R_2018_125 | 01/2018 | ongoing |
| SYNTAGMA | NKS_R_2018_126 | 01/2018 | ongoing |

## Abbreviated organisations

| | | |
|---|---|---|
| AAU | Aalto University | Fi |
| CT | Clay Technology AB | Sw |
| CTH | Chalmers University of Technology | Sw |
| DBI | Danish Institute of Fire and Security Technology | Dk |
| DTU | Technical University of Denmark, Risö | Dk |
| FCR | Firma Carl Rollenhagen | Sw |
| FKA | Forsmarks Kraftgrupp AB | Sw |
| GEUS | Geological Survey of Denmark and Greenland | Dk |
| IFE | Institutt for Energiteknikk, OECD Halden | No |
| LC | Lilikoi Consulting (Teemu Reiman) | Fi |
| LRC | Lloyds Register Consulting | Sw |
| LU | Lund University | Sw |
| LUT | Lappeenranta University of Technology | Fi |
| NRPA | Norwegian Radiation Protection Authority (Statens strålevern) | No |
| NTNU | Norwegian University of Science and Technology | No |
| PWC | PricewaterhouseCoopers | No/Sw |
| RAB | Ringhals AB | Sw |
| SAFIR | The Finnish Research Programme on Nuclear Power Plant Safety | Fi |
| SEI | University of Helsinki, Institute of Seismology | Fi |
| SINTEF | Stiftelsen for industriell og teknisk forskning | No |
| SIS | Danish Health Authority, Denmark | Dk |
| SSM | Swedish Radiation Safety Authority | Sw |
| STUK | Finnish Radiation and Nuclear Safety Authority | Fi |
| UIO | University of Oslo | No |
| UU | Uppsala University | Sw |
| VTT | VTT Technical Research Center of Finland | Fi |
| VYR | State Nuclear Waste Management Fund | Fi |
| ÅFC | ÅF-Consult | Sw |