Nordic nuclear safety research

NKS-R STATUS REPORT

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NKS-R Programme Manager
May 2014

Table of contents

1 Status summary

This report provides a short overview of the current status of the NKS-R programme. Since the last NKS Board meeting in January, final reports for six of the NKS-R activities started in 2013 have been published on the NKS website. New submission dates for the four final reports that are missing have been approved. Contracts have been agreed and signed for all activities started in 2014. All activities initiated earlier than 2013 have been finally reported.

1.1 Seminars

Four NKS-R seminars will be held within the 2014 activities: Nordic-Gen4 seminar (4-5th of September in Lappeenranta), DIGREL seminar for end users (15th of January in Stockholm), L3PSA seminar (20th of January) and a workshop within the ProCom activity (15th of November at IFE Halden).

1.2 Young scientist travel support

Requests have been received. However, none has been eligible for support. Requests have been for participation in project work and for travels to international seminars outside the Nordic countries.

1.3 Published reports

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

NKS-299	February 2014	NKS-R Decommissioning Seminar 2013	Decom-sem
NKS-300	February 2014	The expected and experienced benefits of Human performance tools in nuclear power plant maintenance activities – Intermediate report of HUMAX project	HUMAX
NKS-301	February 2014	Improving design processes in the nuclear domain. Insights on organizational challenges from safety culture and resilience engineering perspectives	SADE
NKS-302	March 2014	Guidelines for reliability analysis of digital systems in PSA context – Phase 4 Status Report	DIGREL
NKS-303	March 2014	Addressing off-site consequence criteria using Level 3 PSA – Phase 1 Status Report	L3PSA
NKS-304	March 2014	Software reliability analysis for PSA	DIGREL
NKS-305	March 2014	Evaluation of Existing Applications and Guidance on Methods for HRA – EXAM-HRA Phase 3a Summary Report	EXAM-HRA

The reports listed above are all final reports for work done in 2013 within the respective activities. Most of the activities result in one joint final report. However, participants in some

of the activities prefer to submit separate final reports. In addition, some of the activities are divided into sub-activities which provide separate reports. E.g. the DIGREL activity produced two final reports for 2013 (one overall DIGREL report and one software reliability report). Project reports (overall DIGREL report and software reliability report) for the entire period of the activity will be published in 2015.

2 Activities initiated in 2013

Ten activities were initiated in 2013. Five of the activities were continuing activities and five were new. Four final reports are still missing. An overview of the status of 2013 NKS-R activities is presented in table 1.

Table 1. NKS-R 2013 activities

Activity	Description	First invoice	Report	Second invoice	Report number
Decom-sem	Decommissioning seminar 2013	x	x	x	NKS-299
DECOSE	Debris coolability and steam explosion	x	-	-	
DIGREL	Guidelines for reliability analysis of digital systems in PSA context	x	x	2/3	NKS-302 NKS-304
DPSA	Deterministic-probabilistic safety analysis methodology	x	-	-	
ENPOOL	Experimental and numerical studies on suppression pool issues	x	-	-	
Exam HRA	Evaluation of existing applications and guidance on methods for human reliability analysis (HRA)	x	x	x	NKS-305
HUMAX	Maximizing human performance in maintenance	x	x	2/3	NKS-300
L3PSA	Addressing off-site consequence criteria using Level 3 PSA	x	x	3/4	NKS-303
POOLFIRE	Predictive analysis of pool fires in enclosures by means of CFD models for risk assessment of nuclear power plants	x	-	-	
SADE	Safety culture in design – improving resilience throughout the life-cycle of nuclear power plants	x	x	x	NKS-301

3 Activities initiated in 2014

Nine activities were started in 2014. Seven of these are continuing activities and two are new. Contracts have been signed for all activities. In this chapter short descriptions are given for the activities. For more detailed status reports see attachments.

3.1 ATR

Impact of Aerosols on the Transport of Ruthenium in the primary circuit of nuclear power plant.

Previous experiments have shown that the fraction of gaseous ruthenium transported through the primary circuit of an experimental setup at VTT was higher than what would be expected in thermodynamic equilibrium calculations. Focus of the ATR project is to study the impact of aerosols on the transport of ruthenium in the containment air of a BWR. Some of the most radiotoxic elements that may be released from the fuel into the containment's atmosphere during a severe accident are iodine and ruthenium. In 2014, the impact of aerosols on the transport of ruthenium, especially gaseous Ru species, will be studied in primary circuit conditions. Different aerosol species (e.g. Ag, CsI and RuO2), will be injected to the gas flow together with the volatilized RuO4. Thereafter the impact on the transport of ruthenium will be studied. A better understanding of the containment atmosphere composition during a severe accident will lead to improved strategies for reducing the risk of ruthenium release to the environment.

Activity leader: Christian Ekberg, Chalmers

NKS-R funding: 300 kDKK

Milestones:

1) Experimental facility ready by the end of April
2) Experiments/tests done at VTT by the end of June
3) Experiments/tests done at Chalmers by the end of September/October
4) Analysis of samples ready by the end of November/December

Status

The construction of the experimental facility is ready. The testing of the facility is ongoing and the experimental work will be initiated during the last part of May. There are no deviations to the original plan.

3.2 DECOSE

Debris coolability and steam explosion

Uncertainties in assessment of (i) debris bed properties and coolability, (ii) steam explosion impact in BWRs will be reduced by experimental and analytical studies. The experimental part of the project will investigate key physical phenomena of the debris bed formation and coolability. Experimental data will be validated using simulation tools, leading to more reliable predictions of the debris bed coolability in case of an accident with a severe core damage. An analytical approach will be utilized to improve the prediction of coolability and to assess the uncertainties in modelling of steam explosion impact. The project is almost half way and is scheduled for another three years.

Activity leader: Pavel Kudinov, Kungliga Tekniska Högskolan

NKS-R funding: 500 kDKK

Deliverables:

1) Report on COOLOCE experiments and coolability analysis and simulations carried out by VTT
2) Report on experimental and analytical work carried out by KTH on debris bed formation and coolability
3) Report on analysis of steam explosion in Nordic type BWRs by KTH and VTT

Status

There are no major deviations between plans and results except for:

- VTT Task 8 (Analysis of steam explosion in a BWR containment) is a bit delayed due to change of the personnel. VTT has now recruited a diploma thesis worker who is learning to use the FCI codes and will continue with the task. A research visit with KTH scientists is possible. Final report is expected to be submitted at the end of May 2014.

3.3 DIGREL

Guidelines for reliability analysis of digital systems in PSA context

Practical guidelines for analysis and modelling of digital systems in probabilistic safety assessment (PSA) for nuclear power plants are developed within the DIGREL activity. The activity comprises three interrelated activities. Firstly, a taxonomy for failure modes of digital I&C systems has been developed by a task group of OECD/NEA Working Group RISK. Secondly, in a parallel Nordic activity, a fictive digital I&C PSA-model has been developed for the demonstration and testing of reliability modelling approaches. The third activity has been to develop a method for the quantification of software reliability in the context of PSA. The interim results of the project have been published annually in NKS report series (NKS-230, NKS-261, NKS-277, NKS-302 and NKS-304). In 2014, the three activities will be finalized and a guidelines report will be prepared for the nuclear industry.

Activity leader: Jan-Erik Holmberg, RiskPilot

NKS-R funding: 300 kDKK

Tasks, milestones and deliverables

Start	**1.1.2014**
T + 3 M	WGRISK/DIGREL task group meeting, finalisation of the failure modes taxonomy report
T + 6 M	PSAM12 conference paper presentations
T + 10 M	Final draft of the NKS report and (covering all activities 2010–14)
T + 12 M	DIGREL seminar (15th January 2015)
T + 13 M	NKS final report on guidelines of reliability analysis of digital I&C systems in PRA

Status

There are no deviation to the original plan. The task group meeting was held in Paris March 3-4 and a final draft of the WGRISK report has been prepared. The overall progress of the activity is 20 %.

3.4 DPSA

Deterministic-probabilistic safety analysis methodology
The goals of the project are (i) to develop DPSA modelling approaches for scenarios where timing of the events, including PSA Level 1 and recovery actions, has significant effect on the results, and (ii) to develop methods for improving PSA and DSA using DPSA generated data. The project started one year ago and is scheduled to run for another four years.

Activity leader: Pavel Kudinov, KTH

NKS-R funding: 400 kDKK

Tasks:

1) To develop further the methodology for application of IDPSA with PSA/DSA to the Nordic nuclear energy industry and regulatory needs;
2) To address further in-depth following issues of risk importance for different severe accident scenarios.
    a. Relocation of the core melt to the lower plenum, as initial conditions for the melt-vessel structure interactions, melt release and ex-vessel steam explosion and debris bed coolability in Nordic BWRs;
    b. The influence of timing in PSA level 1 sequences and possible recovery actions on the amount and properties of the melt in the lower head;
3) To suggest improved approaches to modelling of steam explosion and coolability risks in PSA, considering information provided from IDPSA analysis.

Status
There are no major deviations between plans and results.

3.5 ENPOOL

Experimental and numerical studies on suppression pool issues
Steam injections into the pressure suppression pool of a boiling water reactor and their effects are studied within this project. Short term dynamic phenomena may cause pressure loads on pool structures and long term thermal transients following the steam injection may influence the pool's pressure suppression capacity, which is why this is an important area of research. Experiments and numerical analyses of steam injections through blowdown pipes into the suppression pool are carried out and the main objective is to develop computational models which can be used to simulate the effects of steam injection. In 2013, the experiments concentrated on the dynamics of the free water surface in a blowdown pipe to provide data on mixing of a thermally stratified pressure suppression pool and on direct contact condensation. The experiments carried out with the test facility provide a representative database for numerical studies and modeling, which are carried out under the ENPOOL activity. This activity started in 2011 and continues in 2014.

Activity leader: Timo Pättikangas, VTT

NKS-R funding: 651 kDKK

Deliverables of VTT:

1) CFD calculations of blowdown with model of a sector of BWR containment

2) FEM calculations of chugging loads in BWR containment
3) Summary report on the CFD and FEM methods developed in the project

Deliverables of KTH:

1) Further development of the Effective Heat Source and Effective Momentum Source models
2) Validation of the models against latest available PPOLEX data
3) Pre- and post-test simulations of the new series PPOOLEX tests
4) Report on development, implementation, and validation of the Effective Heat Source (EHS) and Effective Momentum Source (EMS) models for prediction of thermal stratification and mixing in the pressure suppression pool

Deliverables of LUT:

1) Execution of the experiment series with a sparger
2) Reporting of the sparger experiments
3) Execution of the experiment series on DCC
4) Reporting of the DCC experiments
5) Delivery of relevant experiment data to the simulation partners

Status
The beginning of the test series at LUT is delayed by two months due to the problems with the PIV system. Resource problems have delayed the progress of the project at VTT. “Situation improves in June, when one member of the project team returns from leave of absence.”

3.6 HUMAX

Maximizing human performance in maintenance
Maintenance is a key safety function in any complex sociotechnical system, such as a nuclear power plant. The aim of the activity is to enhance understanding on how to maximize human performance in maintenance activities of nuclear power plants. In 2013, the use of specific tools, or lack thereof, has been analysed for three Nordic nuclear power plants (NKS-300). Interviews have been made with maintenance workers and those responsible for developing human performance programs on their opinions on the human performance tools. The project will be finalized in 2014 and the aim is to provide recommendations on how to design and implement effective human performance tools.

Activity leader: Maren H. Rø Eitrheim, IFE

NKS-R funding: 500 kDKK

Tasks and milestones:

Tasks	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Planning activities in 2014											
Conclude data analysis of the case studies at Nordic NPPs and draft 1-2 scientific papers											
Suggest what activities HPTs may best support vis-à-vis other socio-technical solutions											
Develop recommendations on how to design and implement effective HPTs											
Disseminate findings: Continuous dialogues with the power companies											
Final report											

Status
Overall, the project progresses according to plan. Analyses of data obtained in the three case studies at Nordic plants (TVO, Loviisa and Ringhals) are in their final phases. Data collection in the international survey has been completed, and data analysis is currently ongoing. Project coordination is carried out using regular video-meetings, where ongoing research activities are discussed.

3.7 L3PSA

Addressing off-site consequence criteria using level 3 PSA
The aim is to deepen the Nordic understanding about the merits and limitations of probabilistic off-site consequence analysis for nuclear facilities. The project began in 2013, and is in its second year of a planned three years. The project's first year focused on the development and analysis of an industrial survey about Level 3 PSA, which included several workshops and meetings with Nordic utilities, regulators, and safety experts. Level 3 PSA risk metrics including health, environmental, and economic effects have been researched and discussed in the first year's project report (NKS-303). The project has generated significant interest internationally and has interfaced with international organizations including the IAEA and the American Nuclear Society. The ultimate goal of the project is to produce a guidance document for Level 3 PSA in Nordic countries.

Activity leader: Andrew Wallin-Caldwell, LRT

NKS-R funding: 300 kDKK

Tasks and milestones:

1) Final report of appropriate risk metrics and regulation, guides and standards
2) Detailed project plan for a pilot application including tools for dispersion and consequence analysis
3) Outline of the guidance document
4) Seminar in January 2015

Status
"The project is proceeding as planned in the project plan that was developed during 2013. It must be noted that the budget for the project is limited. Thus far, the working group, stakeholders, and parties interested in the project have been quite enthusiastic and ambitious in what can be accomplished under the Task 3 guidance document and the Task 4 pilot project. It is important to be mindful of the resources and scope of the project, and continue to be mindful of scope creep and analysis limitation throughout the duration of the project."

3.8 Nordic-Gen4

Nordic nuclear forum for generation IV reactors
The objective of this forum is to promote communication and interaction between Nordic researchers in the generation IV reactor area. The network has existed since 2009. Originally the focus was on material issues, but now the scope is wider. The main activity has been to organise seminars with participants from academia (senior researchers and students) and industry. A two-day seminar will take place in Lappeenranta 14-15th September 2014, where both invited speakers from Europe and PhD-students will have a chance to present and discuss their research. Other activities of the network include smaller meetings, students visits as well as maintaining the website http://nordic-gen4.org/.

Activity leader: Mattias Thuvander, Chalmers

NKS-R funding: 200 kDKK

Tasks and milestones:
1) Organize a two-day conference 14-15th September in Lappeenranta
2) Update and extend the Nordic Gen-IV web page
3) Other networking activities, including meetings between VTT, IFE, Chalmers and DTU

Status
The work is proceeding in accordance with the plan.

3.9 ProCom

Measuring procedure competence
Exstensive research has been performed by different organisations to identify the functions that enable reliable and resilient procedures. Measuring these functions reliably presents its own set of challenges. These are mainly (i) identifying reliable markers for each competence and (ii) developing guidance so that observers can reliably assess the crew's degree of proficiency on each competence. Institute for Energy Technology, IFE, in Halden has acsess to a huge amount of data from simulator studies of complex emergency scenarios, that can be used for identifying procedure competence. The activity is a one year project ending in december 2014.

Activity leader: Michael Hildebrandt, IFE

NKS-R funding: 600 kDKK

Tasks, milestones and deliverables:

	Date
T1: Identification of behaviours that indicate procedure competences (all)	01/05/2014
T2: Pilot test of method (lead: IFE & KSU)	01/08/2014
T3: Review of the method (lead: VTT)	15/09/2014
T4: Development of a video illustrating procedure following problems and strategies (lead: IFE)[1]	15/09/2014
T5: Summary of lessons learned on the use of eye tracking for studying procedure use (lead: IFE)	15/09/2014
M1: Development of handbook completed (lead: IFE)	01/10/2014
M2: Draft report (lead: IFE)	01/11/2014
Workshop (all)	15/11/2014
T6: Review of report (lead: Ålesund)	01/12/2014
D1: Final report	31/12/2014
D2: Procedure use video	31/12/2014

Status
The project is progressing as planned, and according to the time schedule indicated in the NKS contract.

4 Overview of all NKS-R activities 2010-2013

It is seen from the table below that all activities started in 2012 and earlier have been finalised. An activity is considered to be started at 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
DECOSE	NKS_R_2012_100	01/2013	unfinished
DIGREL	NKS_R_2010_86	01/2013	03/2014
DPSA	NKS_R_2013_107	01/2013	unfinished
ENPOOL	NKS_R_2011_90	01/2013	unfinished
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	unfinished
SADE	NKS_R_2011_97	01/2013	02/2014

Attachments

A1. Status report ATR

Status report NKS ATR2, Contract no AFT/NKS-R(14)111/1

The construction of the experimental facility is ready. It is mainly similar to the set-up which was used in the previous experiments at VTT (T. Kärkelä et al. "Experiments on the behavior of ruthenium in air ingress accidents – final report", VTT-R-01252-07 (2007)). It includes an inlet section with mass flow controllers to adjust the carrier gas (air) flow rate accurately. The air flow is directed to the high temperature tubular flow furnace (alumina tube) and the source of ruthenium as RuO_2 powder is located there. The ruthenium source is heated to 1000 °C – 1500 °C in an oxidizing airflow (5 l/min) and the formation of gaseous ruthenium oxides takes place. Downstream the furnace, the reaction products are cooled down in a stainless steel tube. Aerosol particles are collected on a plane filter and gaseous ruthenium is trapped with a NaOH solution.

As a significant difference to the previous set-up, an atomizer has been added to the inlet of the facility in order to produce various seed particles. One of the main objectives of this work is to study the effect of seed particles on the transport of gaseous ruthenium.

For the online monitoring of aerosol products, the facility is equipped with Electrical Low Pressure Impactor (ELPI), Scanning Mobility Particle Sizer (SMPS), Condensation Particle Counter (CPC) and Tapered Element Oscillating Microbalance (TEOM) devices. Thus information on the particle number size distribution, particle number concentration and particle mass concentration will be gathered. Samples of particles in a gas phase will be collected with a vacuum aspiration sampler on microscope grids for the further analysis on particle morphology and elemental composition.

Gaseous and aerosol samples will be analysed with several techniques, e.g. ICP-MS, INAA, Raman, XPS, SEM-EDX, TEM-SAED.

The testing of the facility is ongoing and the experimental work will be initiated during the last part of May.

A2. Status report DECOSE

STATUS REPORT OF DECOSE-NKS PROJECT IN 2014
May 06, 2014

Work at Royal Institute of Technology (KTH), Division of Nuclear Power Safety
DECOSE-NKS and APRI-8

Pavel Kudinov, Sergey Yakush, Simone Basso, Dmitry Grishchenko, Alexander Konovalenko, Sachin Thakre, Weimin Ma, Aram Karbojian.

1. Joint analytical activity on debris bed coolability which will include: code–to–code comparison, development of recommendations and best practice guidelines for simulations, defining reference cases for coolability analysis in plant accident conditions, post-test analysis and code validation against COOLOCE data and pre-test analysis to determine conditions for the future COOLOCE experiments (Tasks 7).
Validation of the DECOSIM code against existing COOLOCE data is ongoing. The tests with cylindrical (with impermeable walls), conical debris beds, and cylindrical debris bed with permeable walls, conical bed on a cylindrical base are under consideration. Code performance (convergence, time step limitations) has been improved significantly. Validation to be continued as new data will become available from COOLOCE, POMECO-HT and POMECO-FL facilities.
Definition of reference cases for coolability analysis in plant accident conditions is ongoing. Code–to–code comparison for the selected cases and development of recommendations and best practice guidelines for simulations is planned.
A set of surrogate models for computationally efficient prediction of the onset of debris bed dryout and post-dryout debris bed coolability are under development.

2. Investigation of particulate debris spreading, PDS-C tests and pre-test analysis to determine COOLOCE test conditions and procedure, PDS-P (pool) tests on particulate debris spreading in a pool (Task 4).
Experiments in PDS-C (Particulate Debris Spreading – Closures) facility with different types of particles (stainless steel cylinders, spheres, their mixtures, gravel, and zirconia-silica beads) have been carried out and the post-processing of new data is ongoing. A scaling approach has been developed for characterizing empirical closures for the particulate debris flux in non-dimensional variables. A model for prediction of particulate debris spreading based on the proposed scaling approach has been developed. The model is used for pre-test analysis of COOLOCE experiment with particulate debris spreading and further analysis of prototypic severe accident scenarios with uncertainty quantification. PDS-P facility is under preparation for the set of new tests with different particles and gas injection flow rates.

3. Investigation of the effect of the particle size on the DHF in POMECO-HT and POMECO-FL (Task 1d).
Investigation of the effect of particle size and morphology on the DHF is ongoing.

4. DEFOR-A series of tests with corium simulant material on debris bed formation (Task 2).
DEFOR-A tests and post-test analysis with corium melt simulant materials are ongoing. High temperature melt release through a plate with lower melting temperature material immersed under water is investigated in order to assess ablation of the hole. Both axial and radial ablation are investigated in the tests. A surrogate model for prediction of the debris agglomeration mass fraction is under development.

5. Application of MC3D and TEXAS-V to analysis of steam explosion in a BWR containment (Task 8).
The steam explosion calculations in the flooded drywell of Nordic BWR have been carried out using MC3D and TEXAS-V codes. The sensitivity study to the scenario and modeling parameters have been carried out for melt jet diameter, jet velocity, triggering time, material properties, fragmentation model,

mesh size, system pressure, etc. Morris diagrams was used to characterize sensitivity of the explosion impulse to the input parameters for TEXAS code. Some values for the reference input are selected based on MC3D calculations: specifically cell diameters in 1D TEXAS model are chosen to be representative of the premixing region predicted in MC3D calculations. A surrogate model for prediction of the explosion impulse is under development to be used in comprehensive uncertainty/sensitivity analysis.

6. Reporting of the POMECO-FL, POMECO-HT and PDS experiments and code development results.
Final report for 2013 is under development.
Reporting for 2014 has not been started yet.

7. Delivery of relevant experimental data to the simulation partners.
Not started yet.

Work at VTT
DECOSE-NKS and SAFIR2014:

Eveliina Takasuo, Veikko Taivassalo, Mikko Ilvonen, Ville Hovi, Tuomo Kinnunen, Stefan Holmström, Anna Nieminen, Ilona Lindholm

1. COOLOCE experiment with a representative geometry: truncated cone (Task 1.a.)
The COOLOCE test facility has been modified and prepared for the experiment with truncated cone, e.g. new heaters have been installed. The experiment is scheduled in the end of May.

2. Development of the test procedure for COOLOCE test on particulate debris spreading (Task 4).
No activities yet.

3. Pre- and post-test analyses of the truncated cone geometry using MEWA and the CFD approach (Task 7).
The pre-test simulations for the truncated cone using MEWA have been completed. The post-test simulations will be conducted after the experiment.

4. Modelling of the key debris bed geometries using the CFD approach as part of post-test analyses and code validation (Task 7).
A new version of the MEWA code has been distributed to VTT by Stuttgart University. Simulations of conical and cylindrical test beds as well as some simple drag force tests have been conducted using the new code version, and comparisons to the previous version have been made. In addition, a literature study concerning the possibility to improve the drag force models in the case of multi-dimensional flooding is on-going.

5. Joint analytical activity on debris bed coolability including: code–to–code comparison, development of recommendations and best practice guidelines for simulations, defining reference cases for coolability analysis in plant accident conditions (Task 7).
The modeling work comprises of the pre- and post-test simulations of the experiments with different test bed geometries and flow modes and the development of the full-3D CFD approach to the problem. MEWA post-test simulations have been completed for the following debris bed geometries: cylindrical with open top and sidewall, cylinder with cake simulant and the cone on a cylindrical base. The results of the 2D and 3D simulations have been presented in a SAFIR2014 report which will be submitted as a deliverable of 2013. A short researcher visit from VTT to KTH is being planned.

6. Application of MC3D and TEXAS-V to analysis of steam explosion in a BWR containment (Task 8).
A new diploma thesis worker has started working on the task using MC3D.

7. Reporting of the COOLOCE experiments.
The reporting of the experiment with a truncated cone will be done after the experiment. The reporting of the previous experiments is completed within SAFIR2014 and the report will be submitted as a deliverable of 2013.

8. Delivery of relevant experimental data to the simulation partners.
No activities yet.

Overall Project Summary

Comparison between plans and results with explanation of any deviations:
There are no major deviations between plans and results except for:

- VTT Task 8 (Analysis of steam explosion in a BWR containment) is a bit delayed due to change of the personnel. VTT has now recruited a diploma thesis worker who is learning to use the FCI codes and will continue with the task. A research visit with KTH scientists is possible.

Expected submit date of the final report

- Expected date for submitting the report for 2013 is end of May 2014.

Any issues you would like the board to know

- No issues with the project.

A3. Status report DIGREL

22-002 / DIGREL – Reliability analysis of digital systems in PSA context

Status May 2014/Jan-Erik Holmberg, Risk Pilot AB

Task	Status
WGRISK activity (task group) focusing on the development of best practice guidelines on failure modes taxonomy for reliability assessment of digital I&C systems for PSA	Task Group meeting in Paris March 3–4, 2014. Status reported to OECD/NEA WGRISK Paris March 4, 2014. Final draft of the report prepared. Paper prepared to PSAM12 conference. Progress 90%
Development of the generic digital I&C system example and associated demonstration PSA-model	Working meeting in Stockholm April 25, 2014. Detailed working plan made for 2014 tasks. Progress 15%
Finnish-Swedish-German collaboration specifically on software modelling and quantification	Phone meeting organised April 4, 2014. Detailed working plan made for 2014 tasks. Paper prepared to PSAM12 conference. Progress 15%
Nordic end user workshop	NKS/DIGREL seminar will be organised on January 15, 2015 in Stockholm. Progress 5%
Final reports (public NKS report) - overall DIGREL report - software reliability report	Outlines of the reports prepared. Final versions will be ready in January 2015 Progress 20%

No deviation to the original plan

Overall progress 20%

A4. Status report DPSA

STATUS REPORT OF NKS-DPSA PROJECT IN 2014
May 06, 2014

Work at Royal Institute of Technology (KTH)
Pavel Kudinov, Viet-Anh Phung, Sergey Galushin, Kaspar Kööp, Yuri Vorobyev.

Task 1. To develop further the methodology for application of IDPSA with PSA/DSA to the Nordic nuclear energy industry and regulatory needs.
Status: Development of approaches to identification and characterization of failure domains using Integrated DPSA (IDPSA) data is ongoing. Development of conceptual approaches for establishing connections between PSA-L2 and failure domains which can be identified with IDPSA for the debris bed coolability and steam explosion issues is ongoing in collaboration with LRC.
Task completion: 15 %

Task 2. To address further in-depth following issues of risk importance for different severe accident scenarios: 2.1. Relocation of the core melt to the lower plenum, as initial conditions for the melt-vessel structure interactions, melt release and ex-vessel steam explosion and debris bed coolability in Nordic BWRs; 2.2. The influence of timing in PSA level 1 sequences and possible recovery actions on the amount and properties of the melt in the lower head.
Status: PSA-L1 scenarios have been grouped according to different vessel failure sequences (early/late, high/low pressure). Identification and analysis of scenarios in Nordic type BWR severe accidents sensitive to timing of events for (i) in-vessel stage, (ii) vessel failure modes, and (iii) ex-vessel accident progression analysis is ongoing. Analysis of the influence of failure and recovery timing of ADS, ECCS, Auxiliary Feedwater, and residual heat removal systems on core relocation sequences is ongoing. MELCOR code coupled to GA-IDPSA with scenario classification and clustering approach is used in the analysis in order to establish connections between timing in scenarios and configurations of the debris in the Reactor Pressure Vessel lover head. These configurations provide input for analysis of further accident progression, vessel failure and melt release modes. Clarification of the cliff-edge effect obtained in the analysis with regards to the mass of relocated core materials to the lower plenum (either large relocation masses (> 100 tons) or very small mass) is ongoing.
Development of approach to comparison of MELCOR and MAAP results for prediction of accident scenarios and core degradation sequences is ongoing.
Task completion: 15 %

Task 3. To suggest improved approaches to modelling of steam explosion and coolability risks in PSA, considering information provided from IDPSA analysis.
Status: Areas for potential improvement of PSA-L2 modeling of in-vessel and ex-vessel accident progression taking into account timing of the events and physics of the phenomena are under consideration in collaboration with LRC.
Task completion: 15 %

Deliverable 1. Report on development and application of IDPSA to analysis of core melt relocation to the lower plenum, as initial conditions for the melt release and ex-vessel steam explosion and debris bed coolability in Nordic BWRs, taking into account the influence of timing in PSA level 1 sequences and possible recovery actions.
Status: Report for 2014 has not been started yet.

Deliverable 2. Report on improved approaches to modelling of steam explosion and coolability risks in PSA, considering information provided from IDPSA analysis.
Status: Report for 2014 has not been started yet.

Work at VTT

Ilkka Karanta, Taneli Silvonen.

Task 1. To develop further the methodology for application of IDPSA with PSA/DSA to the Nordic nuclear energy industry and regulatory needs.
Status: Feasibility of different approaches to data exchange between PSA and DPSA tools is under investigation.
Task completion: 15 %

Task 2. To address further in-depth following issues of risk importance for different severe accident scenarios: 2.1. Relocation of the core melt to the lower plenum, as initial conditions for the melt-vessel structure interactions, melt release and ex-vessel steam explosion and debris bed coolability in Nordic BWRs; 2.2. The influence of timing in PSA level 1 sequences and possible recovery actions on the amount and properties of the melt in the lower head.
Status: Steam explosion case study using IDPSA methodology has been performed last year for Olkiluoto NPP units 1&2 in Finland. Knowledge obtained from MELCOR simulations were implemented into a probabilistic containment event tree model of the plant constructed with SPSA. Emphasis of the study was on the probabilistic side of the analysis. This year the already existing analyses are supplemented by performing case specific ex-vessel steam explosion simulations using MC3D code. The analysis cases are derived from those scenarios analyzed with MELCOR last year which resulted in vessel melt-through. The possible different vessel failure modes are taken into account as well. Explosion strength depends on e.g. parameter values used in premixing calculations and the time when explosion trigger occurs, and these factors are looked into in a brief sensitivity analysis. Results on explosion strength are compared to values used in last year's event tree model and literature (e.g. SERENA project)

Task completion: 75 %

Task 3. To suggest improved approaches to modelling of steam explosion and coolability risks in PSA, considering information provided from IDPSA analysis.
Status: The ex-vessel debris coolability issue is taken into account by examining literature of analytical treatment of ex-vessel debris coolability. The ultimate goal is to obtain an improved risk-informed approach to debris coolability problem for level 2 PRA purposes using IDPSA methodology.

Task completion: 40 %

Deliverable 1. Report on development and application of IDPSA to analysis of core melt relocation to the lower plenum, as initial conditions for the melt release and ex-vessel steam explosion and debris bed coolability in Nordic BWRs, taking into account the influence of timing in PSA level 1 sequences and possible recovery actions.
Status: Nearly all MC3D simulations of ex-vessel steam explosions in a BWR plant, including a brief sensitivity analysis, have been performed and interpretation of results is underway. Reporting has been started.

Deliverable 2. Report on improved approaches to modelling of steam explosion and coolability risks in PSA, considering information provided from IDPSA analysis.
Status: Literature of analytical treatment of ex-vessel debris coolability has been collected and reporting has been started.

Work at Lloyd's Register Consulting

Yvonne Adolfsson, Ola Bäckström

Task 1. To develop further the methodology for application of IDPSA with PSA/DSA to the Nordic nuclear energy industry and regulatory needs.
Status: Feasibility of different approaches to data exchange between DSA and DPSA tools is under investigation. Development of conceptual approaches for establishing connections between PSA and IDPSA has been started in collaboration with KTH. Investigation of feasibility of using cut-sets for such exchange between PSA and IDPSA is ongoing.
Task completion: 15 %

Task 2. To address further in-depth following issues of risk importance for different severe accident scenarios: 2.1. Relocation of the core melt to the lower plenum, as initial conditions for the melt-vessel structure interactions, melt release and ex-vessel steam explosion and debris bed coolability in Nordic BWRs; 2.2. The influence of timing in PSA level 1 sequences and possible recovery actions on the amount and properties of the melt in the lower head.
Status: MAAP code analysis of core relocation scenarios for relevant sequences is ongoing with the goal of comparison to MELCOR predictions and identification of the major sources of uncertainties in prediction of the effects of timing of events on severe accident progression. Identifications of need for model adjustments and need for complementing MELCOR with additional systems is also on-going. A Master Thesis study within this field has started in cooperation with KTH.
Task completion: 15 %

Task 3. To suggest improved approaches to modelling of steam explosion and coolability risks in PSA, considering information provided from IDPSA analysis.
Status: Work on summary of current PSA-2 modeling approaches and suggestions for improvements for a reference Nordic type BWR design for (i) in-vessel stage, (ii) vessel failure modes, and (iii) ex-vessel accident progression analysis is ongoing and coordinated with a utility.
Task completion: 15 %

Deliverable 1. Report on development and application of IDPSA to analysis of core melt relocation to the lower plenum, as initial conditions for the melt release and ex-vessel steam explosion and debris bed coolability in Nordic BWRs, taking into account the influence of timing in PSA level 1 sequences and possible recovery actions.
Status: Report for 2014 has not been started yet.

Deliverable 2. Report on improved approaches to modelling of steam explosion and coolability risks in PSA, considering information provided from IDPSA analysis.
Status: Report for 2014 has not been started yet.

Overall Project Summary

Comparison between plans and results with explanation of any deviations:
- There are no major deviations between plans and results.

Expected submit date of the final report
- Draft version of the report for 2013 has been developed. Expected date for submitting the final version of the report is mid of May 2014.

Any issues you would like the board to know
- No issues with the project.

A5. Status report ENPOOL

STATUS of NORTHNET RM3 and ENPOOL-NKS ACTIVITIES, May 7th, 2014

Work at LUT, Markku Puustinen, Jani Laine, Antti Räsänen, Lauri Pyy and Joonas Telkkä

Deliverable 1: Execution of the experiment series with a sparger
Design of the sparger model to be used in the tests is under discussion. The test series will be done in autumn. A detailed test plan will be agreed with KTH.

Deliverable 2: Reporting of the sparger experiments
No progress. Expected submit date of the report is November 30th, 2014.

Deliverable 3: Execution of the experiment series on DCC
Facility preparations for the tests are under way. The DN100 blowdown pipe and the new three high speed cameras will be used in the tests. The laser of the PIV measurement system is being repaired by the manufacture. The test series will start as soon as the PIV laser has returned to LUT.

Deviation: The beginning of the test series is delayed by two months due to the problems with the PIV system.

Deliverable 4: Reporting of the DCC experiments
No progress. Expected submit date of the report is September 30th, 2014.

Deliverable 5: Delivery of relevant experiment data to the simulation partners.
No progress.

Work at VTT, Timo Pättikangas, Antti Timperi and Jarto Niemi, VTT

Deliverable 1: CFD calculations of blowdown with model of a sector of BWR containment
Implementation and improving "The large interface model" in Fluent has been continued. Some numerical problems in the implementation of the large interface tracking model still exist. Resource problems have delayed performing of the subtask. One project team member returns from leave of absence in June, which improves the resource situation. Final simulations with the model will be started in August.

Deliverable 2: FEM calculations of chugging loads in BWR containment
Modelling of pressure pulse in water has been studied with the Star-CCM+ CFD code by using different time steps and time discretizations as well as single- and double-precision solutions. FSI calculations using coupling of Star-CCM+ CFD and Abaqus FEM codes have been started. The bi-directional explicit and implicit FSI couplings have been so far briefly tested in a simplified test case.

The final calculations of the BWR containment have been delayed until August.

Deliverable 3: Summary report on the CFD and FEM methods developed in the project
This subtask will be started in August.

Deviation: Resource problems have delayed the progress of the project. Situation improves in June, when one member of the project team returns from leave of absence.

Work at Royal Institute of Technology (KTH), Hua Li, Walter Villanueva and Pavel Kudinov

Deliverable 1: Further development of the Effective Heat Source and Effective Momentum Source models for spargers and RHR nozzles
Pre-test analysis with proposed designs of sparger and RHR nozzles is ongoing. The final designs of the sparger and RHR nozzles will be agreed with LUT.

Deliverable 2: Validation of the models against latest available PPOOLEX data
Validation of EHS/EMS models against recently concluded PPOOLEX MIX-07 to MIX-12 tests has been performed.

Deliverable 3: Pre- and Post-test simulations of the new series PPOOLEX tests
No progress.

Deliverable 4: Report on the model development and validation
No progress.

A6. Status report HUMAX

Project: Maximizing Human Performance in Maintenance (HUMAX)

The purpose of the HUMAX project is to provide recommendations on how to improve the effectiveness of Human Performance Tools (HPTs) in maintenance work. The recommendations will be developed based on insights from three case studies at Nordic nuclear power plants (Ringhals, TVO and Loviisa), an international questionnaire survey, and a literature review.

Overall, the project is progressing according to plan.

Project Group in 2014: Pia Oedewald (VTT), Teemu Reiman (VTT), Kaupo Viitanen (VTT), Christer Axelsson (RAB), Rossella Bisio (IFE) and Ann Britt Skjerve (IFE, co-ordinator).

Milestones:

No.	Activities	Duration (planned)	Status
1	Literature review	January-Mach 2013	Completed in 2013
2	Conclude analyses of the three case studies, and write 1-2 scientific papers based on the results obtained.	March-November 2014	The preliminary results of the three case studies were documented in the intermediate report, January 2014. Abstract accepted for presentation at WOS.net 2014 (details below).
3	Conclude analysis of the international survey.	March-November 2014	On-going
4	Develop recommendations on how to design and implement HPTs.	March-April 2014 and August-October	On-going
5	Disseminate findings.	Continuous dialogues with the power companies	
6	Final report	December 2014	

Overall status:

Overall, the project progresses according to plan.

Analyses of data obtained in the three case studies at Nordic plants (TVO, Loviisa and Ringhals) are in their final phases. Data collection in the international survey has been completed, and data analysis is currently ongoing.

Project coordination is carried out using regular video-meetings, where we discuss and coordinate the ongoing research activities.

Status on the individual activities:

Ad 1) Literature review (2013)
A literature review has been carried out and documented *complete draft* format. The scope of the review was to provide project members with a summarised presentation of the main assumptions and characteristics of the human performance programme movement.

Ad 2) Conclude analyses of the three case studies, and write 1-2 scientific papers based on the results obtained
The project comprises three case studies at Nordic plants. Data was collected during 2013.

- **The Ringhals case:** Data collection has been completed: 9 interviews (2 engineers and 1 group leader from the mechanical, electrical and I&C maintenance departments, respectively) and a web-based survey administered to maintenance staff (337 persons).
- **The TVO case:** Data collection has been completed: 15 interviews (12 maintenance workers and supervisors, 3 control room operators) and a couple of survey questions concerning human performance tools were added at TVO's regular safety culture survey.
- **The Loviisa case:** Data collection has been completed: 22 interviews (maintenance supervisors and managers) and regular meetings have been arranged where the findings have been discussed.

The preliminary results of the three case studies were documented in: Oedewald, P., Skjerve, A.B., Axelsson, C., Viitanen, K., Pietikäinen, E., Reiman, T., 2014. The expected and experienced benefits of Human performance tools in nuclear power plant maintenance activities. Intermediate report of HUMAX project. Nordic nuclear safety research, NKS-300, Roskilde, Denmark.

Abstract accepted for presentation at Wos.net 7th international conference, 30 September - 03 October 2014 Glasgow, Scotland, UK: Oedewald, P., Skjerve, A.B., Axelsson, C. Viitanen, K., Reiman, T: Expected and experienced benefits of Human Performance Tools in nuclear power maintenance activities. In this paper, we will expand on the topics addressed in the intermediate report.

Ad 3) Conclude analysis of the international survey
The purpose of the international survey was to gain better understanding on the expected and measured benefits of using Human Performance Tools, as well as insights into success factors associated with their implementation. The survey was designed based on the insights obtained from the three case studies, and distributed to 1055 respondents, identified based on participation in international meetings focusing on various aspects of Human Performance Programs. The survey received 135 responses from at least 47 organisations (many of the respondents did not indicate where they came from) mainly from North America and Europe. The analysis of data obtained in is currently ongoing.

Ad 4) Develop recommendations on how to design and implement HPTs

A scheme has been developed to facilitate documentation of and dialogues about potential recommendations, identified based on the findings in the study. The goal of this activity is to generate a list containing 15-25 recommendations, which may be of generic use to Nordic plants by December 2014.

Ad 5) Disseminate findings

The preliminary outcome from the case studies on Nordic plants was presented at the Working Group on Human and Organisational Factors (WGHOF) meeting in Paris, 26th March. Parts of the lessons learned about safety management in the HUMAX project have been included in a paper to be presented in a Technical Meeting at IAEA, 10-13 June 2014.

Expected submit date of the final report:
We expect to submit the *final report* 31, December 2014.

A7. Status report L3PSA

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Memo

NKS-R L3PSA - Addressing off-site consequence criteria using Level 3 PSA : Spring 2014 status report from NKS-R L3PSA

To:	NKS	**Cc:**	
From:	Andrew Wallin Caldwell	**Date:**	6 May 2014
Project no:	211593		

1 Summary

Progress of the activity

The first year activities, which included an industrial survey, an investigation of appropriate risk metrics, and participation in the development of guidelines and standards, are mostly completed. The next phase of the project will primarily focus on the pilot project and the guidance document.

The pilot project is split amongst a Finnish Project, and a Swedish Project. The Finnish project has been underway since 2013, while the Swedish project is starting in earnest this year (2014). A significant amount of the work that has been performed on both pilot projects to date is the pilot project planning. This includes outlining the project goals, required inputs, definition of the steps required for performing such a study and the reports that will be produced.

The guidance document work is also in the planning stages. The larger share of the 2014 resources will be allocated toward the pilot study, while a larger share of the 2015 funds are planned to be applied to the guidance document development.

A comparison between plans and results with explanation of any deviations

The project is proceeding as planned in the project plan that was developed during 2013.

It must be noted that the budget for the project is limited. Thus far, the working group, stakeholders, and parties interested in the project have been quite enthusiastic and ambitious in what can be accomplished under the Task 3 guidance document and the Task 4 pilot project. It is important to be mindful of the resources and scope of the project, and continue to be mindful of scope creep and analysis limitation throughout the duration of the project.

Expected submission date for Phase II of project

The second year seminar will be held on January 20th, 2015. The second year report will be completed immediately following that meeting (approximately middle of February 2015), incorporating the findings from the seminar.

2 Introduction

The Level 3 Probabilistic Safety Analysis (Level 3 PSA) project is seeking to deepen Nordic understanding about the merits and limitations of probabilistic off-site consequence analysis for nuclear facilities. The project began in 2013, and is entering its second year of a planned three years. The project's first year focused on the development and analysis of an industrial survey about Level 3 PSA,

which included several workshops and meetings with Nordic utilities, regulators, and safety experts. Level 3 PSA risk metrics including health, environmental, and economic effects have been researched and discussed in the first year's project report. The project has generated significant interest internationally and has interfaced with international organizations including the IAEA and the American Nuclear Society. The ultimate goal of the project is to produce a guidance document for Level 3 PSA in Nordic countries.

3 Progress of the activity

After completing a large survey, an investigation of appropriate risk metrics, and being directly involved in international drafting guides and working groups in the first year of the project, the second year will be focused on performing Level 3 PSA and formulating guidance based on the previous year's work and the progress completed during this year.

3.1 Project funding

This project is partly funded by NKS and partly by Nordic and Finnish utilities and the Swedish regulator SSM. The work is being performed by Scandpower in cooperation with (ÅF) ES-konsult (Sweden), Risk Pilot (Sweden) and VTT (Finland). The Finnish participation is funded also by the SAFIR program.

3.2 Project timeline, distribution and deliverables

The total project is divided in three phases, phase 1 representing the scope of work to be conducted during 2013, and phase 2 and 3 covers scope of work for 2014 and 2015 respectively. The distribution of the total work is outlined in the Table 1. The project deliverables are summarized in Table 2.

Table 1. Distrubtion of project tasks over duration of the project.

Task	2013	2014	2015
Task 0 – Industry Survey	100%	-	-
Task 1 – Appropriate Risk Metrics	75%	25%	-
Task 2 – Regulation, guides and standards	75%	25%	-
Task 4 – Pilot application and tools	-	50%	50%
Task 3 – Guidance document	-	33%	67%
Project management	33%	33%	33%

Table 2. List of project deliverables.

Deliverable	Date
Detailed project plan	May 2013 (complete)
Reference group meeting	May. 2013 (complete)

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Project seminar 1	Jan. 2014 (complete)
First year report	Jan. 2014 (complete)
Major Sub-report Survey of Level 3 PSA Industrial Purpose/Application Status of Task 1 - Risk Metrics (~75%) Status of Task 2 - Regulation & Standards (~75%) Status of Pilot Application (SAFIR/PRADA – VTT)	
Project seminar 2	Jan. 2015
Second year report	Jan. 2015
Major Sub-reports Level 3 PSA Risk Metrics Report Level 3 PSA Regulation, Guides and Standards Report Status of Pilot Application (33%)	
Final report (Following year 3)	Jan. 2016
Major Sub-report Level 3 PSA Guidance document Input from previous tasks including pilot application Including: 1. Recommendations for Level 1 and 2 PSA 2. Methodology guidance	

3.3 Project setup

One challenge presented in this work is the coordination of several organizations within the working group. Since there are several organizations that are working in the project a project set-up meeting was held in the spring of 2013 where it was discussed which organization will take lead in which tasks during 2013. Leading organizations for different tasks are given in Table 3. LR Consulting is acting as project coordinator.

Table 3. Task coordination.

Task	Leading org.
Task 0 – Industry Survey	ÅF (ES-konsult)
Task 1 – Appropriate Risk Metrics	Risk Pilot
Task 2 – Regulation, guides and standards	LR Consulting

Task 4 – Pilot application and tools	VTT
Task 3 – Guidance document	All
Project management	LR Consulting

The funding organizations is also composed of several organizations, and have been involved in the project as stakeholders:

- Swedish NPPs: OKG, RAB and FKA
- Swedish regulator: SSE
- Finnish NPPs (through SAFIR): TVO, Fortum and Fennovoima
- Finnish regulator (through SAFIR): STUK

Other stakeholders have also been identified, e.g. insurance companies, but since they are not part of the funding organizations they are not listed here. They are however of relevance for the project when it comes to Task 0 (see below)

During the project the following meetings have been held that involve above listed stakeholders:

- 2013-05-08: WebEx meeting with stakeholders to discuss project plan and involvement of stakeholders.
- 2013-10-02: NPSAG Autumn Seminar - Presentation of project status and general discussions with Swedish stakeholders

More detailed information about project progress is given below.

4 First year activities (2013)

There were many highlights from the previous year's work. Some of the accomplishments from last year's work are summarized in this section. The activities that are on going this year (2014) are summarized in Section 5.

Task 0 – Questionnaire

The purpose of the questionnaire was to collect base information about current international practices and motivations of utilities and regulators for Level 3 PSA. Even though Level 3 PSA is required only in a few countries, the interest is broader. The results from the questionnaire will contribute to the scope and contents of the Task 3 guidance document and the development of the Task 4 Pilot project.

The results of the questionnaire highlighted many varied insights, interests, and concerns for Level 3 PSA.

The possible advantages of Level 3 PSA were summarized as follows:

- Facilitate communication with insurance companies and the analysis could lead to better insurance possibilities
- Facilitate communication with the society in large and thereby create higher acceptance for nuclear power in society
- Better understanding of societal risks of commercial nuclear power and thereby improve preparedness work
- Provide better design and siting considerations for new construction projects
- Cost benefit metric for plant retrofits

- Improve and extend earlier levels of PSA, Level 1 and 2, in creating a more holistic point of view (this is not a unified opinion).

The respondents cited that the main challenge to Level 3 PSA are the uncertainties involved in the calculation, which themselves may be difficult to quantify. Since the challenges to Level 3 PSA are still somewhat undefined further study into the capability of Level 3 PSA is warranted.

Task 1 – Risk Metrics

Task 1 defined three categories of metrics

- Health effects
- Environmental effects
- Economic effects

It was determined that Health effects need to be a focus of the pilot project as it is fundamental to what one thinks of when discussing Level 3 PSA. Environmental effects are almost as fundamental. This could be essential when discussing filtered venting for example. Economics may not be "necessary" but is of high interest.

A risk metric has two components: 1) probability metric and 2) consequence (or impact) metric. Regarding the probability metric, it is a matter of choosing the normalization unit for risk comparison purposes. The consequence metric is associated with the impacts that are quantified in the consequence assessment part of Level 3 PSA.

Consequence metrics were categorized into health effects, environmental impact, and economic impacts. Health effects and environmental impact are rather similar impact metrics from the estimation and purpose point of view. The assessment of these impact metrics should be of interest for all stakeholders. It could be expected that even internationally the stakeholders could agree on which metric to use and risk criteria to be applied. At least for health effects, there are references for safety goals and associated numerical criteria. For the environmental impact, numerical criteria may not be necessary.

There are a number of open issues to be further explored, e.g., how far in time and place the estimations need to be done, i.e., what is the time frame for the risk metrics and how far away from the plant should the impact be accounted for? The pilot study, which is planned within the project, should elaborate more on these risk metrics when the scope of the study is determined. The pilot study should also elaborate how level 2 PSA release category related risk metrics could be used as surrogates for level 3 PSA criteria.

Task 2 – Regulations, guides, standards

International work in Level 3 PSA is ongoing. During the past year significant work was performed at the IAEA. In previous years there was significant progress in the ANS Standard on Level 3 PSA, however, last year little work was performed on the Level 3 PSA standard.

The IAEA work is planned to continue with TECDOC meeting May 2014.

The work in the Task 2 area will continue through 2014. The focus on the continuation of these activities will be the development of the IAEA Level 3 PSA TECDOC, which will have several Consultant meetings over the coming years.

Internationally, there is a significant amount of work being done in Level 3 PSA. Countries such as the Netherlands and South Africa continue to maintain Level 3 PSA models as it is part of their regulatory requirements. A Large scale USNRC study is underway and preliminary results will begin to be discussed and later published in the coming years. Development of a possible replacement to the COYSMA program is underway and being discussed. There is also significant interest in this NPSAG / NKS project on Level 3 PSA and the next year seminar shall be planned at least 6 months in advance to accommodate the international participants.

Task 3 – Guidance document

Work on the guidance document will begin during this year, however, the focus of the work this year will be the pilot project.

Task 4 – Pilot project

- The Finnish project began during 2013. The Swedish part of the project will being during 2013.
- The Finnish pilot project will investigate the Fukushima scenario.
- Currently, the pilot project plan is out for Finnish stakeholder comments
- The plan to continue further with the technical work is March 2014.

The main result of Task 4 in the first year is a plan for a pilot study. In it, the IDPSA methodology will be applied to the Fukushima Daiichi NPP disaster. It seems that this is the first time when IDPSA is applied on level 3, and therefore valuable experience on the application may be obtained.

There are several issues concerning Fukushima. The first is that there were several source terms at different times from different sources (reactors and used fuel storage). Significant sources of uncertainty include source terms and the amount of population in the affected area. All of these issues have to be addressed computationally in the pilot study.

5 Development of current year activities (2014)

The working group has held two meetings following the first year seminar which took place on January 21st 2014. A brief description of the meetings is provided in Table 4. The first year seminar marked the completion of *Task 0 – Industrial Survey* and *Task 1 – Appropriate Risk Metrics*. The activities within *Task 2 – Regulations, guides, and standards* are ongoing and summarized in Section 5.3.

Table 4. 2014 Project meetings.

Meeting / Date	Description
First Year Seminar – January 21st, 2014	Description to stakeholders and all interested in attending about the activities performed during the first year of the project
Phase II planning meeting – February 27th, 2014	Develop detailed plan and actions for Task 3 guidance document, and Task 4 Pilot project described in Sections 5.1 and 5.2, respectively.
Spring update meeting – April 23rd, 2014	Working group meeting, discussing the progress of each of the members on the actions outlined in the Phase II planning meeting.

5.1 Swedish pilot project

The pilot project will be the primary focus of the 2014 activities within the project.

The tools and methods used for performing the analysis will be limited to those that are available and the where the working group has experience. This means that the study will be based on the thesis work by Andrew Caldwell[1].

1 Caldwell, A.2012. "Addressing Off-site Consequence Criteria Using Level 3 Probabilistic Safety Assessment". M.Sc. Thesis, KTH Royal Institute of Technology, Stockholm. ISSN 0280-316X

To date, much of the focus has been on planning the pilot project and collecting input data.

5.1.1 Goals of the pilot project

The project group outlined a list of goals during the first planning meeting. Goals were formulated on a relatively high level. The final list of goals ended up being rather lengthy, as well as, quite optimistic. The budget of the project is quite limited, but the working-group will do everything possible to meet the following list of goals:

- Clarify what insights that can be gained from a Level 3 PSA
  - Demonstrate what additional can be gained in addition to Level 2 PSA (e.g. when threshold criteria are imposed on nuclear releases what if threshold is exceeded marginally or substantially)
- Demonstrate the resources required to perform a Level 3 PSA
- Clearer understanding of what the key uncertainties are
- How the existing release category structure fits-in to off-site consequence needs
- Gain insight in the application of the risk metrics proposed in Task 1
- Support the guidance document and provide practical background to the guidance
  - Demonstrate and capture lessons learned and applied/communicated in Guidance Document.
- Identify development needs and future work
- Provide additional, practical insight, for contributing to external organizations e.g. IAEA
- What is the risk importance of the filter system
  - could be key to include environmental / contaminated area
- To what level of detail can certain conclusions be drawn, how well do "shortcuts" and surrogates provide insight to off-site consequence analysis?

5.2 Swedish pilot project organization

Three reports will be developed over the course of the pilot project:

- Level 3 PSA Pilot Study input specification
  - Based on LENA requirements / assumptions what inputs are need
  - what formats are required
  - What limitations have been found
  - What additional information could be (could have been) useful.
  - Complete before Summer semester
- Scope of analysis
  - Satisfy as many of the goals we prescribed in the previous meeting with the resources available
  - Countermeasures
  - Results
  - Uncertainties
  - Complete by year end
  - Start concurrently with Input specification
- Methodology specification
  - Describe LENA
  - Complete by year end
  - Application and result interpretation specification
  - Complete by first half 2015

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5.3 Guidance document

The guidance document represents the central deliverable of the project. A general/draft outline has been formulated for the guidance document.

5.4 Task 2 – Regulations, guides, and standards

Progress on the Level 3 PSA standard has been modest over the past year. The Standard writing committee began work on the standard in 2004, and progress has been somewhat un-even over the past several years. The standard has had periods of significant progress, and periods of somewhat slow development. Judging based on the current status of the Level 3 PSA standard, the related Level 2 PSA standard, and the relatively modest progress of each during the past year, the completion of the ANS/ASME guidance on Level 2 and Level 3 PSA will take several more years.

The IAEA work will continue the next several years. The IAEA TECDOC is in the very early stages of development, and several more Consultant Meetings will be required to continue and eventually complete it. The IAEA has also discussed the possibility of additional regional workshops, but it is possible that there will be no additional regional workshops.

5.5 Comparison between planned and actual progress

The project is proceeding as planned in the project plan that was developed during 2013. In fact, more of the project was completed during 2013 than was earlier planned, which provides additional resources for 2014, specifically for the pilot project and guidance documents.

It must be noted that the budget for the project is limited. Thus far the working group, stakeholders, and the parties interested in the project have been quite enthusiastic and ambitious in what can be accomplished under the Task 3 guidance document and the Task 4 pilot project. It is important to be mindful of the resources and scope of the project.

The next meeting will be a stakeholder meeting held on June 2nd, 2014. This meeting will share the progress which is summarized in this report with the project stakeholders.

6 Expected date for final report

The second year seminar will be held on January 20th, 2015. The second year report will be completed immediately following that meeting, incorporating the findings from the seminar.

7 Other issues for information to NKS/NPSAG

There are no outstanding issues.

A8. Status report Nordic-Gen4

Activity Report
Nordic-Gen4, Nordic Nuclear Forum for Generation IV Reactors
AFT/NKS-R(14)103/12

The purpose of the activity is to promote networking and interaction between research organizations in the Nordic countries within the field of generation IV nuclear reactors. The following actions have been performed or are planned.

1. A student from DTU Nutech is currently undertaking a simulation project at Chalmers, under the supervision of Prof. Demaziere. The project is partly financed from the NKS-R activity.

2. The website nordic-gen4.org has been updated.

3. A new logo has been designed.

4. There will be a meeting at Arlanda airport on June 12 with participants from Chalmers, DTU, VTT, IFE, UU and hopefully KTH. The purpose of the meeting is to update each other on the ongoing research at the different universities/institutes and to do some planning of the upcoming seminar in Lappeenranta.

5. There will be a seminar in Lappeenranta September 4-5, see info on nordic-gen4.org. The seminar is a joint activity between Nordic Gen4 and Gen4Finland.

The final report will be sent no later than 31 January 2015.

The work is proceeding in accordance with the plan.

There are no particular issues to communicate to the NKS-R board.

2014-05-07/Mattias Thuvander, Chalmers

A9. Status report ProCom

Institute for Energy Technology

Note

To: NKS att. Karin Andgren

From: Maren H. Rø Eitrheim

Copy:

Date: 2014-05-06

Measuring Procedure Competence, ProCom, AFT/NKS-R(14)112/13

The NKS project Measuring Procedure Competence utilizes experiences from two areas of work in the international research program at IFE Halden (HRP):

(1) Training of Control Room Operators: Assessment and Improvement
Development of a Team Self-Assessment Tool (TESA)

The Team Self-Assessment Tool (TESA) has been developed to allow control room crews assess their own level of competences. The TESA tool includes basic technical competences and teamwork competences during normal operation, emergencies and outage. A subset of the basic technical competences during emergencies has been selected as a starting point for development of the procedure competence tool.

(2) Resilient Procedure Use

Resilient Procedure Use is a study of staffing and support tools for knowledge-based operator actions in complex scenarios. The simulator study in HAlden Man-Machine LABoratoy (HAMMLAB) provides rich examples of how emergency operator procedures are applied in complex and unexpected situations. We're utilizing simulator runs from this study to test and refine the procedure competence tool. Snapshots from the simulator runs will also be utilized to illustrate the procedure competences in a practitioner's handbook.

Procedure competence and behavioural markers

In this project we look at how control room crews apply emergency operating procedures. By procedure competence, we mean their ability to combine procedure skills, knowledge and attitudes *in practice* to handle emergency situations in an effective and efficient manner, and according to specified plant standards (IAEA, 2006). These competencies may be developed through a combination of education, experience, and training.

To measure procedure competence, an external observer will have to look at the actual performance of the crew. For the 'non-observable' aspects of performance, the observer need to draw conclusions based on the verbal exchange and reflections in the crew, in addition to the actual activities performed. For example, the ability to choose an optimal procedure strategy might be observed through the actual procedure applied and discussions of its purpose and appropriateness in the crew. These are the *behavioural markers* of the procedure strategy competence of the crew, i.e., the concrete, observable behaviours that will be rated by the observer.

IFE

The current version of the procedure competence tool

In the current version of the procedure competence tool, we have suggested four competence areas: procedure planning, procedure execution, utilization of backgrounds, and adaptability. For each of these competence areas, we have specified rating factors (e.g., Ensure sufficient progress) and related behavioural markers (e.g., Major action steps are discussed and given high attention; Briefings are performed if steps are unclear). The rating factors are organized according to a typical time sequence of a scenario (planning, execution, verification etc.). The tool content and language has been evaluated by several process experts and researchers at IFE. The tool has been tested in a number of scenarios in the Resilient Procedure Use study, both online and by use of a Video analysis tool post hoc.

In the current version of the tool, the observer rates each behavioural marker on a 5-point scale (1 is very weak - 5 is very strong). The scores for each of the behavioural markers are then applied for calculating overall competence grades on procedure planning, execution etc. The observer is also encouraged to make comments on observations throughout the session.

Procedure Competence Rating Crew: Scenario: Date: Observer:

No	Competence	Rating factor	Behavioural markers	Weight	Score	Weight X Score	Comp. grade	Observations
1	Procedure planning	Choose optimal procedure strategy	The applicability of the procedure strategy is discussed					
		Understand procedure purpose	Procedure goal and main actions explained in own words					
2	Procedure execution	Ensure sufficient progress	Major action steps discussed and given high attention	3				
			Minor steps timely and safely executed	1				
			Briefings performed if steps are unclear	2				
			Look ahead and prepare subsequent procedure steps	2				
		Apply fold out pages	Changes of criteria in fold out pages timely announced	3				
		Monitor Critical Safety Functions (CSF)	Changes of CSF timely alerted and actions started	3				
		Correct transfer to other procedures	Transfer to a new procedure is explained	2				
			SUM					
3	Utilization of backgrounds	Apply additional background information	Relevant background information explained					
			If background applicable, steps are executed accordingly					
		Handle Key Utility Decision Points (KUDP)	KUDP used for decision making when needed					
4	Adaptability	Flexible execution of procedure	If step(s) not applicable, alternative actions performed	3				
		Evaluate procedure effectiveness	Discuss if current procedure brings plant to safe state	3				
		Anticipate possible outcomes	Discuss and predict long term consequences	2				
		Independent thinking	Compare different procedure strategies and main actions	2				
			Agree on final goal and start actions to achieve safe state	2				
		Monitor goal achievement progress	Discuss strategy progress and effectiveness	2				
			SUM					

The current version of the procedure competence tool

On-going test application at KSU Ringhals

The procedure competence tool is currently being tested at KSU Ringhals. Representatives from KSU Ringhals and IFE will have a meeting 8th of May to discuss experiences from using the tool during simulator training and possible improvements to the tool. The tool will then be revised, and a new version released before the summer.

IFE

Progress of the activity

The project is progressing as planned, and according to the time schedule indicated in the NKS contract:

	Activity	Date	Status	Comments
T1	Identification of behaviours that indicate procedure competences (IFE)	01/05	Behavioural markers are identified; a first version of the tool is ready.	
T2	Pilot test of the method (KSU, IFE)	01/08	Ongoing, meeting 08/05	
T3	Review of the method (VTT)	15/09	VTT work will start when the updated version of the tool is ready (before the summer).	VTT will compare the tool with their theoretical model and provide a separate chapter to the final report.
T4	Development of a video illustrating procedure following problems and strategies (IFE)	15/09		
T5	Summary of lessons learned on the use of eye tracking for studying procedure use (IFE)	15/09		
M1	Development of handbook completed (IFE)	01/10	Topics and issues are identified during the tool development.	
M2	Draft report (IFE)	01/11		
	Workshop (all)	15/11	The preliminary plan is to organize a seminar at IFE Halden in September, but we haven't decided dates and agenda yet.	Invite instructors, process experts and researchers to discuss procedure competence rating in HAMMLAB. Eye-tracking possibilities and lessons learned.
T6	Review of report (Ålesund)	01/12		
D1	Final report	31/12		Expected submit date of the final report is 31/12.
D2	Procedure use video	31/12		