Activities of NUGENIA in the Field of Deterministic and Probabilistic Analysis

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1. Introduction

- The NUGENIA is a young and dynamic association of research organizations, utilities, technical support organizations (TSO) and universities devoted to R&D support of Generation II & III NPP’s.

- NUGENIA was founded in 2011/2012 on the basis of several preceding projects - the SNETP Technology Working Group Gen II & III, the NULIFE and the SARNET.

- Scope of activities of the new association was extended to the whole spectrum of research for NPP installations plus support of EC and SNETP.

- After initial phase of the association life connected with formal establishment of the association under Belgian law, organization of the first Forum, forming of Technical areas and teams, performing priorities exercise and preparation of the NUGENIA Roadmap, the development of new project ideas was started.

- There is more that 100 member organizations in NUGENIA and number of honorary member. There is more than 1000 experts registered at NUGENIA web.
1. Introduction (cont’d)

Major web tools of the NUGENIA:

- Basic web space of NUGENIA
  http://www.nugenia.org

- Nugenia Open Innovation Platform
  http://noip.nugenia.org

- Electronic Content Collaboration Platform ECCP
  https://app.lgi-consulting.org/ecm/nugenia

- Nugenia Monitoring Platform NMP etc.
1. Introduction (cont’d)

The work in NUGENIA is structured into 8 major Technical Areas (TA):

- **TA1** Plant safety and risk assessment
- **TA2** Severe accidents
- **TA3** Core and reactor performance
- **TA4** Integrity assessment and ageing of systems, structures and components
- **TA5** Fuel, waste management and dismantling
- **TA6** Innovative LWR design & technology
- **TA7** Harmonisation
- **TA8** In service inspection and qualification
2. Technical Area 1 “Plant safety and risk assessment”

Technical Area 1 is subdivided into the following 8 subareas (STA):

<table>
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<th>TA / STA leader</th>
<th>Company</th>
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<td>Plant safety and risk assessment</td>
<td>Pavel Kral</td>
<td>UJV Rez</td>
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<td>1.1</td>
<td>Data, Methods and Tools for Risk Assessment</td>
<td>Anna Häggström</td>
<td>Lloyds Register</td>
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<td>1.2</td>
<td>Deterministic Assessment of Plant Transients</td>
<td>Pavel Kral</td>
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<td>Impact of External Loads and Hazards on Safety Functions</td>
<td>Yvonne Andersson</td>
<td>Lloyds Register</td>
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<td>1.4</td>
<td>Effect of Electrical Grid Disturbance</td>
<td>Ali El-Akoum (Michel Rioual)</td>
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<td>1.5</td>
<td>Effects of Human Errors and Reliability Evaluation</td>
<td>Gunnar Johansson</td>
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<td>1.6</td>
<td>Advanced Safety Assessment Methodologies</td>
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<td>Design of Reactor Safety System</td>
<td>Juhani Hyvarinen</td>
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<td>Pre-Normative Research</td>
<td>Zdenek Kriz</td>
<td>CVR</td>
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2. Technical Area 1 (cont’d)

Structure of the TA1 part of the NUGENIA Roadmap (Global Vision):

- **Scope**
- **Objectives**
- **State of the art**
- **Challenges**
- **Subareas description**
- **Priority ranking**
- **References**

Totally 50 pages of technical text in the TA1 part.
The 8 technical sub-areas of TA1 address the following major objectives:

- Advancements in NPP probabilistic safety assessment (PSA) and human reliability analysis (HRA) – improvements in data acquisition, methods and tools, etc.;
- Further development of computational tools for deterministic plant assessment (DSA) including coupled codes and progress towards multi-level and multi-physics computational capabilities;
- Advanced safety assessment methodologies (identification and reduction of all uncertainties plus increase of their predictability, optimization of safety margins etc.);
- Development of methods and tools to better insure complimentarily of probabilistic and deterministic assessment, including integration of such methods;
- Extended validation of deterministic computational codes and benchmarking of probabilistic assessment methods (including determination of missing experimental data);
- Improved understanding and modelling of internal events including fire and external hazards and grid disturbances. Improved methods to handle events with low probability and high uncertainties and transfer this to design specifications and to SAMG strategies;
- Develop and apply tools and methods for upgrading of reactor safety systems to handle new safety demands, effective replacement of obsolete components and support of LTO.
Nugenia Open Innovation Platform (NOIP) (http://noip.nugenia.org)

- Dedicated web space for online collaboration and projects creation
- Started in 2013
- Place not only for project development, but also for online discussion, building of team, followers, cross cutting links identification etc.
- Open access to all registered members (more than 1000)
3. Projects development platform NOIP (cont’d)

Development of a project idea at NUGENIA NOIP platform flows in the following phases:

- Submission of Template 1 (one or two pages)
- Evaluation by TA leader (possible consultation and modification) finished by approval and publication of Template 1 at NOIP
- Development of team and project
- Submission of more detailed Template 2
- Evaluation and approval by TA leader
- Publication of Template 2 at NOIP
- Evaluation of Template 2 by NUGENIA Execution Committee (ExCom)
- Appointing of ExCom contact person (CP)
- Awarding of project idea by NUGENIA LABEL
- -------------(further steps outside the NOIP↓)--------------
- Submitting of project proposal to a Call
- Funding or running like in-kind project

Even after completion of this process at NOIP, the NUGENIA support continues – help to find funding opportunities, support of meetings, dissemination of results etc.
3. Projects development platform NOIP (cont’d)

Status of submitted/published project ideas at NOIP (3/2017):

![Status of submitted/published project ideas per TA]

- **Under Review**
- **T1**
- **T2**
- **Labelled NUGENIA**
4. Development of projects in field of deterministic safety assessment (DSA)

An overview of all DSA oriented projects prepared in frame of NUGENIA:

- **NEWHAM** (Nugenia Water Hammer)
- **NONCOND** (Noncondensable Gases Effects on Reactor Coolant System and their Improved Modelling and Analysis)
- **CoupTH** (Development of Coupled Computational Tools for Advanced Prediction of Local TH Phenomena and System Behaviour in Frame of PTS Evaluation)
- **SPH-2PHASEFLOW** (Simulation of two-phase flow patterns with a new approach based on Smoothed Particle Hydrodynamics)
- **SOCRATES** (Safety of Current Reactors – Applying Advanced Tools for Enhanced Safety)
- **EXPRESS** (Express Safety Analysis for Diversification/Modernization of Nuclear Reactor Core)
- **McSAFE** (High Performance Monte Carlo Methods for Safety Demonstration – From Proof of Concept to realistic Safety Analysis and to Industry-like Applications, TA3 crosscutting with TA1)
4. Development of projects in field of DSA - examples

**SPH-2PHASEFLOW**

Status: The SPH-2PHASEFLOW project proposal was prepared and submitted to the NUGENIA Plus Pilot Call in 2014, where it succeeded, was funded and run from 4/2015 to 10/2016.

The aim of this project was to develop a new numerical approach, based on the Smoothed Particle Hydrodynamics (SPH) method, to simulate changes in two-phase flow patterns.

The new numerical approach represents a radical departure from traditional methods and relies on a meshless, particle-based, method that has the potential to capture rapidly-deforming interfaces in two-phase flows.

Dispersed/separated two-phase flow
4. Development of projects in field of DSA - examples

**McSAFE**

Status: Submitted to Horizon2020 Call 2016-2017, succeeded and got funding.

A just starting project focused on further development of Monte Carlo (MC) methods for core analysis aiming to improve the performance and safety of current Gen-II and Gen-III reactors by developing and demonstrating novel and innovative methodologies of MC codes to include stable depletion, thermal hydraulic feedback, time dependent solutions and capability of simulate whole LWR cores at pin level making use of high performance computers (HPC) and finally delivering reference solutions for deterministic codes in case when no experimental data is available.

**Structure and Work Packages of McSAFE project**
5. Development of projects in field of probabilistic safety assessment (PSA)

A number of projects from PSA and HRA area was prepared at the NOIP. After merging of some of them into more integrated project, the list of main project ideas looks like this:

- **HRA-in-RDM** (Development, evaluation and application of methods for Human Reliability Analysis in the process of Risk informed Decision Making);
- **SEMEPRA** (Development of methods for risk assessment of seismic impact in low seismic risk areas);
- **NARSIS** (New Approach to Reactor Safety Improvements).
5. Development of projects in field of PSA - example

NARSIS

Status: Submitted to Horizon2020 Call 2016-2017, succeeded and got funding.

The project aims to propose some elements of improvement to be integrated in the current PSA. Thanks to the diversity of partners constituting the consortium, from academic to operators and TSO, the foreseen theoretical developments and the effectiveness of the proposed improvements will be tested and validated (numerical simulations, experiments) on simplified and real NPP case studies. The project aims at applying its outcomes at the demonstration level by providing improved supporting tools for operational and severe accident management.

Fragility in multi-hazard context – transport infrastructure
6. Development of projects combining deterministic and probabilistic safety assessment

An overview of projects combining PSA and DSA and prepared in frame of NUGENIA:

- **IDPSA** (Integrated Deterministic – Probabilistic Safety Analysis);
- **PROSAFE** (Harmonized understanding of uncertainties and their propagation in Probabilistic evaluations on Safety margin assessments of nuclear reactor pressure vessels and piping);
- **BEPILOT** (Best Estimate Risk-Informed Pilot Safety Analyses);
- **DEFI-PROSAFE** (Definition of reference case studies for harmonized Probabilistic evaluation of Safety margins in integrity assessment for long-term operation of reactor pressure vessel, TA4 project cross-cutting with TA1).
6. Development of projects combining DSA and PSA - example

DEFI-PROSAFE

Status: The DEFI-PROSAFE project proposal was prepared and submitted to the NUGENIA Plus Pilot Call in 2014, where it succeeded, was funded and ran from 4/2015 to 10/2016.

The objective of the project was to develop a probabilistic integrity approach to become a best estimate of the remaining margin as well as to create deck files for CATHARE/RELAP5/ATHLET.

Reference case studies were defined for a benchmark dedicated to investigating the propagation of the uncertainties from the boundary conditions through the structural integrity, in order to get insights in the total safety margin.

The work was based on the lessons learned from earlier projects, such as PROSIR, IAEA-CRP9, FALSIRE, ICAS, and from a review of the work performed in NURESIM, NUREG 1806 and published UPTF results.

Development of Statistical Fracture Event Methodology
7. Other EU projects in portfolio and dissemination of results

Major FP7 projects in the field of safety and risk assessment and computational tools development (related to TA1):

- **NURESAFE**: Simulation Platform for Reactor Nuclear Safety (follower of NURESIM)
- **ASAMPSA-E**: Advanced safety (risk) assessment methodology – extended PSA (follower of ASAMPSA-2)
- **MOTHER (VTT)**: CFD-Modelling T-junction Heat transfer - heat transfer from fluid to the wall

- Presentation and discussion of these projects at annual NUGENIA Forum’s
- Selected reports from these projects placed at Nugenia web Library (see below)
7. Other EU projects in portfolio (cont’d)
8. Summary

- The NUGENIA is a new and fast growing association (founded in 2011, with approximately 110 members at present) of research organizations, utilities, TSO’s and universities devoted to R&D support of Generation II & III NPP’s.

- The NUGENIA online platform NOIP is a progressive tool for development of projects, building of teams and sharing information among NUGENIA members on their project ideas.

- Major objectives of Technical Area 1 of NUGENIA (TA1) are the identification and elaboration of R&D topics connected with development, assessment and application of state-of-the-art methods and tools for NPP safety and risk assessment.

- An overview of projects (either running or in proposal stage) related to Technical Area 1 of the NUGENIA was given in the presentation.

- Some representative projects from deterministic, probabilistic and DSA-PSA integrating fields were described in more detail.