NEA NUCLEAR SAFETY RESEARCH JOINT PROJECTS WEEK: Success Stories and Opportunities for Future Developments

9-13 January 2023

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Welcome

Day 3 – Wednesday 11 January

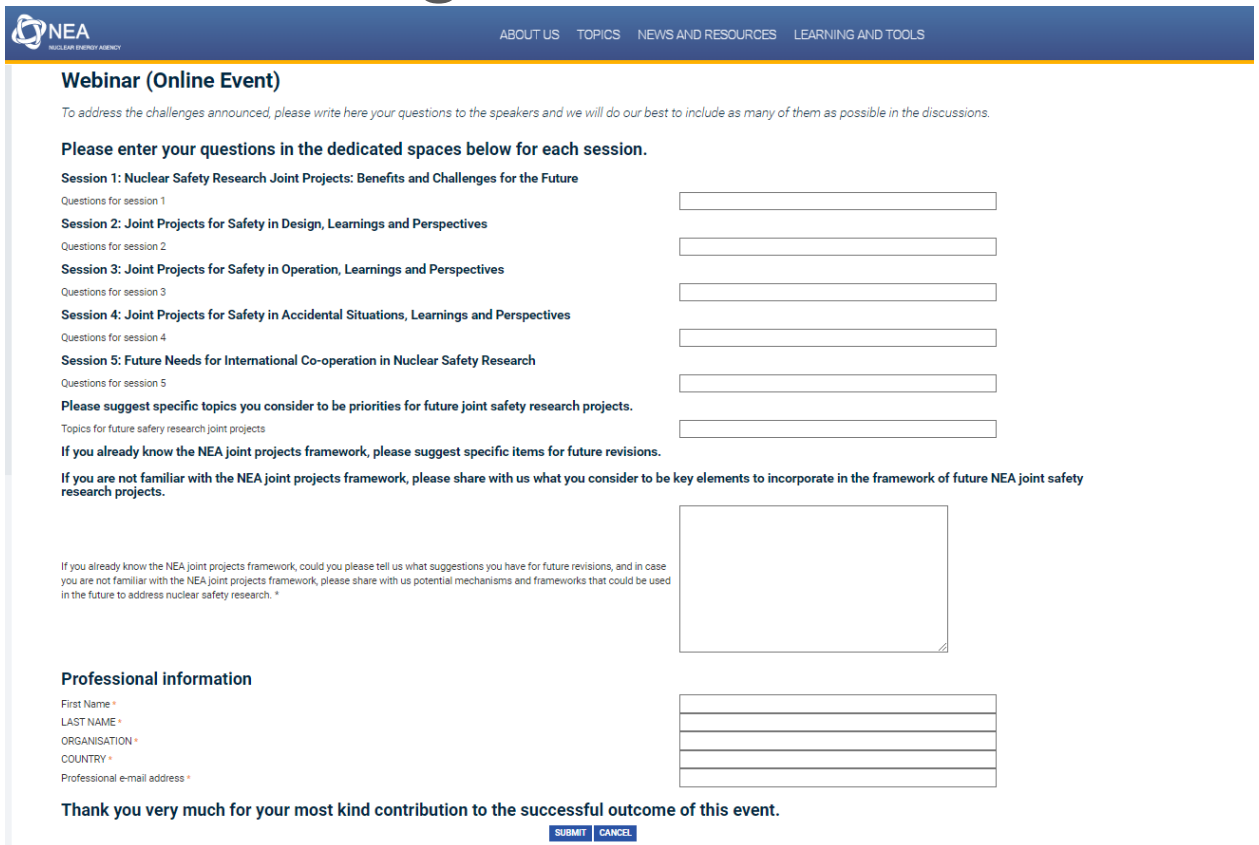
NEA NUCLEAR SAFETY RESEARCH JOINT PROJECTS WEEK: Success Stories and Opportunities for Future Developments

9-13 January 2023

Questions: Questions, feedback and suggestions

Event public page: Nuclear Energy Agency (NEA) - NEA Nuclear Safety Research Joint Projects Week: Success Stories and Opportunities for Future Developments (oecd-nea.org)

Form: Questions, feedback and suggestions link available in the registration confirmation email



NEA ABOUT US TOPICS NEWS AND RESOURCES LEARNING AND TOOLS

Webinar (Online Event)

To address the challenges announced, please write here your questions to the speakers and we will do our best to include as many of them as possible in the discussions.

Please enter your questions in the dedicated spaces below for each session.

Session 1: Nuclear Safety Research Joint Projects: Benefits and Challenges for the Future

Questions for session 1

Session 2: Joint Projects for Safety in Design, Learnings and Perspectives

Questions for session 2

Session 3: Joint Projects for Safety in Operation, Learnings and Perspectives

Questions for session 3

Session 4: Joint Projects for Safety in Accidental Situations, Learnings and Perspectives

Questions for session 4

Session 5: Future Needs for International Co-operation in Nuclear Safety Research

Questions for session 5

Please suggest specific topics you consider to be priorities for future joint safety research projects.

Topics for future safety research joint projects

If you already know the NEA joint projects framework, please suggest specific items for future revisions.

If you are not familiar with the NEA joint projects framework, please share with us what you consider to be key elements to incorporate in the framework of future NEA joint safety research projects.

If you already know the NEA joint projects framework, could you please tell us what suggestions you have for future revisions, and in case you are not familiar with the NEA joint projects framework, please share with us potential mechanisms and frameworks that could be used in the future to address nuclear safety research. *

Professional information

First Name *
LAST NAME *
ORGANISATION *
COUNTRY *
Professional e-mail address *

Thank you very much for your most kind contribution to the successful outcome of this event.

SUBMIT CANCEL

Session 3

Joint Projects for Safety in Operation, Learnings and Perspectives

SESSION MODERATOR

Mr Alexandre VIKTOROV

Director-General, Directorate of Power Reactor Regulation, Canadian Nuclear Safety Commission (CNSC), Canada

Mr Alexandre (Alex) VIKTOROV has been with the CNSC, the Canadian regulatory authority for over 25 years, and currently hold the position of the Director General for Power Reactor Regulation. As such, he has responsibility for the licensing and regulatory oversight of all power reactors in the country. Prior to becoming the DG, he had been involved or led diverse activities and projects within the CNSC, such as relicensing and subsequent execution of oversight at Pickering nuclear power plant, regulatory evaluation of safety analysis with particular focus on best estimate and uncertainty methodology, Design Extension Conditions, implementation of Canadian post-Fukushima actions, fuel and containment behaviour. Before joining the CNSC, Alex was engaged in research and safety analysis of nuclear facilities.

Session 3

Joint Projects for Safety in Operation, Learnings and Perspectives

- ► Examples of Fire Research Projects

FIRE-DB

Dr Marina RÖWEKAMP

Senior Expert, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS), Germany

Dr Marina RÖWEKAMP holds a Diploma in Physics and PhD (Dr. rer. nat.) in Physical Chemistry/Materials Science from University of Bonn, Germany. She is the Senior Chief Expert for Hazards (internal and external with a specific focus on fires) and for Probabilistic Safety Assessment (PSA) at GRS (Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH) – the Federal German Nuclear Technical Safety Organisation (TSO) – where she has served for more than 34 years. She is the Chair of the NEA Fire Incidents Records Exchange (FIRE) Project for all six project phases, the NEA CSNI Expert Group on Fire Risk (EGFR), the NEA joint projects PRISME 2 and PRISME 3 and is current Vice-Chair of NEA CSNI Working Group on Risk Assessment (WGRISK) after having been Chair for seven years. She is the German member of the NEA joint projects HEAF and HEAF 2.

Examples of Fire Research Projects – FIRE (Fire Events Records Exchange) Database

Dr. Marina Röwekamp (GRS, Germany)

– Chair of the FIRE Database Project Management Board –

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Introduction

- Background
  - Fires are significant contributors to the overall risk of nuclear installations – reactors as well as non-reactor facilities of the nuclear fuel cycle
  - ➢ The FIRE Database Project was initiated in 2001 as long-term project for collecting and analysing fire event data from nuclear power plants
  - Meanwhile in Phase 7 (2023 – 2025), the Project includes 14 member countries from Europe, Asia and North America
    - ❖ Belgium
    - ❖ Canada
    - ❖ Czech Republic
    - ❖ Finland
    - ❖ France
    - ❖ Germany
    - ❖ Japan
    - ❖ Republic of Korea
    - ❖ Netherlands
    - ❖ Spain
    - ❖ Sweden
    - ❖ Switzerland
    - ❖ United Kingdom
    - ❖ United States of America

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Objectives

- Collect fire event experience by international exchange in an appropriate format in a quality-assured and consistent database
- Collect and analyse fire events over the long term so as to better understand such events and their causes, and to encourage their prevention
- Generate qualitative insights into the root causes of fire events in order to derive approaches or mechanisms for their prevention and to mitigate their consequences
- Establish a mechanism for efficient operation feedback on fire event experience including the development of policies of prevention, such as indicators for risk-informed and performance-based inspections
- Record characteristics of fire events in order to facilitate fire risk analysis, including quantification of fire frequencies

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Working Procedure

- Nomination of a National Coordinator by each member country being responsible for data collection, quality assurance and coordination within the country
- Fire event information are typically provided by the operator of the installation who retains ownership of the data
- Event data are recorded on the Database according to pre-agreed standards (Coding Guidelines) that are continuously improved to make best use of the data for PSA and other types of analysis
- An updated Database version is periodically created, typically once a year
- Full FIRE Database is accessible to National Coordinators only
- A user version containing event data in anonymized form is intended to be shared with Project member organisations, paying members, and organisations providing data
- Strong co-operation with the HEAF 2 and PRISME experimental projects, e.g. common FIRE/PRISME cable fire benchmark

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FIRE Database Applications

- One goal of data collection: generation of generic fire frequencies for different reactor types and plant operational states (POS) for PSA use
  - FIRE meanwhile covers more than 610 events representative for more than 10000 years of observation
  - For events during full power, low power and shutdown states not excluded from statistics generic fire occurrence frequencies can be estimated for different reactor types, selected member countries, etc.
- Other applications with significance for regulatory assessments include but are not limited to:
  - In-depth investigations of fires as singular events and as combined events of fires and other hazards
  - Analysis of apparent and root causes of fire events
  - Modelling of real fire scenarios, e.g. by a common benchmark exercise with the PRISME Project for a cable fire event selected from the FIRE Database

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PSA Use – Generic Fire Occurrence Frequencies

- FIRE Database can be used, amongst others
  - for identifying all types of events and scenarios to be included in PSA models ensuring that all mechanisms are accounted for
  - as support to Fire PSA by real data from NPP operating experience, particularly to evaluate fire occurrence frequencies
  - for comparing member countries´ national fire event data with accumulated international data
- For generating generic fire frequencies for NPPs in FIRE Database member countries, corresponding observation times are systematically collected and updated for each reactor on an annual basis

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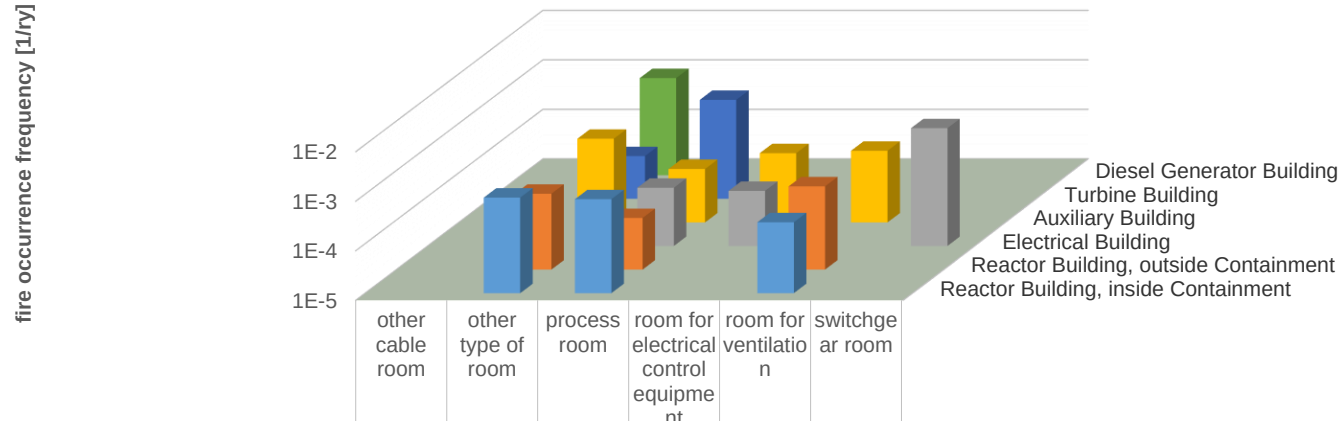
Generic Room Specific Fire Frequencies

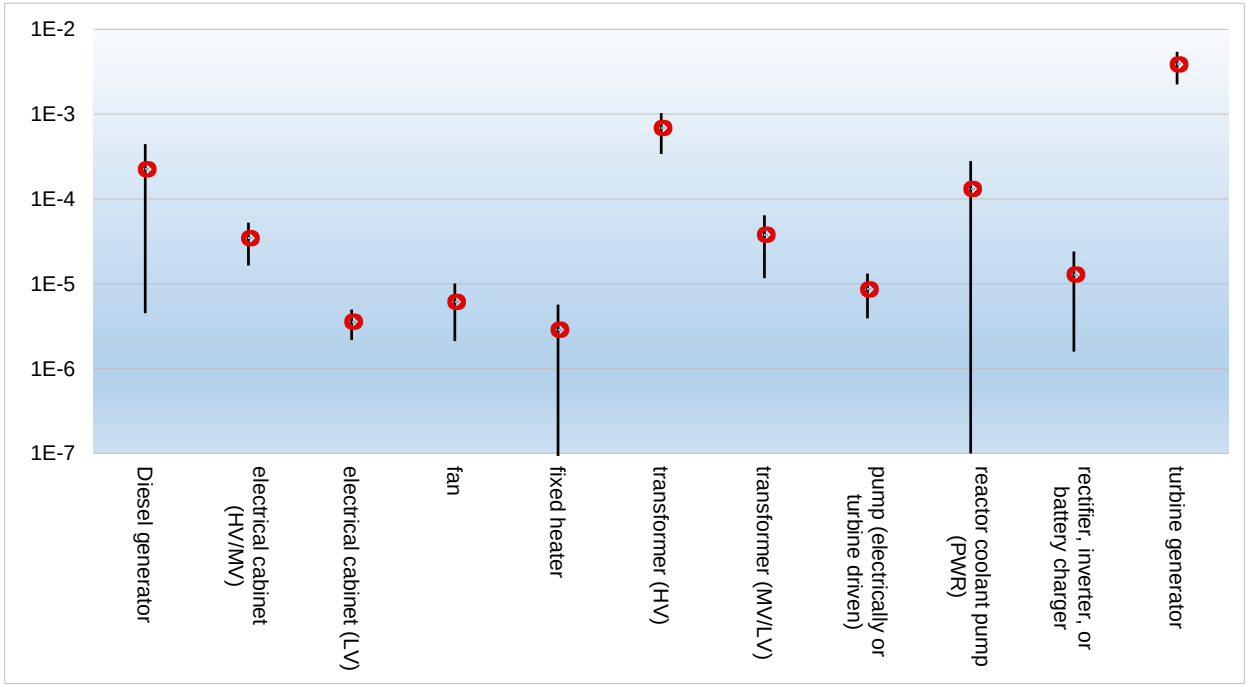
- Well-defined observation times are available for full power operation as well as low power and shutdown plant operational states
- Generic fire frequencies can be generated for various types of rooms and buildings based on average room numbers



	other cable room	other type of room	process room	room for electrical control equipment	room for ventilation	switchgear room
Reactor Building, inside Containment		8.5E-04	7.9E-04		2.7E-04	
Reactor Building, outside Containment		3.4E-04	1.1E-04		4.8E-04	
Electrical Building			1.5E-04	1.3E-04		2.40E-03
Auxiliary Building		4.9E-04	1.2E-04	2.5E-04	2.8E-04	
Turbine Building		7.3E-05	1.0E-03			
Diesel Generator Building		9.2E-04				

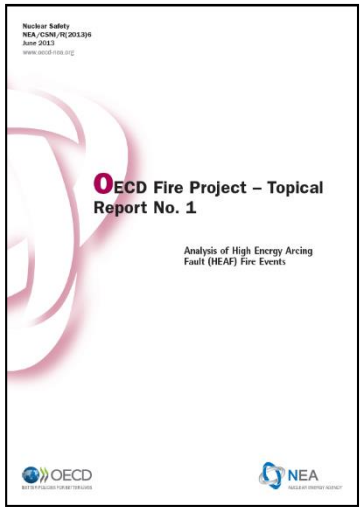
Generic Component Fire Frequencies

- Generic ignition frequencies can be generated for various types of components
  - Comparison with national data from Fire PSA is in principle possible
  - Main challenge: fire frequencies for cables still difficult to derive



High Energy Arcing Fault (HEAF) Induced Fires

- OPEX indicates importance of high energy arcing faults (HEAF) as important phenomenon for causing fires
- Actually, 67 HEAF induced fire events representing a fire occurrence frequency of ~ 7 E-03 / year
  - 30 of the HEAF induced fires are event combinations
  - Non-negligible contribution of HEAF induced fires to the overall fire risk during the entire plant lifetime
  - FIRE Project activity resulted in in-depth investigations, at least in Germany, Japan and the United States of America, and an OECD/NEA experimental HEAF Project



- ➢ HEAF should be considered in NPP design and operation
- National regulations in some member countries meanwhile consider HEAF and HEAF induced fires

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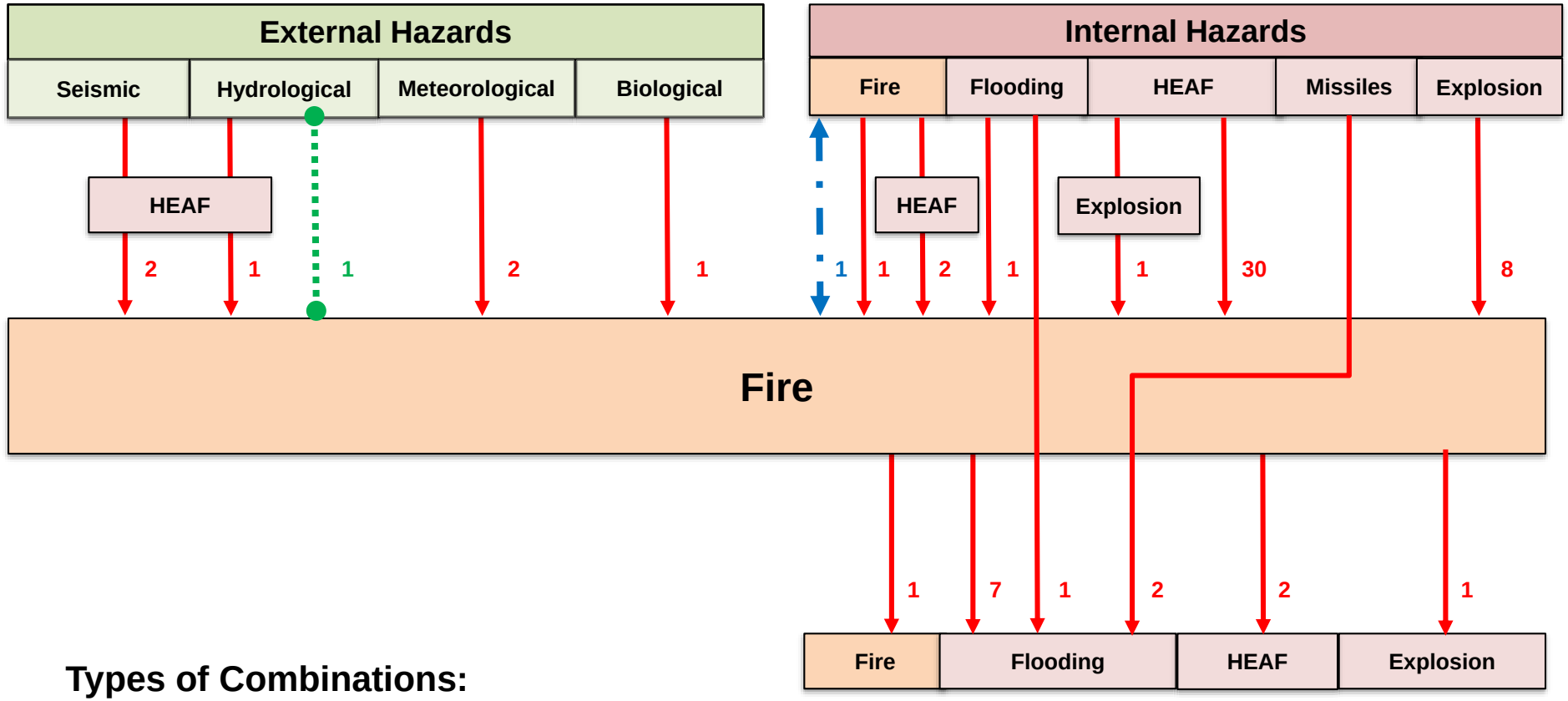
Event Combinations of Fires and Other Hazards



Types of Combinations:

- consequential hazards
- correlated (by common cause) hazards
- unrelated (independent, coincidental) hazards

Root Causes of Fire Events in FIRE Database

- Analysis of root causes regarding the typical root cause categories
  - Technical causes: **equipment**
  - Typical human erroneous actions: **human**
  - Inappropriate procedures or not following procedures: **procedures**
- Basis: 480 events with known root causes included in statistics:

Type of Root Cause	Percentages of Root Causes	
	Full Power Operation	Low Power and Shutdown
Equipment	78 %	27 %
Human	29 %	19 %
Procedures	14 %	6 %

Note: Multiple root causes possible

Main Challenges for the Project

- Data collection can be time consuming for NPP operators with their different priorities
- A detailed event data collection is often no more possible for events from the far past, particularly if additional data are needed for a new Project activity
- Event reporting criteria vary between member countries =>
  this needs to be considered for the evaluation of trends
- Regulatory framework within different member countries can affect interest in Project activities (e.g., when is an installation considered a nuclear installation, is the same regulator in charge for commercial NPPs and other nuclear installations such as research reactors, is the same level of information available for all types of installations and countries)
- Raw data are confidential limiting the publication possibilities mainly to generic results of data analyses
- New members need to make commitments that they will provide all necessary fire event data from the past and in future

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Further Ongoing FIRE Database Activities

- Ongoing activities incl. Topical Reports to be expected in FIRE Phase 7
  - Organisational and administrative fire protection at NPP sites in FIRE member countries – insights from the FIRE Database for potential improvements
  - Comparison of fire resistance standards applicable to nuclear installations in FIRE member countries
  - Fire suppression success analysis (fire extinguishing systems and/or manual firefighting)
- Already started extensions of the Database
  - Fire event data collection from research and demonstration reactors and corresponding adaption of the FIRE Database
  - Collection of fire events from reactor units under decommissioning and respective modifications of the Coding Guideline

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Outlook and Perspectives

- Possible developments and extensions of the Database under discussion by FIRE members
  - Cross-cutting topics between FIRE and ICDE Databases on common cause failures (CCF) of active fire protection features
  - Possibility for future fire event data collection from small modular reactors (SMRs) and other advanced nuclear technologies (ANTs)
- Potential future activities
  - New activities resulting from ENSREG Topical Peer Review (TPR) insights on “Fire Protection” by end-2024
  - ➢ Resolution of challenges and identification of fire research needs
- Increased membership benefits
  - Significant increase in generic fire event data, particularly for reactor types with limited operating experience
  - Covering challenges regarding fire safety of new reactor types from the beginning

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Thank you for your attention

For further questions, please contact

NEA Secretariat Markus Beilmann Markus.BEILMANN@oecd-nea.org

or

FIRE Management Board Chair Marina Röwekamp Marina.Roewekamp@grs.de

All NEA publications and institutional documentation available at
www.oecd-nea.org

PRISME

Dr Sylvain SUARD

Head of Fire Experimentation Laboratory, Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France

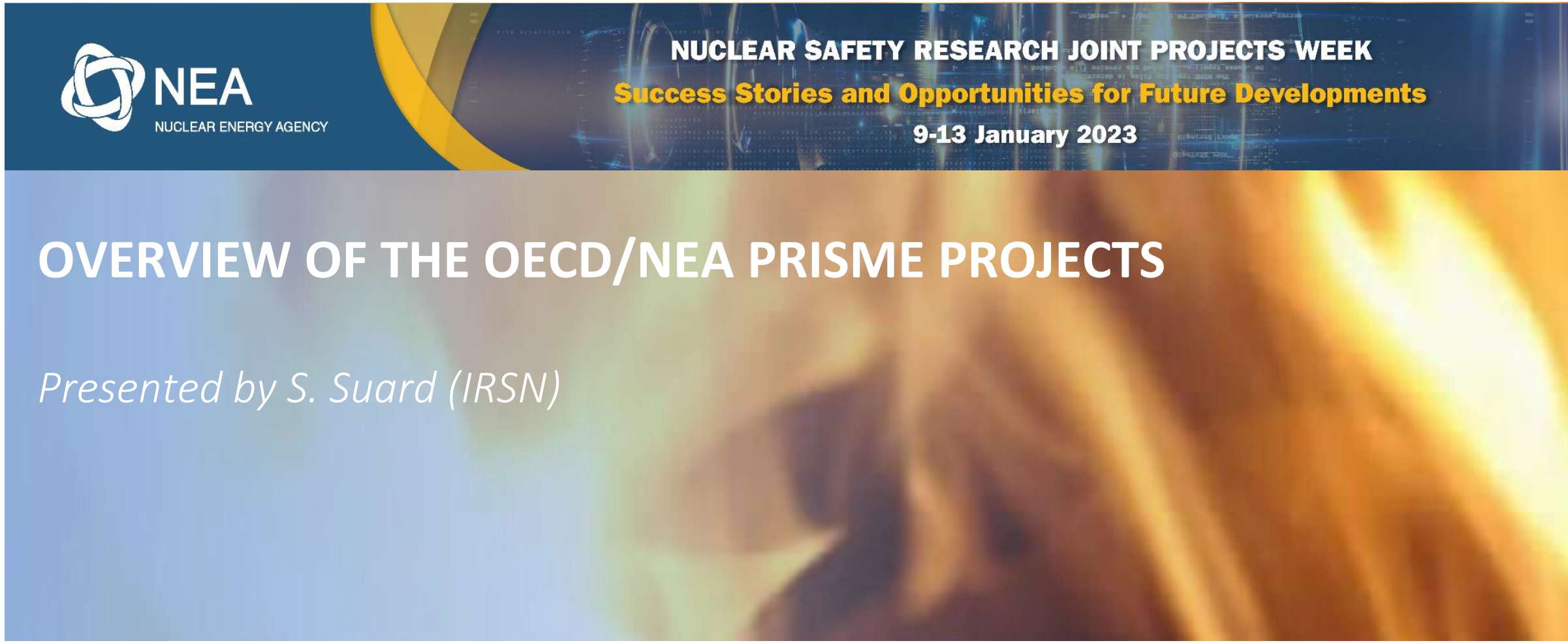
Dr Sylvain SUARD is the Head, since 2016, of the Fire Experimental Laboratory at the Institut de Radioprotection et de sûreté Nucléaire (IRSN). He is also the IRSN Project Leader of the third phase of the NEA PRISME joint project and Vice Chair of the Programme Review Group (PRG) for the OECD HEAF joint project. Prior to this, he conducted researches in the field of fire modelling, sensitivity analysis and verification and validation of numerical models. He received a Master's degree in fluid mechanics and energetics flows from Paris VI University and a PhD in Combustion, Energetic and Thermal Sciences from the University of Provence.

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

NEA
Nuclear Energy Agency

OECD
BETTER POLICIES FOR BETTER LIVES

IRSN
INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE



OVERVIEW OF THE OECD/NEA PRISME PROJECTS

Presented by S. Suard (IRSN)

GENERAL DESCRIPTON OF THE PRISME PROJECTS

- PRISME (2006 – 2010) / PRISME 2 (2011 – 2016) / PRISME 3 (2017-2022)
- 5 - 6 year Project in the framework of OECD/NEA
- Operating Agent: IRSN – Unique experimental platform GALAXIE
- Main issue: Improve the knowledge of fire risk in nuclear facilities - Management of fire events and recommendations in fire modeling and safety assessments are output of the Projects
- Pool fire / electrical Cable fire / electrical Cabinet fire – Fire propagation

GENERAL DESCRIPTON OF THE PRISME PROJECTS – MAIN OBJECTIVES

Physical phenomena and mechanisms:

Fuel combustion & Fire propagation

Confinement effect

Hazardous phenomena

Effect of the fire on the installation

GENERAL DESCRIPTON OF THE PRISME PROJECTS

[MEMBERS FOR THE 3 PROJECTS

- Regulators, TSO, Operators, Research centers

[ORGANISATION OF THE PROJECT

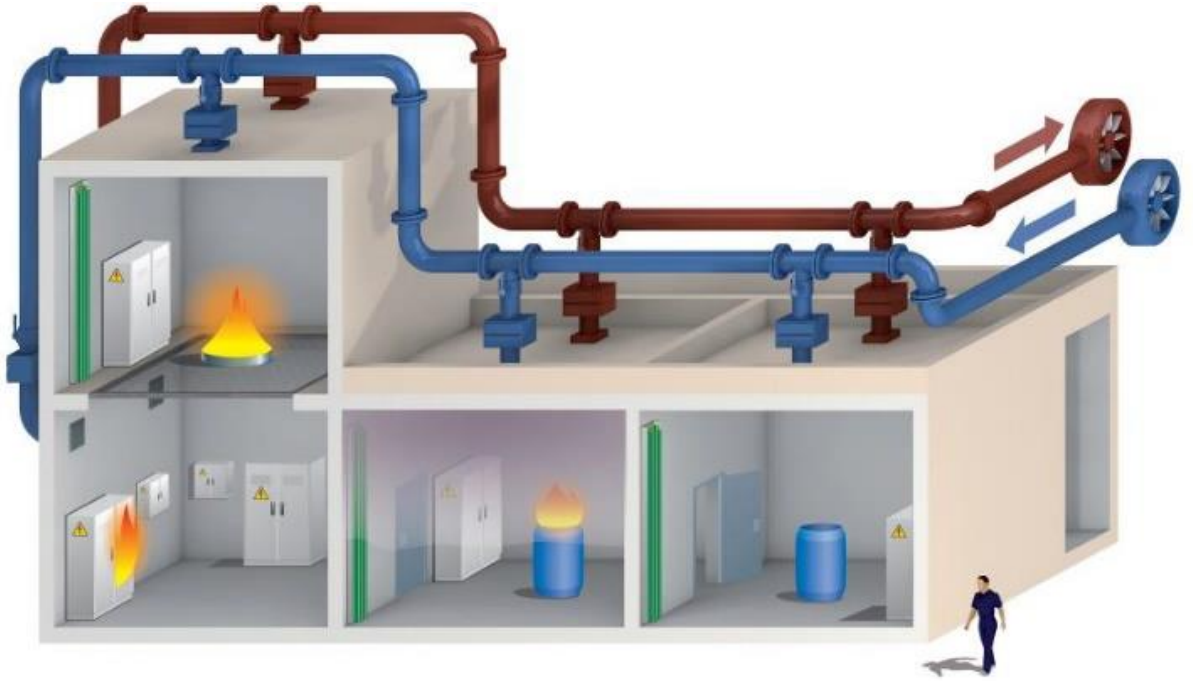
- 2 meetings / year
- 3 days meeting: Analytical Working Group – Program Review Group – Management Board
- Benchmark activity & Publication for AWG

Common benchmark exercise with the OECD-NEA FIRE Group
→ Publications in the PRISME 3 Special Issue

MAIN OUTCOMES and BENEFITS – Facilities and competences development

[DIVA FACILITY: Confined and mechanically ventilated compartment

- 3 rooms of 120 m^3, 1 corridor of 150 m^3
- 1 Upper room of 170 m^3
- Pressure + 500 hPa -100 hPa
- Reinforced concrete walls



[SATURNE FACILITY: Open environment

- Open compartment (10 m x 10 m x 20 m)
- Fire tests up to 3 MW
- Fuel characterisation

MAIN OUTCOMES and BENEFITS – Facilities and competences development

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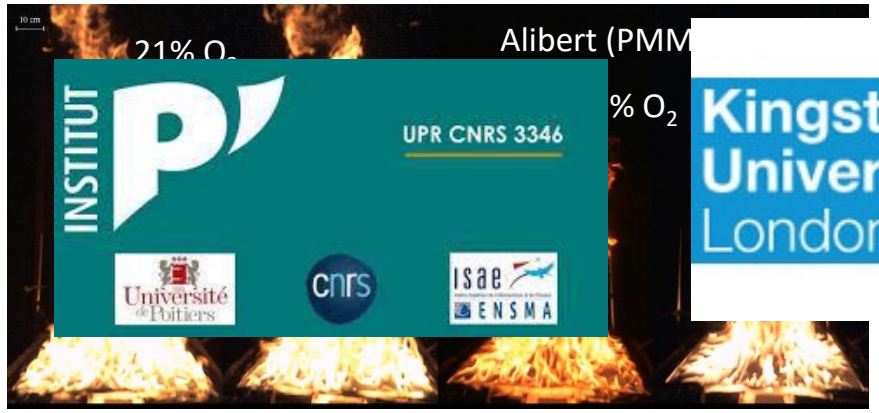
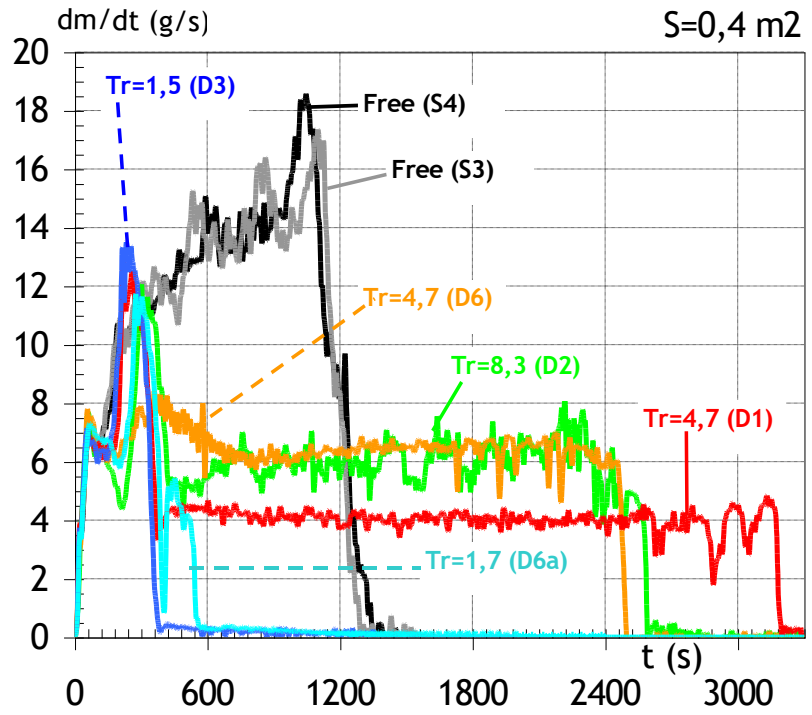
MAIN OUTCOMES and BENEFITS – Facilities and competences development

- **HIGH LEVEL IN FIRE ANALYSIS:** Publications & congress
- **INTERNATIONAL & NATIONAL COLLABORATIONS WITH UNIV.:** Gent Univ., Kingston Univ., Univ. of Maryland,…
- **DEVELOPMENT OF NEW MEASUREMENTS AND METROLOGY**
- **DEVELOPMENT OF NEW EXPERIMENTAL DEVICES** → Several doctorate & post-doctorate



MAIN OUTCOMES and BENEFITS – Nuclear safety applications



Fire Safety Journal 61 (2013) 54–64

Contents lists available at ScienceDirect

Fire Safety Journal

journal homepage: www.elsevier.com/locate/firesaf

Toward predictive simulations of pool fires in mechanically ventilated compartments

S. Suard [a,b,*], M. Forestier [a], S. Vaux [a,b]

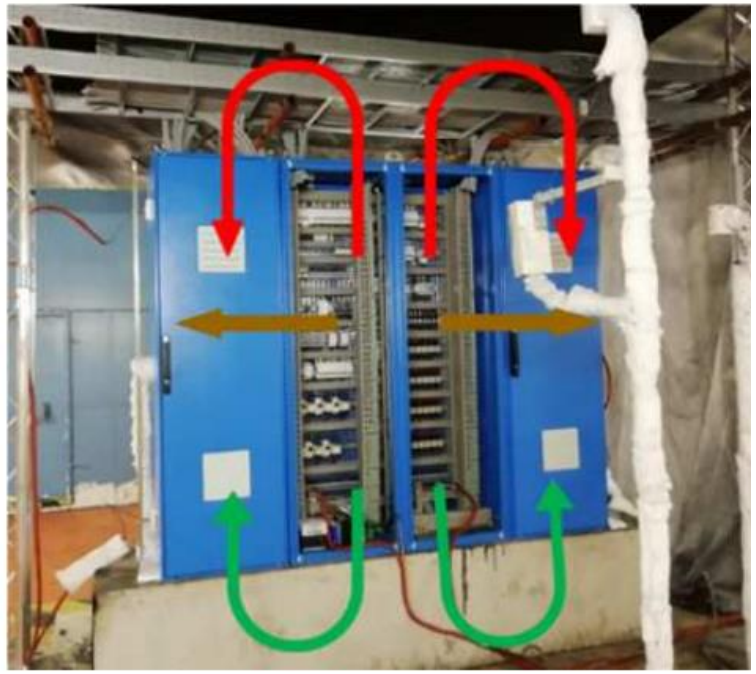
[a] Institut de Radioprotection et de Sûreté Nucléaire (IRSN), Laboratoire de l'Incendie et des Explosions (LIE), BP 3, 13115 St Paul-Lez-Durance Cedex, France
[b] ETIC Laboratory, IRSN-CNRS-UAM(I, II), 5, Rue Enrico Fermi, 13453 Marseille Cedex 13, France

Fire modelling and code validation process (V&V)

[INCREASE KNOWLEDGE & BUILDING OF AN EXPERIMENTAL DATABASE

- Oxygen depletion inside the compartment and effect on fire duration
- Highlighting a balance between the combustion process and the environment of the fire inside the installation

- IRSN: SYLVIA & ISIS
- EdF: MAGIC, SATURNE
- GRS: COCOSYS
- IBMB, VTT…: FDS



MAIN OUTCOMES and BENEFITS – Nuclear safety applications

Fire Safety findings

[HIGHLIGHTING OF FIRE PROPAGATION IN CASE OF ELECTRICAL CABINET FIRE

- Only few experiments on this issue
- Studies of propagation paths for electrical enclosures in different configurations
- Study the fire spread with different paths: **false floor, upper cable trays, through walls**
- Study the **effect of the cable type** (well v.s. low qualified)
- Study the **effect of the environment** (open atmosphere v.s. confined and mechanically ventilated

MAIN OUTCOMES and BENEFITS - Networking

- TSO [Bel V, CSNC, GRS, IRSN, KINS, VTT…]
- Regulators [CSN, NRA, NRC, ONR…]
- Operators [EdF, ENGIE…]
- Research organizations [CRIEPI, IBMB, KAERI, Univ. (Aalto, Gent, Kingston, Lund, Maryland)]

Definition of the program (PIRT Process)

↓

Benchmark activities

↓

Test specifications

↓

Test analysis

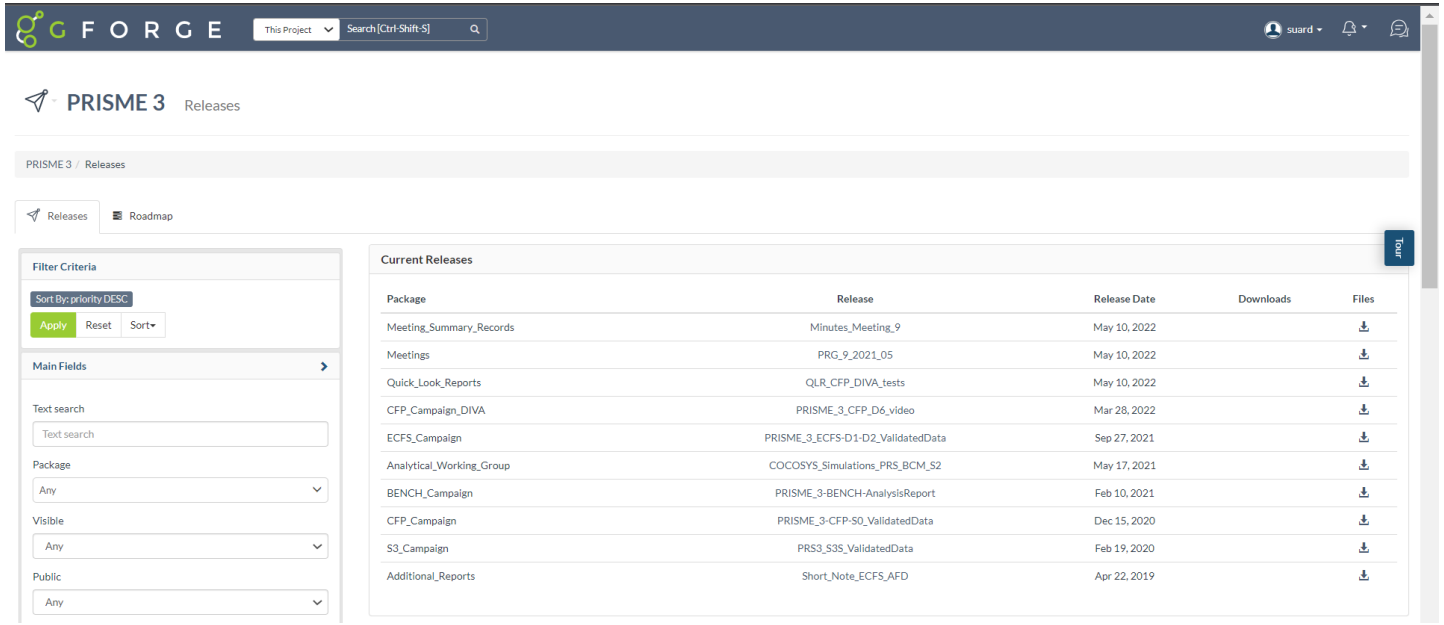
↓

Code Validation

MAIN OUTCOMES and BENEFITS - Values

Experimental data of the 3 Projects are being made available to NEA members countries through the NEA Data Bank.

[A SECURE WEBSITE FOR EACH PROJECT: IRSN GFORGE



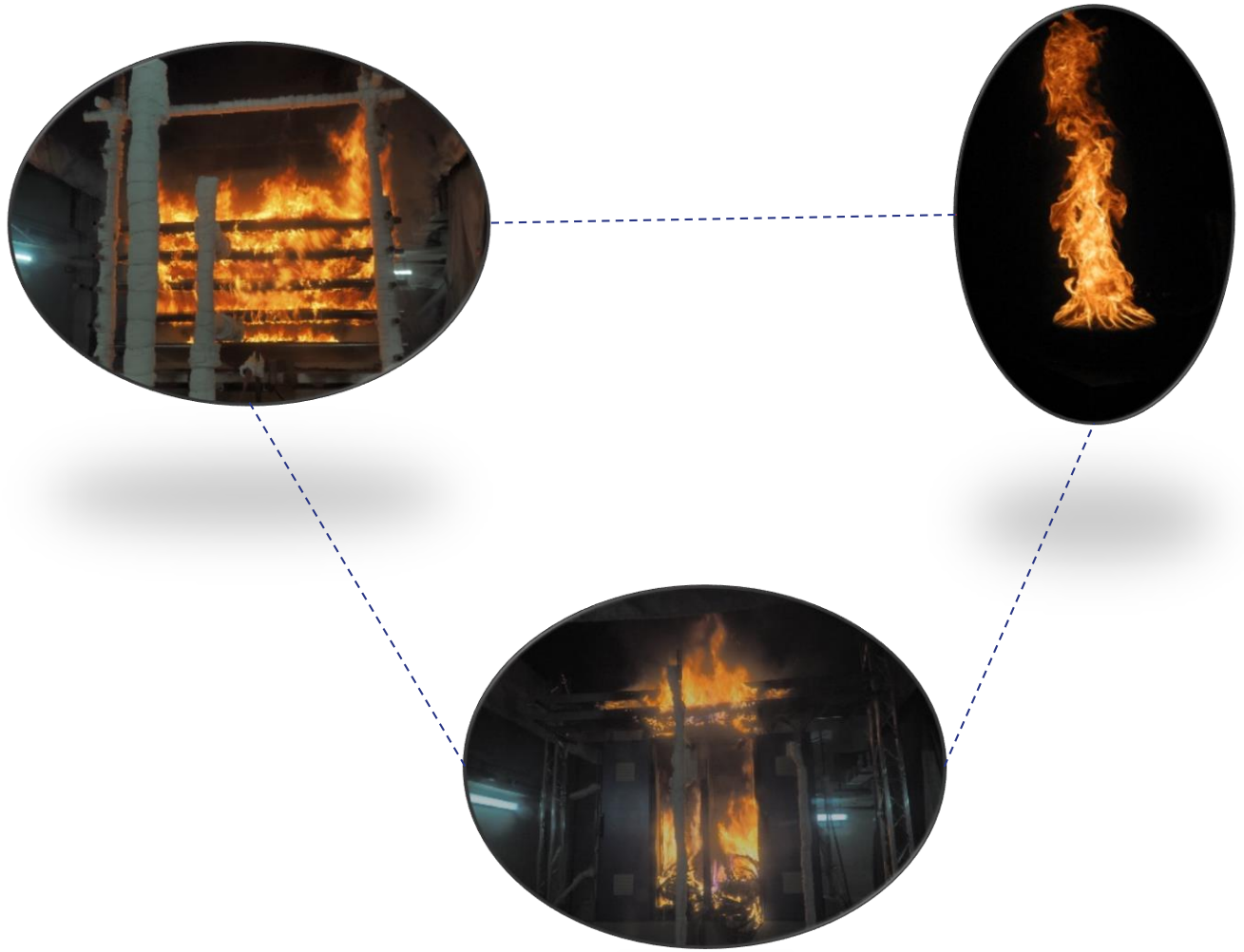
[MAIN RESULTS PRESENTED IN CONGRESS & PUBLICATIONS OF SPECIAL ISSUES

FEEDBACK ON MAIN CHALLENGES RELATED TO THE PROJECT DEVELOPMENT

SHARING A COMMON OBJECTIVE

- Compromise between different interests: interests of safety analysts, interest of researchers/modelers and different interests/priorities of participating organizations

- To guarantee throughout all the program, with the realization of the various campaigns, a notable gain for all the members of the project



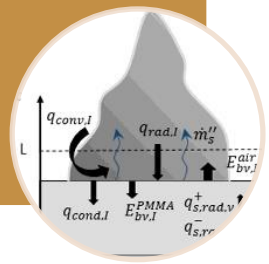
FEEDBACK ON MAIN CHALLENGES RELATED TO THE PROJECT DEVELOPMENT

- To maintain an experimental platform at a high level of operability for the whole duration of the project

Experimental Platform

- To maintain, throughout the project, the resources at a high level of competence

Fire analysis



- To mix the technical skills of the project by involving different organization (University, TSO, operator, test managers, fire safety engineers…)

Varying skills

INSIGHT ON FUTURE R&D NEEDS AND TRENDS

- CONTINUATION OF THE PRISME PROJECT → FAIR PROJECT (Fire Risk Assessment Through Innovative Research)

- FOLLOW-UP PHASE BUT DIFFERENT → INCLUDING A STRONGER ANALYTICAL APPROACH LED BY THE DIFFERENT CODE USERS

- MORE COMPLEX SITUATION TO BE REPRESENTATIVE OF INSTALLATIONS

- NEW CAMPAIGNS ORGANIZATION (MEDIUM AND LARGE SCALE – ALL THE PROJECT DURATION)

New safety issues challenged by experimental fire tests

INSIGHT ON FUTURE R&D NEEDS AND TRENDS

Identification by the SESAR Group on the necessity to maintain the GALAXIE Platform

[EXPERIMENTAL PLATFORMS NEED TO BE ATTRACTIVE

- Large scale configurations, highly representative
- Experimental research devices
- Non-intrusive optic measurements, increasing the level of understanding and allowing efficient fire modeling

CONCLUSION

Each of the PRISME projects has improved fire modelling, validation level of simulation tools, safety expert knowledge considering complex fire hazardous issues

Enhance awareness amongst safety analysts on projects results and progress in simulation tools

Allowing a good synergies between researchers and safety analysts into the several organizations involving in the CSNI Fire research projects as PRISME, HEAF and FIRE

Thanks to all PRISME members for fruitful discussions, the chairs of the management boards and of the program review groups, for managing the projects and the OECD/NEA for the high-quality support during these years.

Session 3

Joint Projects for Safety in Operation, Learnings and Perspectives

- Example of a Human Technology and Organisation Project

HALDEN HTO

Mr Andreas BYE

Chief Scientist, Programme Manager of the OECD NEA Halden Human-Technology-Organisation (HTO) Project, Institute for Energy Technology (IFE), Norway

Mr Andreas BYE is Chief Scientist at IFE (Institute for energy technology) in Norway and is heading the NEA Halden Human-Technology-Organisation (HTO) Project since 1st January 2021. He has been working at IFE for more than 30 years focusing on Human Factors and Human Reliability Analysis (HRA) work. Andreas Bye is member of the international HRA Society Board and the steering group of the Norwegian Human Factors in Control Association.

OECD NEA
Halden HTO
Project

11 January 2023

Andreas.Bye@ife.no

HALDEN PROJECT
HTO

Example of a Human Technology and Organisation Project

Andreas Bye
Programme Manager
OECD NEA Halden HTO Project

NEA
NUCLEAR ENERGY AGENCY

NUCLEAR SAFETY RESEARCH JOINT PROJECTS WEEK
Success Stories and Opportunities for Future Developments
9-13 January 2023

History, The Halden Reactor Project

- OECD Halden Reactor Project 1958 –
- The Halden Reactor closed down in 2018

HBWR: † 27.06.2018

The Halden Reactor Project, process control

- 1967: Process supervision and control
  - On the Halden Reactor
- OPCOM, 1972. Computerized control of the Halden Reactor
- HAlden Man-Machine LABoratory, HAMMLAB
  - Simulator laboratory, VVER, BWR, PWR, SMR
  - First version 1983
  - 4 versions and buildings since then

The Halden Projects

OECD Halden Reactor Project 1958-2020

F&M Programme

MTO Programme

1.1.2021

Halden Projects 2021 ->

OECD Halden Reactor Project F&M Extended 2021-2023 (database)

OECD NEA Halden HTO Project 2021 -

Other Decommissioning opportunities

OECD NEA Halden HTO Project

- **International collaborative research for the safe and reliable operation of Nuclear Power Plants, focusing on Human-Technology-Organisation**
  - OECD Nuclear Energy Agency (NEA)
    - Division of Radiological Protection and Human Aspects of Nuclear Safety (RP-HANS)
  - Operating agent: IFE (Institute for Energy Technology) in Norway
  - 3-yearly joint research program
- **Jointly funded by the membership**
  - Agreement signed by 20 Parties in 12 countries
  - 42 organisations pre-approved Third Parties (Regulators, Utilities, Vendors, TSOs, R&D centres)
  - Budget for 2021-2023 is 148 MNOK (13.8 MEUR)

Facilities and competence development

- Human-Technology-Organisation (HTO) is about operational safety
- The importance of Human Aspects of Nuclear Safety is emphasized lately (NEA established RP-HANS in 2014)
- Human aspects are often unexpected and cannot always be predicted
- Empirical research is necessary
- Halden has kept an empirical focus with a focus on operational laboratories
  - HAlden huMan Machine LABoratory (HAMMLAB)
  - VR-lab (and AR, XR)
  - Cybersecurity lab
  - SMR simulator
  - Robotics lab
- Interdisciplinary research
  - Psychologists
  - NPP operations experts
  - Engineers, computer scientists
- Quantitative and qualitative methods
- Examples of University collaborations: NTNU Norway, University of Toronto, Regional College Østfold

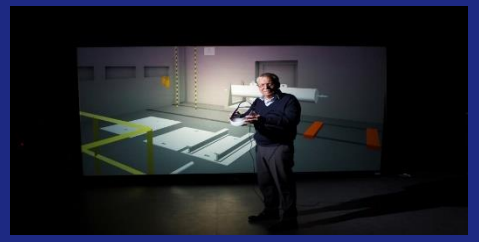
HAMMLAB, Halden human-machine laboratory

Cybersecurity Centre

Nuclear Safety Applications

- Technical basis for guidelines and standards
  - Human Factors Engineering (NUREG-0711)
    - Integrated System Validation (ISV)
- Support for Human Factors Engineering
  - Virtual Reality tools and processes for HFE of new plants
  - Human System Interface design, guidelines and recommendations
- Data and knowledge for Human Reliability Analysis (HRA) and safety analysis of digital I&C
  - Underlying knowledge (e.g., for HRA methods)
  - Practitioner advice
  - Methods (comparison study)
- Knowledge, advice and best practice for nuclear plants
  - Crew organization
  - Training
- Example systems for operations and maintenance
  - Signal validation
- Example systems and robotics utilization for decommissioning
- Methods and human handling of cyber-security

HTO-labs



HTO Topics 2021-2023

01	Human Performance
02	Digital I&C - Safety Assurance
03	Control Room Design & Evaluation
04	Human-Automation Collaboration
05	Digital Systems for Maintenance and Operations
06	Digital Transformation of Decommissioning
07	Cyber Security for Main Control Rooms

Networking

- 20 Parties in 12 countries
- 42 organisations pre-approved Third Parties
- Regulators, Utilities, Vendors, TSOs, R&D centres
- Collaboration arenas:
  - Board and PRG meetings (2 per year)
  - Country visits every third year
  - Guest scientists (“Secondees”)
  - 2 conferences per 3 years (Enlarged Halden Program Review Group Meeting (EHPRG))
  - Summer schools
  - Workshops
    - Physical
    - New after Covid-19: Virtual workshops
    - Coming: Hybrid workshops and meetings
  - Active participation in other NEA groups, e.g., WGHOF, Expert Groups (e.g., SMR)
  - Active participation in conferences, especially on nuclear safety

Members of the Halden HTO Project, Parties

- Canada: CNSC, CNL, COG
- China: SNERDI
- France: IRSN
- Germany: GRS, Framatome
- Japan: CRIEPI
- Korea: KAERI
- Netherlands: NRG
- Norway: IFE
- Sweden: SSM, OKG, FKA, RAB
- United Arab Emirates: FANR
- United Kingdom: NNL
- USA: DOE, NRC, EPRI

Values

Dissemination of major outcomes:

- Technical reports
  - Typical three year period:
    - 75 technical reports
    - 60 papers to conferences and journals
- Meetings and Workshops 2021-2022
  - 2 Enlarged meetings (one week, presentations of all results)
  - 8 general joint workshops
  - Many workshops and meetings with specific members (Teams workshops, country visits)
  - HTO is quite broad field, specific thematic workshops are necessary
- Data from empirical runs, basis for future studies in addition to the reported

Challenges, 1

How safety research joint projects should ensure safety research is performed in an efficient and effective manner for the benefit of all stakeholders of the nuclear energy sector, given their future expectations for both conventional and a variety of innovative technologies?

- Cost sharing
  - However, must be directly relevant for stakeholders' goals
- Mechanisms for stakeholder involvement (see networking)
  - Balance in establishing joint goals as well as fulfilling individual stakeholder goals
  - Direct stakeholder involvement gives better results, also for other stakeholders
- Empirical research, common data ground
  - Independent of the various methods used by different stakeholders

Challenges, 2

How safety research joint projects could better serve development and maintenance of key competences and research infrastructures, including education of new talents for the future of the nuclear energy sector?

- Infrastructure is important, including human resources in maintaining infrastructure
  - Labs are a good mechanism to gather and keep competent people
- Exchange mechanisms such as guest scientists
- Summer schools

Challenges, 3

What could be the new approaches and arguments for facilitating decisions from public and private stakeholders of the nuclear energy sector to fund the future safety research joint projects for the benefit of nuclear innovation and safety in general?

- Old argument: The nuclear sector must be science based!
- Trends in nuclear:
  - New builds
  - New technology (SMRs)
  - General technology development in the society require new safety guards (cyber security)
- HTO importance:
  - There is a technology drive in the society that challenges safety (digital I&C, cyber, AI)
  - Human interaction with technology changes and must be tested (more automation)
    - From manual operation to surveillance, this changes the operator role
    - Example SMR: Surveillance of many (simpler?) small units is cognitively different from surveillance of one big (more complex?) unit

Challenges, 4

What mechanisms could be set to establish future priorities for international co-operation in nuclear safety research?

- International cooperation is important
- NEA has a vital role in nuclear safety collaboration
  - Establishing the arena
  - Standard agreements
  - Best practices in e.g., export control
- The meetings of decision makers to set priorities is important in this respect (e.g., CSNI)
- Thorough processes in due time is needed in order to get stakeholders on board

Insights on future R&D needs and trends

- We have proposed a new Halden HTO programme for the period 2024-2026
- Country visits to all partners autumn 2022
- Main trends:
  - Plant modernization (e.g., U.S. DOE Light Water Reactor Sustainability program)
    - Including efficiency considerations of plant organizations to be more competitive
  - New builds, Gen III+ and smaller plants
  - Safety focus: Analysis (PSA/HRA) and design (human role and digital I&C)
  - SMRs
    - Human-automation collaboration and multi-unit operation
  - Non-electric application of nuclear power
    - Adaptation to energy grid based on renewables, e.g., Load following
    - Hydrogen production
  - Cyber security
  - Decommissioning (e.g., robotics)
  - Safety culture and organizational factors
  - Competence (re-)building

Conclusions

- Joint safety research projects are needed in nuclear
- NEA plays an important role as facilitator
- Human aspects are vital for nuclear safety
- The OECD NEA Halden HTO Project is a success story of establishing a new safety project based on a long history from the Halden Reactor Project
  - A new Halden HTO programme for the period 2024-2026 is proposed

Thank you!

Andreas.Bye@ife.no

Session 3

Joint Projects for Safety in Operation, Learnings and Perspectives

- Example of a Material Ageing Project

SMILE

Ms Lotta NYSTRAND

Senior Technical Sales Manager, Studsvik, Sweden

Ms Lotta NYSTRAND is Senior Technical Sales Manager at Studsvik, Sweden, with 30 years of working experience mainly involving the corrosion of fuel and reactor materials. Her experience varies from Senior Technical Sales Manager to Project Management, and to corrosion of Fuel and Reactor Materials and to Failure Analysis. She holds a MS (1987) in Engineering Physics, from the Chalmers University of Technology in Gothenburg, Sweden.

Studsvik

NEA
Nuclear Energy Agency

SMILE PROJECT
(STUDSVIK MATERIALS INTEGRITY LIFE EXTENSION)

Lotta Nystrand, Anders Jenssen, Martin Bjurman

NEA Nuclear Safety Research Joint Projects Week

11 January 2023

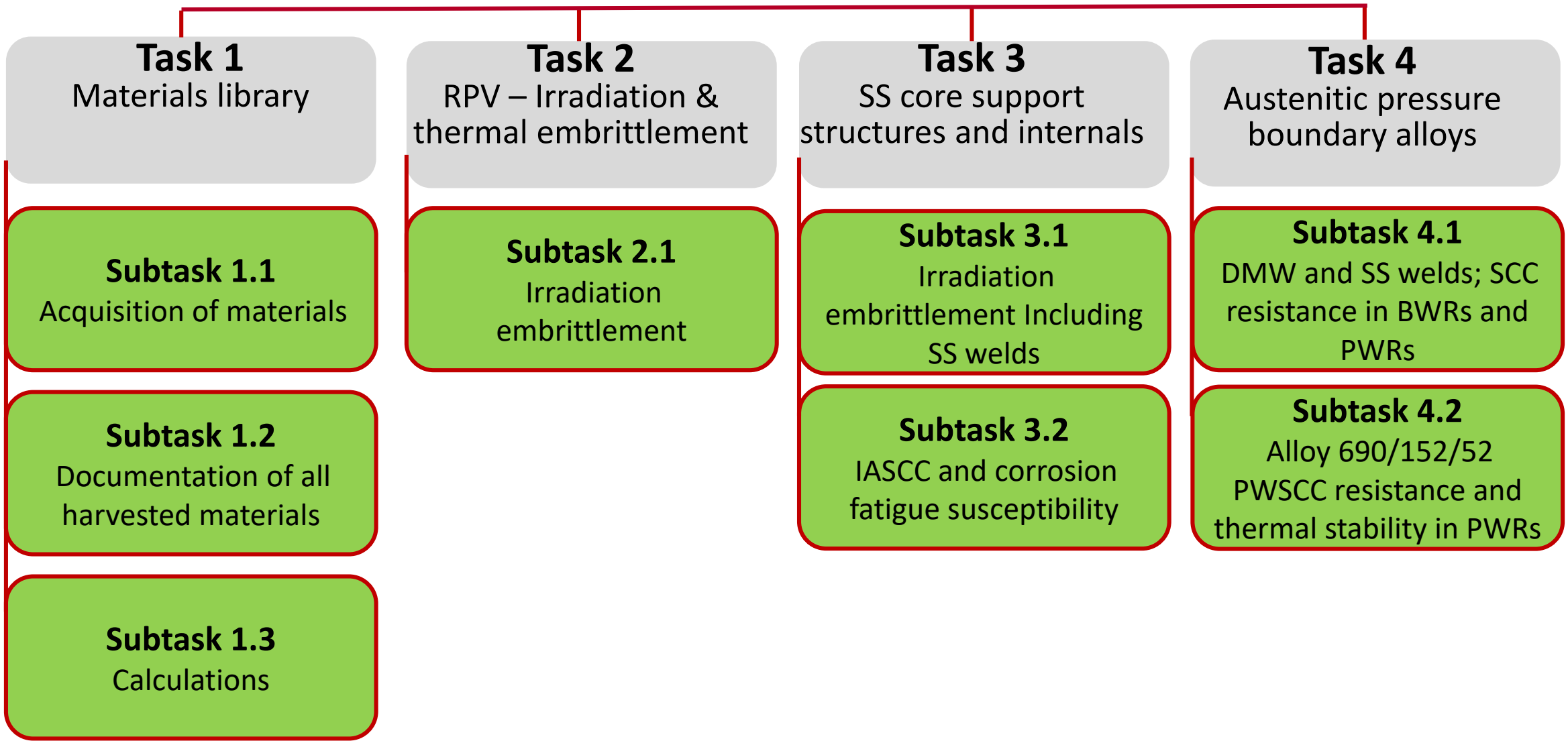
OUTLINE

- SMILE Project overview
- Initiation and Development of the SMILE project
- Main outcomes and highlights
  - Facility and competence development
  - Nuclear safety application
  - Networking and collaborations
  - Values
- Future needs
- Conclusion

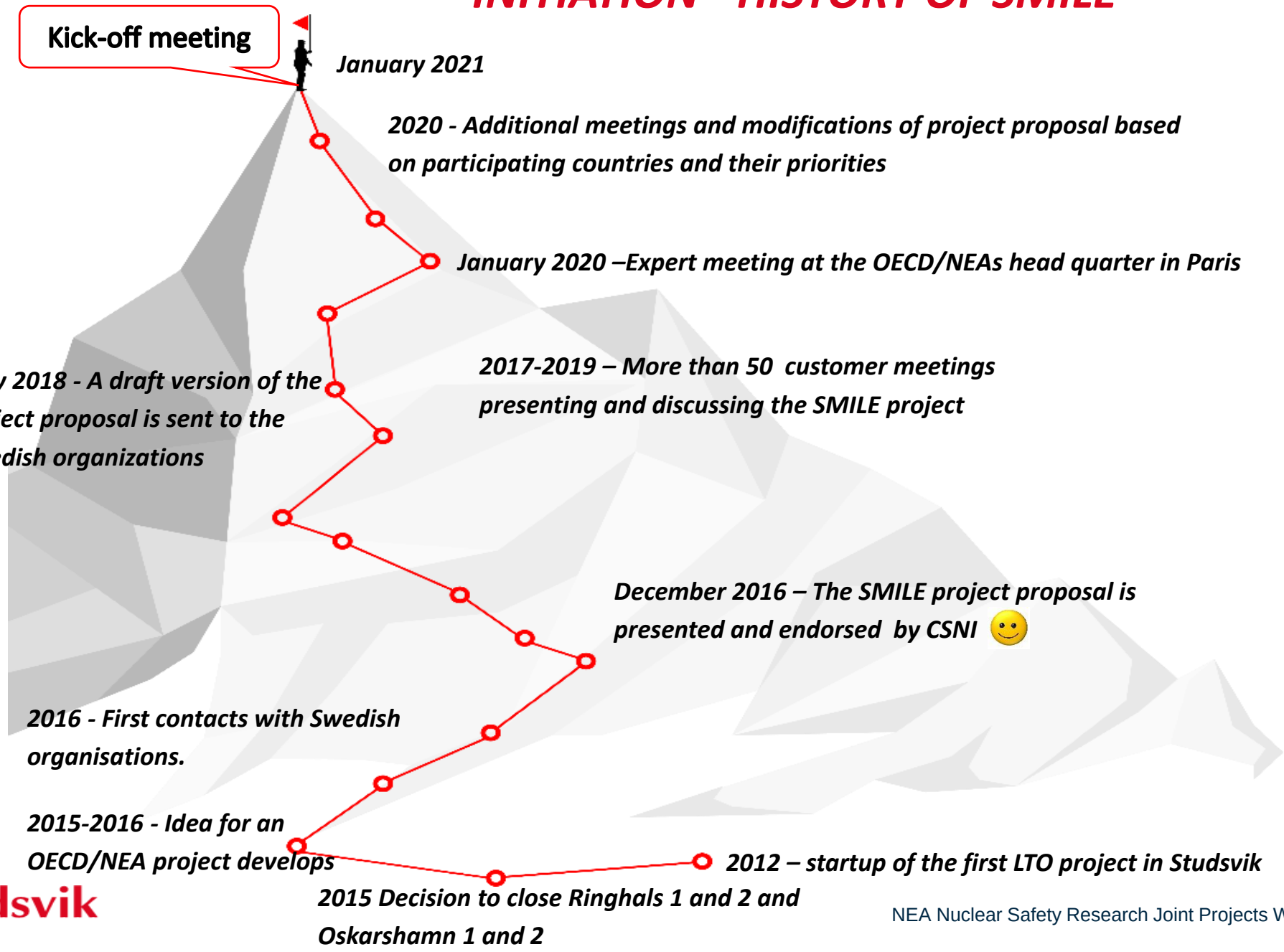
SMILE OVERVIEW - THE NEED

- Studsvik has launched SMILE (Studsvik Materials Integrity Life Extension), a project that supports LWR operators and authorities worldwide in plant ageing management
- The main objective is to provide critical data and mechanistic understanding of materials ageing mechanisms in support of plant ageing management, life extension programs and operating license renewals
- The experimental approach leverages a unique opportunity to harvest materials from Swedish LWRs that have recently shut down after 40+ years of operation
  - Examination and testing of fully aged materials directly relevant to LWRs will provide information that can be used to improve and develop models for the prediction of ageing
- SMILE is a 5-year project that started in January 2021
  - Currently SMILE has 15 member organizations from 8 countries

SMILE TASK STRUCTURE



INITIATION - HISTORY OF SMILE



MAIN HIGHLIGHTS

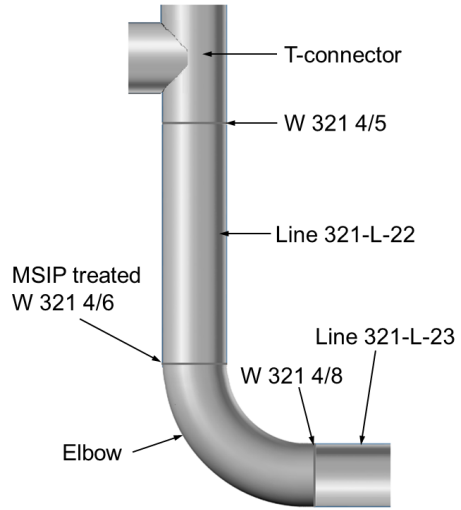
- SMILE addresses aging mechanisms of structural materials used in the primary coolant systems of LWRs
  - Focus on high-priority knowledge gaps identified in e.g., the EPRI (Electric Power Research Institute) materials damage matrix (MDM) studies
  - Based on methodologies for materials aging management, such as the EPRI Issue Management Tables (IMTs), and the IAEA International Generic Ageing Lessons Learned (IGALL)

- SMILE leverages a unique opportunity to examine and test materials harvested from Swedish reactors decommissioned after 40+ years of operation

- SMILE includes examination and testing of e.g.:
  - Highly irradiated wrought stainless steel and weld metal after 40+ years in service
  - Alloy 690 and Alloy 52 weld metal from the world's second oldest replacement steam generator(1989) and oldest RPV head (1995)
  - RPV steel from very low dose, to very high dose, including archive material, as well as BMI nozzles

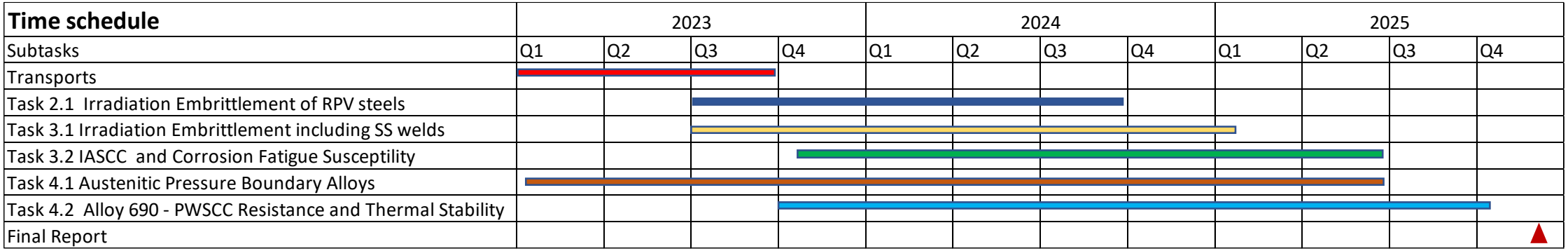
MAIN OUTCOMES/HIGHLIGHTS – FACILITIES AND COMPETENCE

- Development of Materials Library (Task 1)
  - Harvesting materials - methodologies
  - Transporting to hot cell
  - Developing Infrastructure for handling and storage for larger pieces of activated materials
- Residual stress measurements on activated/aged materials (Tasks 2, 3 and 4)
- Development of NDE on large (activated) materials (Tasks 3 and 4)
- Improvement He and H analyses (Task 3)



MAIN OUTCOMES/HIGHLIGHTS - NUCLEAR SAFETY APPLICATION

- The main objective is to provide critical data and mechanistic understanding of materials ageing mechanisms in support of plant ageing management, life extension programs and operating license renewals
- Examination and testing of fully aged materials directly relevant to LWRs will provide information that can be used to improve and develop models for the prediction of ageing
  - Expand and validate existing data base for irradiated stainless steel and nickel base alloys to higher doses (Task 3)
  - Validate or compare to previous test reactor data results (Task 3)
  - Investigation of the reliability of currently used irradiation embrittlement models (Tasks 2 and 3)
  - Validate current stress corrosion cracking growth rate data & models on irradiated/aged real plant components (Tasks 3 and 4)



NETWORKING AND COLLABORATIONS 1 (2)

- Two in person meetings per year
  - Defining common priorities
  - Presentations and discussion on test results and test plans
  - Workshops on specific issues or results
- SMILE members
  - Utilities,
  - Regulators
  - TSOs
  - Universities and Research Organizations
  - *New members*
    - *China (CNPO, SNERDI, NSC)*
    - *Finland (VTT)*

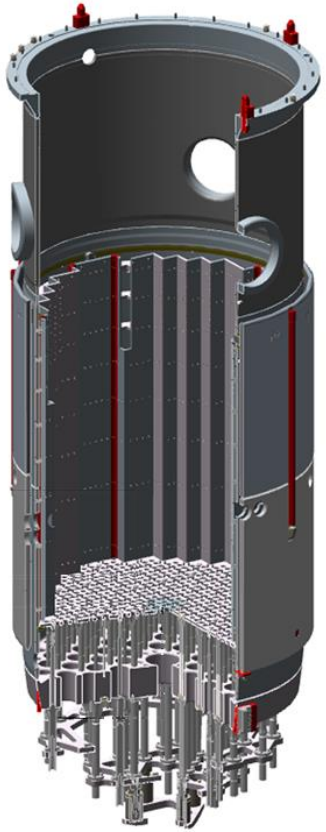
NETWORKING AND COLLABORATIONS 2 (2)

- Collaboration
  - Universities and research organizations
  - Side projects on harvested material
    - MPA – linked to other research projects
    - SCK CEN – linked to other research project
    - VTT – linked to national research programme
    - Workshops on International Harvesting Cooperation
    - WGIAGE/NEA

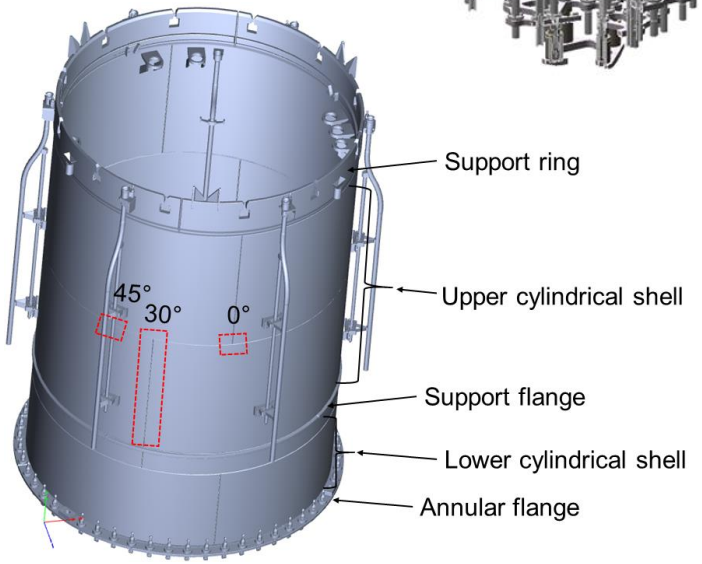
VALUES 1 (2)

- Irradiation embrittlement of RPVs (Task 2)
  - Contributing to the development/validation of predictive models by studying the metallurgical reasons for irradiation embrittlement
- Irradiation embrittlement and IASCC of RPV internals, including welds (Task 3)
  - Improving the understanding of susceptibility to IASCC and reduction in fracture toughness as a function of neutron irradiation
  - Minimizing uncertainties in databases regarding effects of dose rate and void swelling for irradiated austenitic stainless steels and nickel base alloys

PWR RPV internals

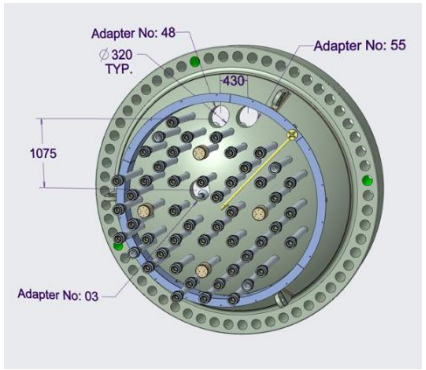


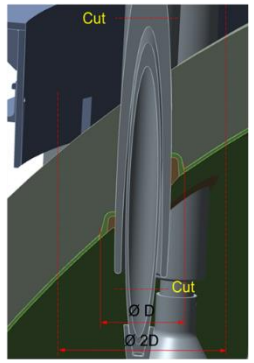
BWR core shroud



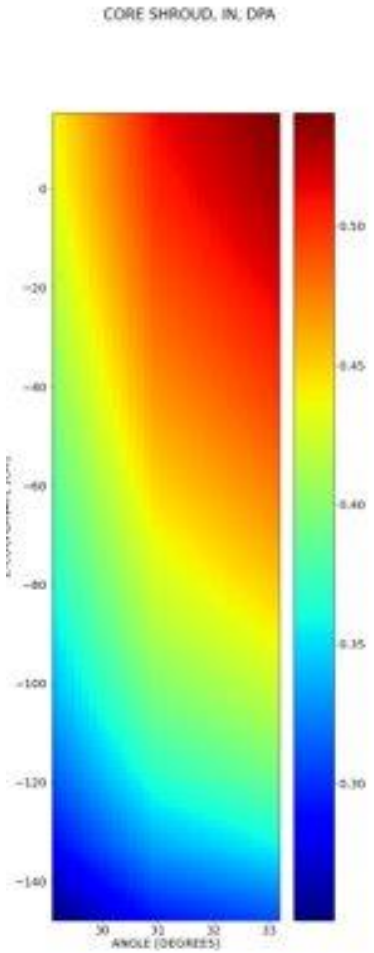
VALUES 2 (2)

- SCC of DMWs and SS welds, and PWSCC resistance and thermal stability of high chromium nickel base alloys (Task 4)
  - Understanding if the long-term effectiveness is adequate where IGSCC mitigation techniques have been utilized
  - Testing addresses gaps in long term stability (LRO), stress relaxation and resistance to SCC of Nickel base and Stainless steels
- Benchmark neutron dose calculations by gamma spectroscopy of harvested material (Tasks 1, 2 and 3)





Alloy 690 CRDM penetrations



CHALLENGES RELATED TO THE PROJECT DEVELOPMENT

It has been challenging to;

- Set the priorities of the work programme in a balanced way maximizing the members various interests
- Receive a timely commitment for participation and sufficient funding for a rather cost-intensive project
- Adapt the work programme to revised time schedules of external activities, such as the harvesting schedules
- Attract some organizations already involved in national/international activities in the same topical area considering the fee allocation principle is based on country
- Coordinate with side-projects

FUTURE NEEDS

- Remaining Gaps
  - SMILE focus on high-priority knowledge gaps identified in e.g., the EPRI (Electric Power Research Institute) materials damage matrix (MDM) studies
  - High priority Gaps not covered in SMILE i.e.
    - Environmental effects on Fatigue resistance; Pressure Boundary Components
    - Thermal and Irradiation Embrittlement Synergistic Effects on CASS
    - Steam Generator Tubes and Internals Wear and High Cycle Fatigue
    - Cass Piping Component Thermal Aging Embrittlement and Long-Term Integrity Assessment
- New findings
  - The project is still early in life and results are to be finalized
- Additional harvested material aiming for life extension beyond 60/80 years
  - Higher doses
  - Further aging
- Incorporation of results in models, plant ageing management and regulations are beyond the SMILE project

CONCLUSION

- The SMILE project leverages a unique opportunity to extract and test real plant aged materials and components with the aim of improving and validating the knowledge of materials ageing phenomena and their kinetics
- Harvesting of materials from decommissioned Swedish BWRs and a PWR
- Establishment of a materials library at Studsvik
- Examination and testing in three experimental tasks:
  - Irradiation embrittlement of RPVs
  - Irradiation embrittlement and IASCC of RPV internals, including welds
  - SCC of DMWs and SS welds, and PWSCC resistance and thermal stability of high chromium nickel base alloys
- Performing research within the framework of an international project is an efficient use of limited resources.
- Because SMILE is an international cooperative project, it enables interaction and exchange of knowledge, experience, etc. among countries, various types of organizations (regulators, utilities, vendors, laboratories, etc.), and age generations.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to all SMILE members for their contributions and financial support. This project was enabled by the contribution of materials, including preparations and harvesting, by OKG Aktiebolag and Ringhals AB.

Thank You for Your Attention!

Studsvik

Panel SESSION 3: Joint Projects for Safety in Operation, Learnings and Perspectives

Dr Marina RÖWEKAMP

Senior Expert, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS), Germany

Dr Sylvain SUARD

Head of Fire Experimentation Laboratory, Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France

Mr Andreas BYE

Programme Manager of the OECD NEA Halden Human-Technology-Organisation (HTO) Project, Chief Scientist, Institute for Energy Technology (IFE), Norway

Ms Lotta NYSTRAND

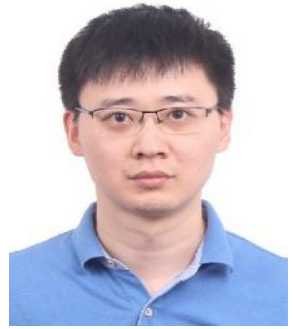
Senior Technical Sales Manager, Studsvik, Sweden

Dr Jean SMITH

Program Manager, International Materials Research, Nuclear Sector, Electric Power Research Institute (EPRI), United States

Mr Raoul AWAD

Deputy Director-General, Federal Authority of Nuclear Regulation (FANR), United Arab Emirates



Mr Wei GAO

PSA Engineer, CNNP Nuclear Power Operations Research Institute (NPRI), China

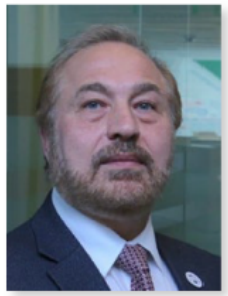
Dr Jean SMITH

Program Manager, International Materials Research, Nuclear Sector, Electric Power Research Institute (EPRI), United States

Dr Jean SMITH is Programme Manager for the International Materials Research (IMR) Program at the Electric Power Research Institute (EPRI). She joined EPRI in 2010 as a Senior Project Manager in the Materials Reliability Programme (MRP), and prior to her current position, she was a Principal Technical Leader in IMR. In both IMR and MRP, her research focused on irradiated materials testing, environmentally-assisted fatigue, and failure analysis support. Previously, Dr Smith was a corporate engineer at Exelon (now Constellation Energy) providing support to the nuclear fleet in the areas of materials degradation management, corrosion prevention, and component failure analysis. She also held a graduate research appointment at Argonne National Laboratory where she investigated the reduction of fatigue life of austenitic stainless steels exposed to light water reactor environments. Dr Smith began her career in the petroleum industry as a metallurgist for Texaco Research and Development supporting all aspects of petroleum production including exploration, refining, and finished products. She holds a Bachelor of Science in metallurgical engineering from Missouri University of Science and Technology and Master of Science and doctorate degrees in materials engineering from Rensselaer Polytechnic Institute.

Mr Raoul AWAD

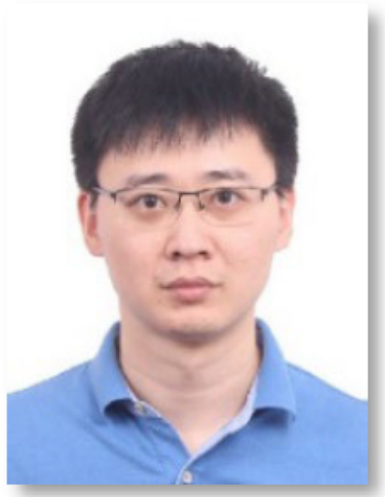
Deputy Director-General, Federal Authority of Nuclear Regulation (FANR), United Arab Emirates



Mr Raoul AWAD is the Deputy Director General leading the Operations Division at the UAE Federal Authority for Nuclear Regulation (FANR) where he is charged with carrying out regulatory and advisory functions in the areas of nuclear and radiation safety, safeguards, and security in accordance with UAE nuclear law. Previously, he was the Director General of Regulatory Improvement and Major Projects Management Directorate at The Canadian Nuclear Safety Commission (CNSC). He was responsible for supporting the CNSC's mission and mandate by managing the licensing of new innovative nuclear technologies including small modular reactors, implementing the CNSC management system, managing the planning and performance process, and co-ordinating cross-cutting corporate improvement initiatives. Until 2016, he was the Director General of Security and Safeguards Directorate. In this capacity, he was responsible for developing, implementing and maintaining programmes to ensure that adequate security measures were in place for the protection of nuclear facilities and nuclear material in Canada and to ensure Canada's conformity with international obligations and commitments. In addition, he was responsible for developing, implementing and maintaining CNSC's Nuclear Emergency Management Programme. Until 2009, Mr Awad worked as Director of the Operation and Engineering Assessment Division in the CNSC, where he was responsible for providing regulatory leadership and expertise on mechanical, civil and material engineering. Prior to 1997, Mr Awad worked on multiple projects related to design, inspection and assessment and multiple research projects. In 1980, Mr Awad completed a mechanical engineering degree and in 2004, he completed a master's degree in Business Administration at Université du Québec à Montréal (UQAM). He has published a number of Technical Papers and Articles in the area of structure integrity and of key safety-related structures, systems, and components.

Mr Wei GAO

PSA Engineer, CNNP Nuclear Power Operations Research Institute (NPRI), China



Mr Wei GAO has been a PSA engineer in the CNNP Nuclear Power Operations Research Institute (NPRI) since 2021. He is currently the team leader for NPRI's risk-informed decision making programme. From 2019 to 2020, he was a graduate research associate at Ohio State University and conducted research on risk and reliability analysis. After graduating, he served as a PSA engineer at the Shanghai Nuclear Engineering Research and Design Institute (SNERDI) from 2011 to 2018. He was the team leader for several Seismic PSA projects. He also developed some PSA-related software, including a fault tree solver and a risk monitor system. Wei Gao holds a Bachelor's degree in nuclear engineering and technology from Harbin Engineering University and a Master's degree in nuclear energy science and engineering from SNERDI.

NEA
NUCLEAR ENERGY AGENCY

NUCLEAR SAFETY RESEARCH JOINT PROJECTS WEEK

Success Stories and Opportunities for Future Developments

9-13 January 2023

Day 4 – **Thursday, 12 January 2023**

Session 4: Joint Projects for Safety in Accidental Situations, Learnings and Perspectives

Moderator: *Hideo NAKAMURA, Japan Atomic Energy Agency (JAEA), Japan, Technical Associate*

Introduction ➢ **Martina ADORNI**, NEA/SAF, Nuclear Safety Specialist

13:00-13:10 ➢ **Hideo NAKAMURA**

13:10-14:00 ▸ **Examples of Containment Thermal-Hydraulics, Mitigation Systems and Hydrogen Risk Management Projects**

THAI/THEMIS, ***Sanjeev GUPTA****, Deputy General Manager, Head of Reactor Safety & Engineering, Becker Technologies, Germany*

HYMERES/PANDA, ***Domenico PALADINO****, Leader Experimental Thermal-Hydraulics group at the Paul Scherrer Institute, Switzerland*

14:00-14:25 ▸ **Example of an Accident Progression and Melt Coolability In-Vessel and Ex-Vessel Project**

ROSAU, ***Jeremy LICHT****, Nuclear Engineer, Principle Investigator for the ROSAU Project, Argonne National Laboratory, US*

14:25-14:50 ▸ **Example of a Source Term Project**

STEM/ESTER, **Christophe MARQUIE**, Deputy Head of the Experimental Department, Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France

14:50-15:00 **Break**

15:00-16:00 ▸ **Panel Discussion:** Perspectives for Nuclear Safety Research Programmes and Frameworks to Enhance Management of Accidents

▸ **Panellists:** Sanjeev GUPTA; Domenico PALADINO; Jeremy LICHT; Christophe MARQUIE; Katharina STUMMEYER, Head of Division, Project Management Agency, Gesellschaft für Anlagen- und Reaktorsicherheit, (GRS), Germany; Won-Pil BAEK, Senior Research Fellow, Korea Atomic Energy Research Institute (KAERI), President of the Korean Nuclear Society, Korea

Day 5 – **Friday, 13 January 2023**

Session 5: Future Needs for International Co-operation in Nuclear Safety Research

Moderator: William D. MAGWOOD, IV, Director-General, Nuclear Energy Agency

Introduction
13:00-13:10 ➢ Didier JACQUEMAIN, NEA/SAF, Senior Nuclear Safety Specialist

➢ William D. MAGWOOD, IV

13:10-13:30 ▸ ***Post-Fukushima Daiichi Co-operative Safety Research Projects and Opportunities for Future Research****, Toyoshi FUKETA, Advisor, Nuclear Regulation Authority (NRA), Japan*

13:30-13:50 ▸ ***Nuclear Innovation-2050: An NEA Initiative to Foster Innovations in the Nuclear Sector****, Fiona RAYMENT, OBE FREng, Chief Science and Technology Officer, National Nuclear Laboratory (NNL), the United Kingdom*

13:50-14:10 ▸ ***Addressing Future Research Prioritisation under the NEA Committee on the Safety of Nuclear Installations (CSNI) Auspices****, Vesselina RANGUELOVA, Deputy Head of the NEA Division of Nuclear Safety Technology and Regulation*

14:10-14:30 ▸ ***Better Addressing the Challenge of Joint Projects Data Preservation and Dissemination****, Didier JACQUEMAIN*

14:20-14:35 **Break**

14:35-14:50 ▸ **Brief summary of the key outcomes of workshop sessions,** Didier JACQUEMAIN

14:50-16:00 ▸ **Concluding panel discussion**

- *What mechanisms to establish priorities for future international co-operation in nuclear safety research? Which frameworks to address future safety research?*
- **Panellists:** William D. MAGWOOD, IV; Jess GEHIN, Associate Laboratory Director, Nuclear Science and Technology, Idaho National Laboratory, United States; Fiona RAYMENT; Jean-Christophe NIEL; Toyoshi FUKETA; Aline DES CLOIZEAUX, Director, Division of Nuclear Power, Department of Nuclear Energy, International Atomic Energy Agency (IAEA); Roger GARBIL, Head of the Fission Section, Euratom Research Unit, Directorate General for Research and Innovation, European Commission

NEA NUCLEAR SAFETY RESEARCH JOINT PROJECTS WEEK: Success Stories and Opportunities for Future Developments

9-13 January 2023

Thank you for your participation today and see you all tomorrow!

Questions: Questions, feedback and suggestions

Event public page: Nuclear Energy Agency (NEA) - NEA Nuclear Safety Research Joint Projects Week: Success Stories and Opportunities for Future Developments (oecd-nea.org)