The Alliance for collaborative R&D towards Safe & Efficient GEN II& III NPPs

On behalf of NUGENIA coordination board
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Pavel Kral (UJV) Vice-Chair
Luis E. Herranz (CIEMAT)
Ales Laciok (CEZ)
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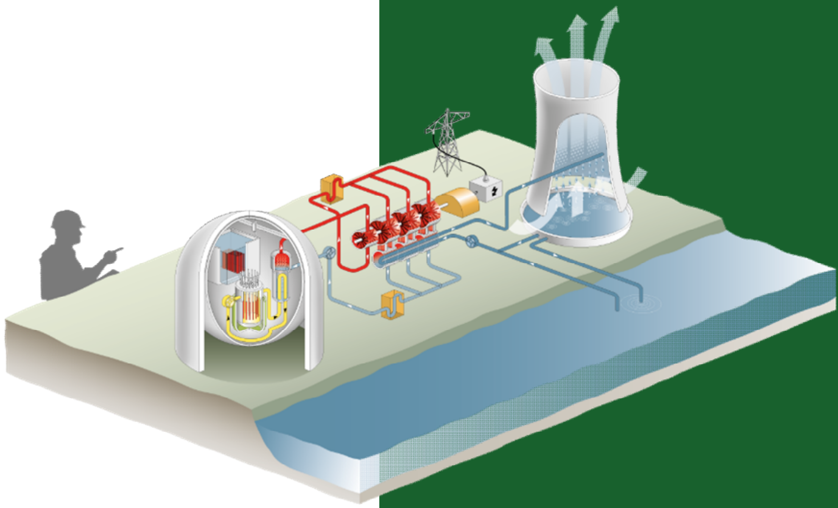
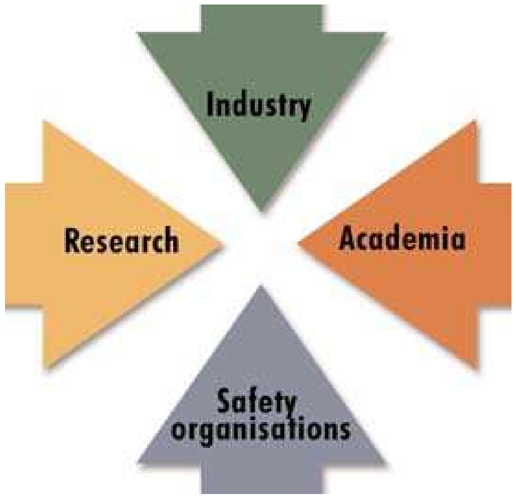


Objectives

Overall NUGENIA objectives



- **Fosters collaboration between industry, SMEs, RTOs, academia and technical safety organisations**
- **Builds knowledge and expertise**
- **Facilitate the emergence of innovation**
- **Achieve projects with high added value to the community,**
- **Maintain and develop the needed skills, competences and infrastructures to tackle the up-coming challenges (LTO, new build, dismantling, ….)**

Technical areas

1. Plant Safety and Risk
2. Severe Accidents
3. Improved Reactor Operation
4. Integrity of Systems, Structures and Component
5. Waste & Spent Fuel Management and Decommissioning
6. Innovative LWR Design & Technology
7. Fuel Development
8. ENIQ - In-Service Inspection and Qualification

Challenges

- ✓ Improve safety in operation and by design
- ✓ High reliability and optimized functionality of systems
- ✓ High reliability of components
- ✓ Improve modeling of phenomena in NPPs
- ✓ Increase public awareness
- ✓ Efficient integration of NPPs in the energy mix
- ✓ Prepare the future to avoid technology obsolescence
- ✓ Performance and ageing of NPPs for long term operation

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Coordination board (charter & composition)

The missions of the NUGENIA Coordination Board include, but are not limited to:

- elaborate, consolidate, update the NUGENIA strategic and technical documents
- contribute to the elaboration, consolidation, update of the SNETP strategic documents
- Initiate, facilitate the creation of project idea
- Propose the mature project ideas for labelling by the SNETP GB
- Monitor NUGENIA's project portfolio

Technical areas

NUGENIA Technical areas (TA) cover different areas of GEN II & III research.

Each technical area is chaired by a TA leader, of by a deputy in case the TA leader is absent and divided in various subareas. Each subarea is chaired by a subarea leader. The meetings of the TAs are organised at least once a year.

TA leaders are elected by the members of the TA. The election mode and the duration of his/her mandate remains at the discretion of each TA, but in the absence of any specific process, the following generic rule should apply: Each TA leader is elected by the identified organisations of the Technical Area for a three-year mandate, renewable.

The missions of the TAs include, but are not limited to:

- Follow-up the progress of projects labelled by SNETP pillars, which fall under their TA;
- Initiate and facilitate the creation of project ideas.

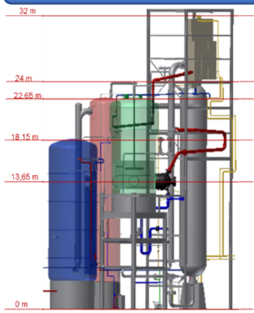
TA1: Plant Safety and Risk

TA/SA	Full TA/SA title	TA / SA leader	Organisation
1.	Plant Safety and Risk Assessment	Pavel Kral	UJV
1.1	Data, Methods and Tools for Risk Assessment	Nicolas Duflot	IRSN
1.2	Deterministic Assessment of Plant Transients	Pavel Kral	UJV
1.3	Impact of External Loads and Hazards	Arja Saarenheimo	VTT
1.4	Effect of Electrical Grid Disturbances	Michel Rioual	EDF
1.5	Effects of Human Errors and Reliability Evaluation	Gunnard Johansson	ES-Konsult
1.6	Advanced Safety Assessment Methodologies	Bernard Chaumont	IRSN
1.7	Design of Reactor Safety Systems	Juhani Hyvarinen	LUT
1,8	Pre-Normative Research	Harri Tuomisto	Fortum

Challenges:

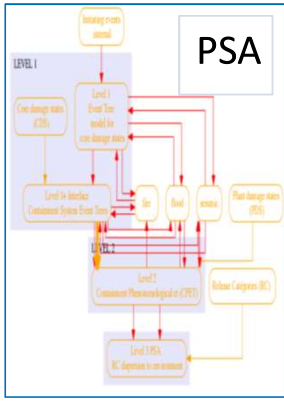
- Comprehensive adoption and use of the Probabilistic Safety Assessment (PSA): risk and margin evaluation for shut-down states, external events, spent fuel pool;
- Deterministic assessment of plant transients: validation of models and tools for reactor physics and thermal hydraulics, coupled multi-physics simulations, containment behaviour, and fluid-structure interactions.
- Impact of external loads (including electrical disturbances) and other hazards on the safety functions.
- Advanced safety assessment methodologies: safety margins and best estimate methods, integrating the deterministic and probabilistic safety assessments.
- Design of new reactor safety systems.
- Pre-normative research

Deterministic assessment

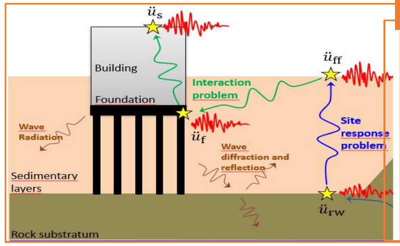


- Multi-physics simulations
- Stratification and mixing in pools and vessels
- Instability in BWR-cores
- 3D flows in RPV
- Gas intrusion
- Spent fuel pool
- Passive safety systems
- Fluid structure interactions (FSI)

PSA



- Earthquake modelling
- Extreme weather conditions
- Simultaneous external events on multi units sites
- Risk on spent fuel pool (SFP).
- Functional dependencies in electrical and safety systems.
- PSA recovery actions (EOP, SAMG, FLEX, external hazards, etc.);
- Hazards in levels 1 and 2 PSA (including SFP)



External Loads and Hazards

- Seismic risk assessment:
  - Probabilistic Seismic Hazard Analysis
  - Access historical data
  - innovative seismic-proof equipment
- Methods for frequency/magnitude assessment
- identify single and multiple external events

Grid disturbance

- Evaluation of impact of new Grid Codes
- Grid disturbance effects
- Plant control and protection systems

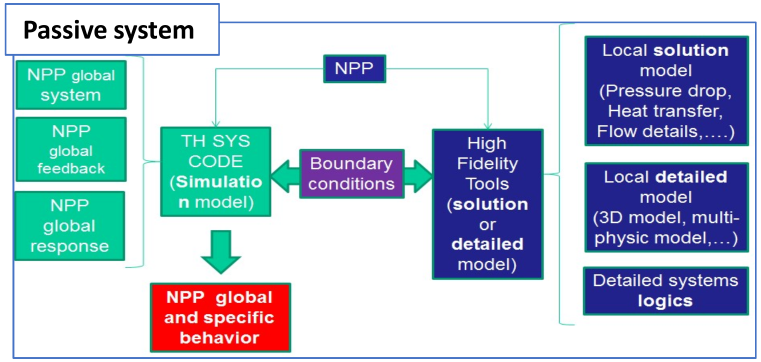
Design of safety systems

- Digital system with integration into existing plants.
- Diversification and robustness of safety systems.
- Passive system for safety functions.
- Reactivity measurements under accident conditions.

Human reliability assessment

- Plant specific properties on HRA
- Appropriate methods for different types of operator actions.
- Human performance data
- Treatment of dependencies & error of commission (EOC)
- Modelling of organizational factors
- Effect of portable equipment from on HRA

Passive system



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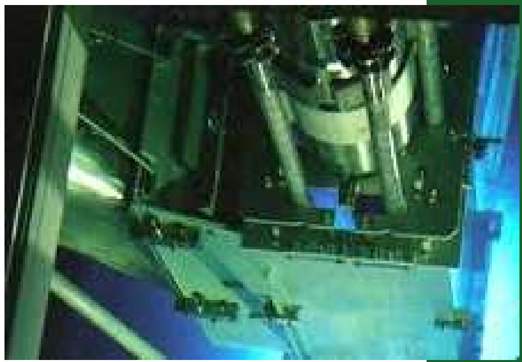
TA2: Severe Accidents

TA/SA	Full TA/SA title	TA / SA leader	Organisation
2.	Severe accidents	Luis E. Herranz A. Bentaib	CIEMAT IRSN
2.1	In-vessel corium/debris coolability	Fabrizio Gabrielli	KIT
2.2	Ex-vessel corium interactions and coolability	Pascal Piluso	CEA
2.3	Containment behaviour, including hydrogen explosion risk	Ivo Kljenak	IJS
2.4	Source term	Sanjeev Gupta	BT
2.5	Severe accidents linkage to environmental impact and emergency management	Federico Rocchi	ENEA
2.6	Severe accident scenarios	Sandro Paci	UNIPI

TA2: Severe Accidents

- **Challenges:**
  - The main safety goal for nuclear power that is to prevent a societal calamity and huge economic loss with an appropriate site evaluation, plant design and management, current NPPs show very low probabilities for Severe Accidents (SA). Even so, these events may happen, as Fukushima and TMI2 accidents demonstrated, and may threaten public health and the environment
  - Despite the progress made in understanding SA unfolding, there are still gaps that need to be addressed to reduce the uncertainties associated to SA safety analysis and to optimize Severe Accident Management (SAM), including long-term.
  - Any investigation to be launched in the coming years should have a direct impact on reducing these uncertainties associated to SA modelling and/or on optimizing SAM, with emphasis to be placed on two aspects:
    - ✓ experimental scenarios as close as possible to SA ones, in terms of materials and prevailing conditions
    - ✓ overcoming limitations set by the experimental scales
  - Not less important, as already happened in the area of thermal-hydraulics, SA modelling should move from single BE calculations (as presently done) towards including uncertainties and sensitivity analyses in a systematic way
  - Given the dimension of the challenges, SNETP is the right workforce to pursue them and international cooperation with Agencies like NEA and IAEA would be instrumental.



MUSA

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TA3: Improved NPPs Operation

TA/SA	Full TA/SA title	TA / SA leader	Organisation
3.	Improved Nuclear Power Plant Operation	Ales Laciok	CEZ
3.1	Improvement of the operation economics	Ales Laciok	CEZ
3.2	Human and organisational factors (HOF)	Jari Laarni	VTT
3.3	Integration of Advanced Digital Technologies	Patrick Morilhat	EDF
3.4	Improvement of core management modelling tools and core monitoring and instrumentation	Radim Vocka	UJV
3.5	Water chemistry and LLW	Martin Krondel	UJV
3.6	Radiation protection	?	IRSN

Goal: Improved performance (incl. economics) of NPPs in changing electricity generation mix and market conditions

Main challenges

- Measures for achieving higher level of flexible operation of NPPs while minimizing negative impacts on lifetime of components.
- Application of risk informed decision making in human factor area and methods, means and tools for improvement of safety culture and operating practices.
- Digital transformation - advanced sensoring (including IoT), high level of automation and robotization, virtual and augmented reality, implementation of digital twins and advanced data analytics and decision making (including machine learning, deep neural network learning and other forms of artificial intelligence).
- Mmaximize cycle energy production with minimum fuel cost while maintaining sufficient margins to improvement of precision of core calculations and better estimation of their uncertainties.
- Advanced and more accurate chemistry control.
- Improvement of radiation protection and reduction of occupational exposures by application of new tools (real time monitoring of received dose, augmented reality tools,..)

TA4: Integrity of Systems, Structures and Component

TA/SA	Full TA/SA title	TA / SA leader	Organisation
4.	System and component integrity	A. Al Mazouzi	EDF
4.1	Integrity assessment	John Sharples	WOOD
4.2	Materials performance and ageing	Inge Uytdenhouwen	SCK-CEN
4.3	Ageing monitoring, prevention and mitigation	Petr Kadecka	UJV
4.4	Equipment qualification, Harmonisation & pre-normative research	Oliver Martin	JRC

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Challenges

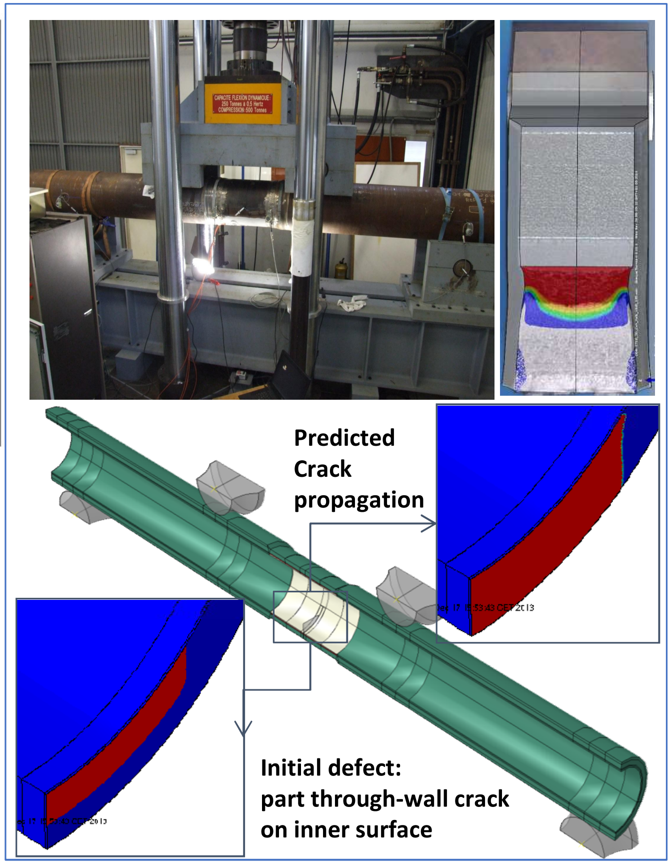
- Develop robust knowledge and methods:
  - ➢ to ensure continuous high integrity and high performance of Systems, Structures and Components (SSCs)
  - ➢ to demonstrate the safety of SSCs with sufficient margins
  - ➢ to increase availability and control the lifetime of SSCs

Materials performance and ageing mechanisms of SSCs:

- Develop robust methods and tools
- Identify and prevent degradation
- Understand, predict and mitigate ageing
- Develop preventive measures and repair technologies.

Monitoring

- Develop new monitoring methods, diagnostics and monitoring simulation tools
- Develop and integrate digital twins



Integrity of SSCs

- Assess nuclear plant components in terms of LTO
- Quantify uncertainty factors
- Develop unified European guidance

Qualification & harmonisation

- Adapt existing codes & standards and methodologies to specific operating conditions
- Remove unnecessary conservatism
- Develop an methodology for qualification of non-nuclear high quality industry equipment
- Support pre-normative research

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TA5: Waste & and Decommissioning

TA/SA	Full TA/SA title	TA / SA leader	Organisation
5	Waste Management and Decommissioning	Anthony Banford	NNL
5.1	Waste management	Anthony Banford	NNL
5.2	Dismantling and decommissioning	Erika Holt	VTT

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TA5: Waste Management & Decommissioning

- **Challenges:**

  (i) to develop enhanced approaches to minimize waste arising, through design operation and decommissioning, i.e adopting a holistic lifecycle approach to waste management and decommissioning,

  (ii) to enhance waste treatment processes & options, and

  (iii) to develop technologies and approaches to deliver decommissioning safer, cheaper, faster and sustainably.

Decommissioning and Dismantling

- Decommissioning strategies, end-points and evaluation
- Plant characterisation, Laser-scanning, 3D modelling,
- Digital planning options for decommissioning –
- Remote operations
- Improve automation of tools

Waste treatment and recycling

- Circular economy
- Lifecycle assessment
- In-situ waste and effluent treatment: Modular, mobile technology
- Challenging wastes
- Sort and segregation
- Technology demonstration

Decontamination & release

- Increase automation in decontamination tasks
- Improve techniques for decontamination
- Intelligent tools for decontamination characterization & control

Storage and Disposal requirements

- Reducing hazard
- Minimizing waste volumes
- Develop recycling options
- Improve disposal options for med /low active waste
- Digital tools

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TA6: Innovative LWR Design & Technology

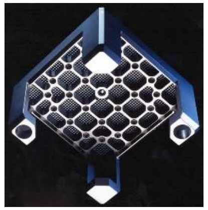
TA/SA	Full TA/SA title	TA / SA leader	Organisation
6.	Innovative LWR design & technology	Eric Hanus	CEA
6.1	Innovative technology for reactor component	Jean Dhers	Framatome
6.2	Innovative LWR concepts such as: High Conversion LWRs, SMR, etc.	Oliver Martin	JRC
6.3	Key success factors for innovative LWR deployment	Gilles Mathonnière	CEA -Itésée
6.4	Public acceptance drivers for new builds	Colette Grundy	NNL

TA6: challenges, ongoing projects and proposals

- **Challenges:**
  - SA6.1: development of new reactor materials, new manufacturing methods, concrete construction, engineering and design tools
  - SA6.2: high conversion LWR, LW-Small Modular Reactors, Supercritical Water reactors
  - SA6.3: market analysis for innovative LWR producing electricity and heat in a moving energy mix
  - SA6.4: development of new methods for public engagement for newbuild

HEA: high entropy alloys, properties and potential for nuclear industry

NUCOBAM: qualification of NUclear COmponent Based on Additive Manufacturing



ELSMOR: towards European Licensing of Small MOdular Reactors

LW-SMR for heat and hydrogen: technico-economics, performances and safety

ECC-SMART: joint European-Canadian-Chinese of SM-supercritical wAter Reactor Technology

SHARE: Social sciences and Humanities in ionising REsearch

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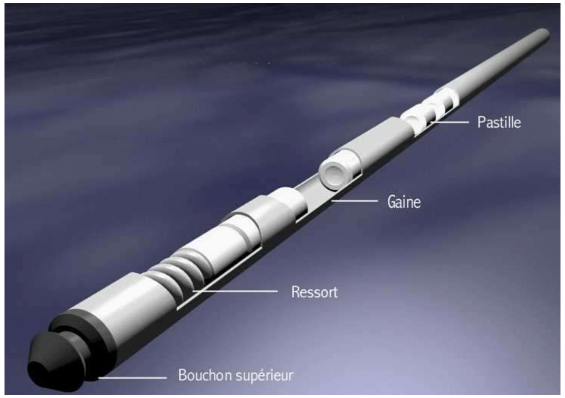
TA7: Fuel Development & Spent Fuel Management

TA/SA	Full TA/SA title	TA / SA leader	Organisation
7	Fuel Development and Spent Fuel Management	Bruno Michel	CEA
7.1	Fuel development for existing, advanced and innovative reactor designs	Dan Mathers	NNL
7.2	Fuel behaviour mechanisms and computational codes	François Barre	IRSN
7.3	Fuel treatment, transportation and interim storage (spent fuel management)	David Hambley	NNL

Increase further safety and resource sustainability for **nuclear fuel elements** in a more varied energy mix



Main challenges

- Extend the validity of the fuel performance codes for new designs, materials and operating conditions
- Guarantee the fuel development of Small Modular Reactors
- Develop Accident Tolerant Fuel elements for the increase of the safety margins under operation and accident conditions
- Improve spent fuel management
- Enable multi recycling of fuels

Multiscale modelling
Physical properties data bases

Fuel evolution
Fission gas behavior
Burnable poisons

Innovative design and microstructure

fuel behavior in transportation and in long term dry storage

Data and behavior of recycled fuel

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TA8: ENIQ - In-Service Inspection and Qualification

TA/SA	Full TA/SA title	TA / SA leader	Organisation
8.	European Network for Inspection and Qualification (ENIQ)	Jose Ignacio Real Rubio	Iberdrola
8.1	Sub-Area for Qualification (SAQ)	Chris Curtis	Jacobs
8.2	Sub-area for Inspection Effectiveness (SAE)	Jens Gunnars	Kiwa-Inspecta

- **ENIQ has been active on inspection qualification since 1992**
  - Qualification Methodology, used in European LWRs and CANDU reactors, and accepted by IAEA and regulators in European countries as recommended practice to follow for inspection qualification
  - ENIQ Framework Document for RI-ISI
  - All ENIQ guidance documents have been revised recently and new versions been published.
- **NDT Qualification Challenges**
  - Qualifying NDT Systems that Make Use of Machine Learning; ENIQ published a position paper on such systems in early 2020 and an ENIQ recommended practice on the same topic will be published soon.
  - Use of Virtual Flaws on Qualification: Practical Trials or Technical Justification
  - Understand the technical barriers that preclude the transport of qualifications between countries and find methods or procedures on how to overcome these. Benchmark project on re-qualifications completed in late 2020.
  - An independent assessment to verify the accuracy of NDT inspection simulation software
  - Use of structural health monitoring systems in NPP to complement ISI
- **RI-ISI Qualification Challenges**
  - Review risk informed pre-service inspection (PSI) for new build and modifications of existing plants.
  - Extension of RI-ISI to all mechanical components, i.e. beyond piping. ENIQ SAE completed a report on this and it will be published soon.
  - Benchmarking with RI-ISI approaches worldwide to harmonize approaches and improve credibility

Take away

Take away

NUGENIA has achieved:

- Strong **involvement** of utilities, vendors, suppliers, safety and R&D
- Annual **work plans** setting priorities, involving public authorities and private organisations
- NUGENIA facilitates the bottom-up emergence of projects within the roadmap
- Balanced cooperation with **international counterparts/SNETP-pillar/other sectors on cross-cutting issues**

…still to do:

- Contribute to preparation of the **next generation** of researchers and engineers
- Future **structuring** within public-private (PPP) and/or public-public partnerships (P2P)
- Increase the **integration of innovation** (shorten the time to market through R&D)
- Development of mutual understanding through **public engagement**

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