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The role of the ETSON Research Group in identifying the R&D needs for safety assessments

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The rationale for ETSON

European Technical Safety Organisations have created a statutory organisation to pursue shared goals

European States and the European Union devoted significant resources over the last decades in order to help build up a sustainable **TSO capacity**.

The creation of ETSON in 2006 aimed at developing the contribution of TSOs to :

- **harmonize nuclear safety assessment practices** in Europe,
- define and implement coherent **European research programmes**,
- share and develop **knowledge and expertise** in safety.

ETSON became an Association (under French law, non-profit association) in **February 2011** in order to develop its activities and implement them more effectively.

ETSON core values

Independence of judgment to ensure that technical analyses and judgments are not unduly influenced by external interests

- Non-profit organisation
- Value charter and Code of ethics to avoid conflicts of interest
- Transparency to national safety authorities and beyond

Holistic approach to safety expertise: Capability to perform safety analysis with a global vision, on a regular basis and with a broad scope

- Provide broad services to regulatory authorities on a regular basis
- Maintain a high level of competence through training and knowledge management
- Conduct R&D programmes
- Exchange information through networking

Joining ETSON requires fulfilling specific criteria.

ETSON key words

- Safety assessment
- Knowledge and expertise
- Research
- Experience
- Best practices
- Harmonization
- Joint development and projects
- Capacity building

https://www.etson.eu/members

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ETSON organisation

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ETSON - BOARD

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VICE-PRESIDENTS - M. Van haesendonck (Bel V), A. Khamaza (SEC NRS),
SECRETARY - J.-C. Niel (IRSN), **TREASURER** - L. Cizelj (JSI)

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JUNIOR STAFF PROGRAMM (JSP)	EUROSAFE PROGRAMME COMMITTEE (EPC)	COMMUNICATION GROUP (ECG)	TECHNICAL BOARD ON REACTOR SAFETY (TBRS)	RESEARCH GROUP (ERG)	KNOWLEDGE MANAGEMENT GROUP (KMG)
Lead: N. Jenner (IRSN)	EUROSAFE Forum Lead: Host Organisation	Lead: D. Mistryugov (SEC NRS)	Lead: O. Dubois (IRSN)	Lead: M. Adorni (Bel V)	Lead: F. Blardat (IRSN)

ETSON - Expert Groups 1 - 14 *(Lead)*

EG1: OEF including Incident and Precursor Analysis (GRS)
EG2: Mechanical Systems (GRS)
EG3: External hazards (man-made and natural hazards) (SSTC NRS)
EG4: Severe Accidents (IRSN)
EG5: Environmemal Safety related qualification of components (IRSN)
EG6: Safety Fluid Systems including auxiliary systems (ENEA)
EG7: Human and Organisational Factors (Bel V)
EG8: PSA (GRS)
EG9: Decomissionning (IRSN)
EG10: Thermal Hydraulic Analyses (Transients, Accidents) (GRS)
EG11: Safety concepts, Defence-in-Depth (CV REZ)
EG12: Core behaviour (operational & accident conditions) (IRSN)
EG13: Emergency Preparedness and Response Group (IRSN)
EG14: Waste Management (IRSN)

Nov 2021

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ERG

ETSON RESEARCH GROUP

ETSON Research Group (ERG)

- **Promotes definition and implementation of nuclear safety research programs in Europe** (since 2000)
  - Identify and prioritize safety research needs → involvement in the regulatory system
  - Defining and launching research programs, accounting for current international R&D → avoid duplication of efforts
  - Disseminating knowledge among ETSON members
  - Elaborate common position on research orientations
  - Share ETSON position with international organizations

→ **R&D is driven by specific regulatory needs**

ETSON Research Group (ERG)

R&D objectives

- Develop and maintain expertise based on safety research
- Access to research and experimental facilities and to up to date scientific information, state of the art codes and methodologies
- Support international community to achieve safety objectives

→ **Develop networking with other TSO**

ETSON Research Group (ERG)

- **ETSON addresses most technical domains relevant for safety**
  - Experienced experimental and modelling teams
  - Operators of experimental research facilities
  - Developer’s team of simulation codes and/or teams that perform their verification and validation
- **Principal domains**
  - Thermal-hydraulics; material testing reactors and fuel behavior; reactor physics and criticality; materials, mechanics, chemistry and corrosion; severe accidents, emergency preparedness and response; uncertainty methods and probabilistic safety assessment; hot laboratories with irradiated materials and research reactors; fires and explosion; waste disposal

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a.

ETSON Research needs in nuclear safety

PROCESS OF RANKING OF R&D PRIORITIES

Research needs in nuclear safety

- **Position Paper on Research needs in nuclear safety, released in October 2011**
  - Prioritize the research needs according to their relevance-to-safety.
  - Account for preliminary lessons from the Fukushima-Daiichi NPP accident.
  - Used for ETSON contribution to the NUGENIA R&D roadmap.
- **ERG views on R&D priorities to implement Directive 2014/87/Euratom**
  - New article 8 introduces a high-level EU-wide safety objective of preventing accidents through defense-in-depth and avoiding radioactive releases outside a nuclear installation.
  - For achieving this objective, the research necessary outcomes are mainly a better knowledge of the involved physical phenomena and its capitalization in methodologies and tools such as simulation codes.

Process of ranking of R&D priorities

- **Strategic orientation on research activities, started in 2017**
  - Update of the ETSON ranking of R&D priority needs to account for the progress of many R&D international projects in diverse frames and the progress of knowledge made by ETSON partners.
  - Basis: list of R&D issues from the 2015 NUGENIA R&D roadmap.
  - Selection of issues (among 150) focusing on the safety aspects.
  - Avoiding the topics where significant R&D is ongoing in an international frame, such as for instance on severe accidents: In-Vessel-Melt-Retention in H2020 (IVMR project) or source term in OCDE frame (STEM2, BIP3, THAI3 projects).

High priority issues

- Results: some scattering of issues but also the possibility to identify issues with a majority of votes → 8 issues were underlined as highest priority (no order of priority among them).
  - Improved thermal-hydraulics evaluation for the existing plants
  - Impact of single or multiple external events
  - Methodologies for beyond design basis assessments
  - Development and validation of severe accident integral codes
  - Spent fuel pool accident scenarios
  - Corium thermophysical and thermodynamic properties
  - Ageing/degradation mechanisms, modelling and materials properties for metallic components
  - Small modular reactors

EUROSAFE 2021: Feedback seminar on research

- NEA concerning data preservation: long term challenge
- ETSON mission evolution proposal: build a bridge between nuclear safety research and safety assessment – Bottom/up approach
- Exchange on uncertainty analysis and related research within ETSON
- Utility of machine learning to better address uncertainties (and save time/money?) but question of reliability of surrogate models
- Addressing safety research priorities for advanced and innovative reactors
- Passive safety features and design extension conditions prior to core degradation
- Gen IV reactor technologies

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b.

ETSON experimental facilities and simulation codes

A few illustrative examples

Thermal-hydraulics (1)

- **Many system codes are used by the ETSON partners**
  - A majority apply TRACE and RELAP5 (distributed by USNRC)
  - A few apply CATHARE (developed by CEA and jointly owned by EDF, Framatome and IRSN)
  - A few apply ATHLET and COCOSYS (part of AC^2 code system developed by GRS)
  - SEC-NRS uses the internally-developed computer code Rainbow-TPP
- **CFD codes**
  - Used to provide more detailed calculation of specific phenomena
  - Interest in the further development of CFD tools has increased: e.g. GRS, is developing OpenFOAM solvers for nuclear safety applications
- **Main use of the codes**
  - Audit & confirmatory calculations, development of code models and input decks
  - Identification of shortcomings in licensing analyses and accident procedures
  - Get insights of potential improvements of accident procedures
  - Strengthen the TSO safety position
  - Support to analytical and experimental activities in international projects

Thermal-hydraulics (2)

- **Experimental facilities**
  - ENEA runs the SPES large-scale facility
  - IRSN runs the THEMA platform for mitigation of reactor accidents (LOCA, SFP)
  - All other members rely on the few facilities that still exist in Europe like PKL (in Germany) and PSB-WWER (in Russia) or in Asia like LSTF/ROSA (in Japan) and ATLAS (in Korea)

- **Challenges for the future**
  - **Maintain knowledge and experts in the field**
  - **Further develop the codes, establish couplings between codes to improve multi-scale and multi-physics capabilities**
  - **Continue to operate the large integral facilities which are difficult to maintain**

SPES Integral Facility, courtesy of ENEA

Severe accidents, emergency preparedness and response (1)

- **Two ETSON members are developing SA simulation tools**
  - AC² consisting of ATHLET, ATHLET-CD, COCOSYS and ATLAS (GRS)
  - ASTEC integral code, considered as a reference code in Europe due to the continuous capitalization of knowledge acquired in Europe (today by IRSN)
  - MC3D multiphase multi-dimensional code for fuel coolant interaction (IRSN)
  - → A large majority members apply the IRSN ASTEC code, and several use AC^2
  - → All ETSON members except IRSN use MELCOR for performing safety studies
- **Main use of the codes**
  - Assess the influence of the plant safety upgrade on meeting SAMG
  - Strengthen the capability for independent severe accident safety assessments
  - Results in support to the review of licensing safety analysis, planning of the emergency response, improving Level-2 and Level-3 PRA methodologies and the source term for the consequence analysis
  - Support to analytical and experimental activities in international projects

Severe accidents, emergency preparedness and response (2)

- **Two ETSON members are developing EP simulation tools**
  - SESAME code system for evaluation of source term released to the environment (IRSN)
  - C3X platform for evaluation of transfers in the environment and of the doses received by the population as a function of meteorological conditions (IRSN)
  - FaSTPro Fast Source Term Prognosis tool for decision-making during emergency situations → Input for the RODOS transport and consequence calculation tool used by the German Office for Radiation Protection (GRS)
- **Main experimental facilities**
  - CHROMIA platform: on chemistry and radiochemistry of fission products (in particular iodine and ruthenium) in severe accidents conditions (IRSN)
  - THEMA platform: PEARL facility devoted to the reflooding of debris beds, at a relatively large scale; and ENACEFF facility on explosion of combustible gases such as hydrogen (IRSN)
  - CERES facility: to test the heat transfer capabilities in case of molten corium in the vessel bottom (MTA-EK)
  - ETSON members participate/ed in OECD projects where facilities like THAI (in Germany), PANDA (in Switzerland) and MISTRA (in France) have been used

Severe accidents, emergency preparedness and response (3)

- **Main challenges**
  - **Despite progress in research, and efforts to capitalize knowledge into integral codes such ASTEC or MELCOR, modelling phenomena for conditions expected in the SA domain are still subject to great uncertainties.**
  - **It is extremely important that the simulation codes and methods are validated for their intended purposes and key research infrastructures still support the reduction of the uncertainties in the phenomena.**

PEARL facility, courtesy of IRSN

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c.

ETSON research projects

Illustrative examples

Benchmarking on Assessment of Radiological Consequences (BARCO): Tasks & Objectives (1)

Task 1

Assessment of the off-site consequences of an accident at the NPP on the territory of Ukraine

Task 2

Modeling of the off-site consequences for the EU/ETSON countries due to the event described in Task 1

Specific Objective 1

- To perform a comparative analysis of the performance of the EP&R calculation tools

Specific Objective 2

- To assess the approaches and methodologies with regard to modeling, data interpretation, use of databases etc.

General Objective: To evaluate EP&R radiological assessments' robustness within the context of the Participants' relevant resources and capabilities

Benchmarking on Assessment of Radiological Consequences (BARCO): Summary & Conclusions (2)

- Reduction of uncertainties in use of radiological assessment tools by different countries where practicable, knowledge of reasons of potential deviations, and implementation of best practice are crucial to improve decision making.
- Code-to-Code Analysis, as well as Matched Pair Analysis, can be applied as an effective approach to data processing in further benchmarking activities.
- Overall conclusions and recommendations regarding the application of the presented atmospheric dispersion modelling and dose projection tools are formed and presented in project deliverables.
- The project participants concluded that **benchmarking activities should be conducted on a regular basis to keep up with all updates in the rapidly growing diversity of the software, and all developments in calculation methodologies.**

Hydrogen Deflagration Benchmark: Objectives (1)

- To be complimentary with the previous benchmarks by addressing more "realistic" conditions:
  - Flame propagation in stratified mixture,
  - Effect of initial temperature on flame propagation,
  - Effect of steam and pressure on the flame propagation
- Extension of the available data base for code validation
- Assessment and improvement of the predictive capability of the participating codes and its users
  - Share experience and knowledge
  - Share fundamental data (laminar flame velocity, ..) needed for modelling (feedback from the previous benchmark)

Hydrogen Deflagration Benchmark: Conclusions & Perspectives (2)

- The adopted stepwise approach allows improving progressively the LP and CFD codes abilities to address flame propagation in homogenous mixture taking into account the effect of initial temperature, pressure and steam.
- Due to the COVID, the schedule was revised to follow the experimental constraint induced by the lockdown periods.
- Nevertheless, the blind results show that:
  - most of the used codes are able to predict qualitatively the pressure evolution inside the vessel.
  - the flame speed maximum value is generally over predicted. This indicates that there are still limitations and weaknesses in the combustion models used in the different codes. These limitations concern the chemistry part, the turbulent combustion model and the coupling between the two models.
- **Further investigation are needed to improve of the combustion models to obtain consistent results between the flame regime and the pressure build-up predicted for a given configuration.**

Conclusive remarks

Conclusive Remarks (1)

- **As a whole, ETSON covers all safety issues with experienced teams and capabilities and can address further R&D challenges**
  - Large and small scale facilities, often unique
  - Development of simulation codes, some being international reference
  - Experienced experimental and modelling capabilities
- **Trainees can be accepted on case by case basis**
- **ETSON allows to concentrate resources, focus on topics of main interest and avoid duplication of efforts**

Conclusive Remarks (2)

- **ETSON is able to keep a high level of competences and expertise**
  - Based on advanced and detailed scientific information
  - In most of the technical domains relevant for safety
  - In a challenging scientific context in continuous evolution
- **ETSON can address further R&D challenges**
  - New materials, fuels, safety systems

R&D is fundamental to support independent and informed safety positions

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Thank you for your attention