ETSON | EUROPEAN TECHNICAL SAFETY ORGANISATIONS NETWORK

Post Fukushima Research in the View of the European TSO Network ETSON

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European TSO Network ETSON

- **Members:**
  - 10 European TSOs: Belgium (BELV), Bulgaria (INRNE BAS), Czech Republic (UJV/CVR), Finland (VTT), France (IRSN), Germany (GRS), Lithuania (LEI), Slovakia (VUJE), Slovenia (JSI) and Switzerland (PSI)
  - 3 associated TSOs: Japan (NRA), Ukraine (SSTC) and Russia (SEC NRS)
- **Objectives**:
  - fostering the convergence of technical nuclear safety practices within the EU and beyond,
  - offer a forum for exchange on safety assessment and research,
  - initiate, implement and conduct common nuclear safety research projects
- **Co-operation on safety research:** implemented by participation in research programs of OECD/NEA, EURATOM and IAEA

Activities of ETSON members related to the Fukushima Daiichi NPP accident

- Operated national nuclear crises centres or supported national crises centres by providing technical and radiological information
- Took part in the definition and conduction of national and European NPP stress tests

⇨ **Obtained deep insights into the technical course of the accident, related human and management aspects, and potential environmental and health effects**

- **Prioritization of research needs since 2010**
  - ETSON published position paper „Research needs in Nuclear Safety for Gen 2 and 3 NPPs“ (October 2011)
  - ETSON contributed to the SNETP report „Identification of Research Areas in Response to the Fukushima Accident” (January 2013)
- **ETSON held workshops** in 2011, 2013 and 2014 dealing with several Fukushima related research subjects

Main conclusions from the Fukushima Daiichi accident and open questions (1)

Main conclusions

- natural hazards were underestimated in the siting an the design of the Fukushima Daiichi NPP and the defense in depth concept was not sufficiently robust
- multiple failure events were not sufficiently taken into account in planning AM
- damages of the infrastructure and hostile environments as well as loss of communication were not appropriately considered in assessing feasibility and effectiveness of AM
- countermeasures were complicated by the fact that several units were impacted at the same time
- major deficits in the regulatory process as well as in the organizational structure

Main conclusions from the Fukushima Daiichi accident and open questions (2)

- **Open questions remained regarding the course of the accidents and their consequences, for instance:**
  - not exactly known through which ways the hydrogen escaped from the PCV and consequently distributed in the building structures.
  - insufficient information on the failure modes and the final states of the reactor pressure and the primary containment vessels
  - potential accident progression in SFP requires deeper consideration

Fukushima related research activities of ETSON

- Relevant research needs in response to the main conclusions and open questions:

1. improve assessment of extreme natural hazards
2. consideration of extreme natural hazards in advanced PSAs
3. full understanding of in-vessel and ex-vessel corium behaviour and improved simulation tools
4. derive options for in-vessel corium retention,
5. studies on hydrogen generation, mitigation, distribution, and explosion,
6. analyse potential severe accident phenomena in spent fuel pools,
7. develop fast running methods for source term assessment,
8. improve international collaboration in emergency preparedness and response
9. studies on on-site accident management
10. including source term mitigation measures,
11. including human factors and organizational aspects under extreme accident conditions
12. radiation protection and epidemiology,
13. clean-up of large contaminated areas and
14. dismantling of damaged NPPs after the occurrence of a SA

not addressed in this presentation

European Severe Accident Reference Code ASTEC (1)

- ASTEC: **A**ccident **S**ource **T**erm **E**valuation **C**ode
  - jointly developed by IRSN and GRS since 1995
  - European SA reference code
  - promoted by European Severe Accident Research Network SARNET
- SA codes provide scientific basis for decisions of regulators and operators on enhancing the safety in the beyond design range

European Severe Accident Reference Code ASTEC (2)

cesam

CODE FOR EUROPEAN SEVERE ACCIDENT MANAGEMENT

CESAM – Code for European Severe Accident Management

- 19 Partners from 11 European Countries + India
- **CESAM** focuses on
  - review of existing ASTEC models with respect to phenomena that occurred during the Fukushima accident,
  - implementation and validation of improved and new models: e.g. BWR, particle bed recombiners,
  - elaboration of reference input decks for the main types of European NPPs including a generic spent fuel pool, and
  - ASTEC calculations for the evaluation of the impact of SAM actions on selected severe accident scenarios.

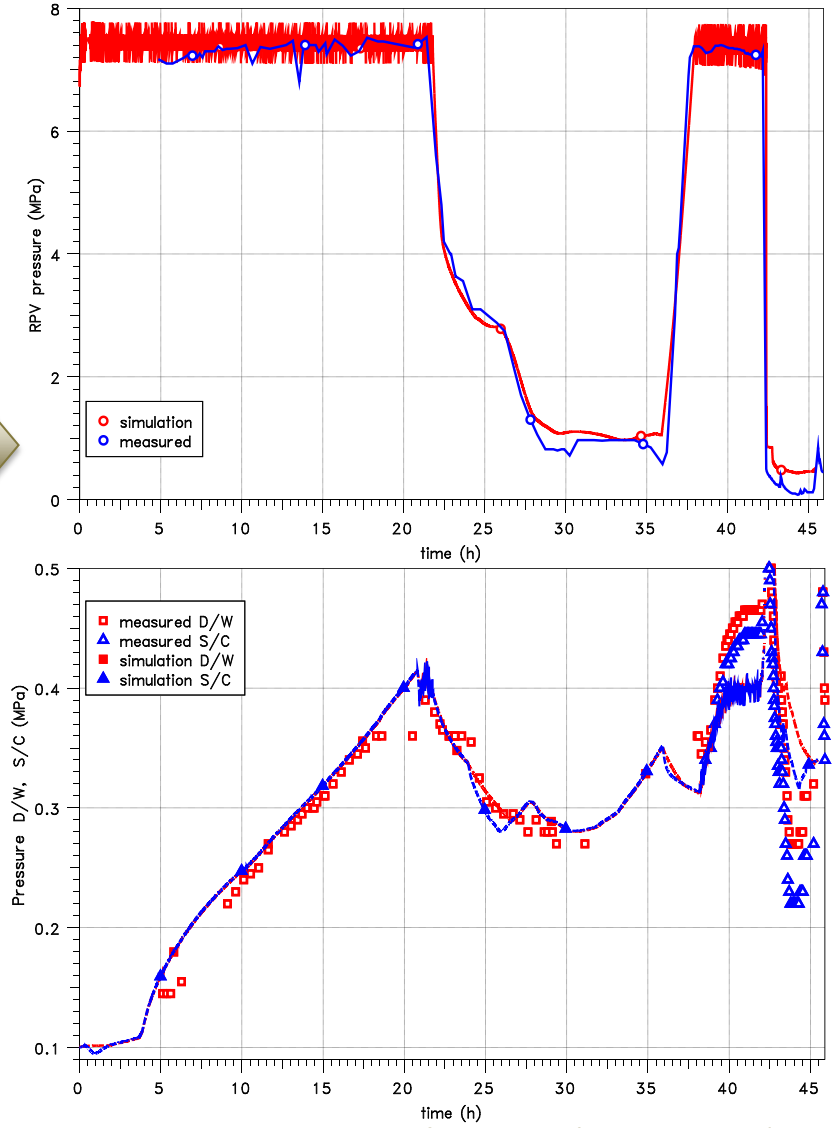
⇨ Support to code users with TSOs, regulators, etc.

OECD/NEA Benchmark Study of the Accident at the Fukushima Daiichi NPS: BSAF (1)

- **The Fukushima Daiichi NPS accident progression is not thoroughly understood.**
- BSAF: started in Nov. 2012
- Aim: analysis of the accident progression at Fukushima Daiichi units 1-3
  - promote understanding of observed phenomena through mutual comparison of code results and with measurements
  - reveal deficits in severe accident models and codes through validation against data available from the Fukushima reactors
  - assist with preparation of a dismantling program: corium removal from PCV
- 13 Participants: … IRSN (France); GRS (Germany); JAEA, NRA (Japan); PSI (Switzerland); NRC (USA); …
- Codes: **SAMPSON** (IAE), **MAAP** (CRIEPI, EPRI), **MELCOR** (JAEA, NRA, KAERI, CIEMAT, PSI, NRC/DOE/SNL), **ASTEC** (IRSN), **ATHLET-CD / COCOSYS** (GRS), **SOCRAT** (IBRAE)

OECD/NEA Benchmark Study of the Accident at the Fukushima Daiichi NPS: BSAF (2)

- BSAF first phase: modelling until stable corium cooling is reached
- Analyses of the Fukushima unit 3 accident sequence using coupled GRS codes ATHLET-CD / COCOSYS
  - calculated RPV and PCV pressure in good agreement with measuring data
  - earlier calculations under-estimated the measured pressure in the PCV during the first 20 hours
  - improved agreement achieved by more detailed modeling of the suppression chamber



Hydrogen phenomena

- **Retention capacity of the containment needs also to be maintained in the presence of hydrogen and other combustible gases**
- Current research activities with ETSON members' involvement concentrate on
  - simulation of the gas distribution in the building compartments considering e.g. the influence of mitigation systems,
  - development of reliable models for hydrogen deflagration and deflagration-to-detonation transition,
  - scaling from experimental facilities to real containments.
- OECD/NEA Project **HYMERES** (**Hy**drogen **M**ixing **E**xperiments for **Re**actor **S**afety)
  - experiments: PANDA (PSI Switzerland), MISTRA (CEA France)
  - main objective of experiments: support enhanced modelling of hydrogen behaviour in the containment by realistic flow conditions

Assessment of the radioactive source term

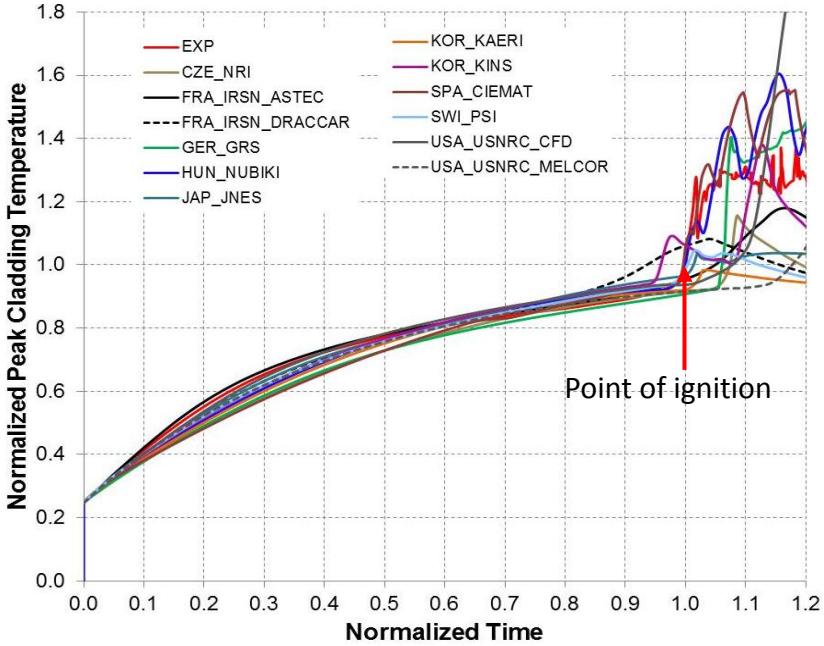
- **Tools are needed for fast and reliable source term prediction during an emergency**
- OECD/NEA benchmark **FASTRUN**:
  - 23 software tools are used by 18 participants
  - tools are evaluated against 5 postulated accident scenarios (2 PWR, 2 BWR 1 PHWR)
  - for each scenario datasets were defined providing information that becomes available not before 1 hour, 6 hours and 1 day after the accident
  - outcome of the benchmark:
    - strengths and weaknesses of the applied tools
    - comparability of the calculated source terms

  ! Benchmark = necessary first step towards international harmonisation of methods and tools for source term assessment

Severe accident phenomena in the spent fuel pool

- **The Fukushima Daiichi NPP accident shed light on potential severe accident sequences in the spent fuel pool**
- Insufficient knowledge about cladding oxidation and burning in the presence of a steam – air – mixture, and about the amount of hydrogen generated under such conditions.
- Zirconium fire investigated in the **Sandia Fuel Project** (OECD/NEA)
- Benchmark showed:
  - good agreement of the calculated central cladding temperatures with the experiment until ignition
  - significant deviation of the calculated temperatures from the experiment after ignition

⇨ Phenomena after ignition not fully understood and further model development required



Natural hazards

- **The Fukushima Daiichi NPP accident revealed the need for the consideration of extreme natural hazards**
- Research is needed to clarify
  - which natural hazards have to be taken into account at certain characteristic sites and
  - which intensity of the natural impact is connected with lower return frequencies than those based to the design
- ETSON members participate e.g. in
  - OECD/NEA Task Group on Natural External Events: specific combination of high winds and floods
  - EU project ASAMPSA_E: systematic extension of the scope of PSA to all potential natural or man-made external as well as internal hazards

Summary

- ETSON members obtained deep insights into different safety aspects of the Fukushima NPP accident.
- ETSON has drawn conclusions about the prior research needs related to the Fukushima accident.
- ETSON made available its expertise to international research projects and benchmarks of OECD/NEA, EURATOM and IAEA.
- Major efforts are spent on the further development of the European severe accident reference code ASTEC.
- ETSON is ready to share the results of these international projects with the TSO community in order to make the best use of research to enhancing nuclear safety worldwide.

Thank you!