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PROBABILISTIC SAFETY ASSESSMENT FOR INTERNAL AND EXTERNAL EVENTS / EUROPEAN PROJECTS H2020-NARSIS AND FP7-ASAMPSA_E

E. Foerster, *evelyne.foerster@cea.fr*
&
E. Raimond, Y. Guigueno, *yves.guigueno@irsn.fr*

IRSN
INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

Context leading to FP7-ASAMPSA_E & H2020-NARSIS projects

- The **Fukushima Dai-ichi nuclear accident** in Japan (March 2011), highlighted a number of **challenging issues** (e.g. cascading event - cliff edge - scenarios) with respect to the application of PSA **questioning the relevance of PSA practice, for low-probability but high-consequences external events.**
- Several initiatives at the international level have been launched (e.g. “stress-tests” in Europe), to **review current practices and assess the NPPs robustness against extreme events** and to identify whether some reinforcements where needed.
- From conclusions of OECD/NEA Committee on the Safety of Nuclear Installations (2013), **risk analyses should**:
  - Include all interactions (physical and logical) and dependency;
  - Include cascading or combinations of events and their impacts;
  - Cover the whole NPP site (not only single buildings).

Context leading to FP7-ASAMPSA_E & H2020-NARSIS projects

- Following Fukushima accident, main bottlenecks identified in PSAs:
  - **PSA process:** not straightforward for all types of external events or in multi-hazard context (cascading or conjunct events).
  - **Extreme events** (i.e. distribution tails) **in a probabilistic context**: an issue, to which extensive MC simulations only provide a partial solution.
  - **Fragility models** to be focused not only on the **physical damage** of components, but also on **functionality loss** of equipment.
  - **Multi-hazard characterization & harmonization** addressed by a few European projects: applicability to complex systems such as NPPs to be demonstrated.

Context leading to FP7-ASAMPSA_E & H2020-NARSIS projects

⇒The **FP7-ASAMPSA_E project** (*"Advanced Safety Assessment Methodologies: extended PSA"*) has been initiated in 2013 to identify good practices for PSA and to accelerate the development of ***"extended PSA"***

⇒The **H2020-NARSIS project** (*"New Approach to Reactor Safety ImprovementS"*) has been initiated in 2017, to **identify gaps** between practice & needs in existing PSA methodologies for external multi-hazard events, and to **improve parts of these methodologies**, based on & complementing other EU projects

Overview of the FP7-ASAMPSA_E project (2013-2016)

- 31 partners: 28 in Europe, 2 in Japan, 1 in US
- Extended PSA definition:

An *extended PSA* applies to a site of one or several NPPs and its environment.

It intends to **calculate the risk induced by the main sources of radioactivity** on the site (reactor core & spent fuel storages, other sources), accounting for **all operating states** for each main source & **all possible relevant accident initiating events (both internal and external)** affecting one NPP or the whole site.

An *extended PSA* shall include a minima:

- **L1 PSA:** scenarios of fuel damage and their frequencies
- **L2 PSA:** scenarios of radioactive releases (frequencies, kinetics and amplitude of such releases)

It could include also a **L3 PSA** (risk for the population, environment and/or economy).

For existing NPPs, linking with the **"Design Extension Conditions" concept** *(as defined by IAEA or WENRA)*

Overview of the FP7-ASAMPSA_E project (2013-2016)

- The project aimed at **helping European** (& non-European) **stakeholders to :**

- **Accelerate the development of *extended PSA***
- **Verify that all *the major contributions to the risk*** induced by the interaction between NPPs & their environment **are identified and managed**.

Share of experience and identification of some good practices on probabilistic risk assessment for NPPs, as well as **gaps** between the existing practices and the needs for PSA applications :

- **100 experts from 31 organizations** (utilities, vendors, service providers, research companies, universities, TSSOs …) from Europe (21 countries), USA, Japan and Canada
- **Link with OECD (CSNI-WG-RISK)**

Overview of the FP7-ASAMPSA_E project (2013-2016)

Achievements:

↗ 27 technical reports published by the partners & state-of-the-art

- **General issues for PSAs** : lessons of the Fukushima Dai-ichi accident, list of external hazards to be considered, methodology for selecting initiating events and hazards, risk metrics, link between PSA and DiD, applications of extended PSA in decision making
- **Methods for the development of external hazard PSAs :** earthquake, flooding, extreme weather, lightning, biological hazards, external explosion, fire, aircraft crash
- **Level 2 PSAs and severe accident management strategies :** nominal power and shutdown reactor states, SFP, external hazards in level 2 PSA, SAM strategies optimization
- **End-Users needs and bibliography**

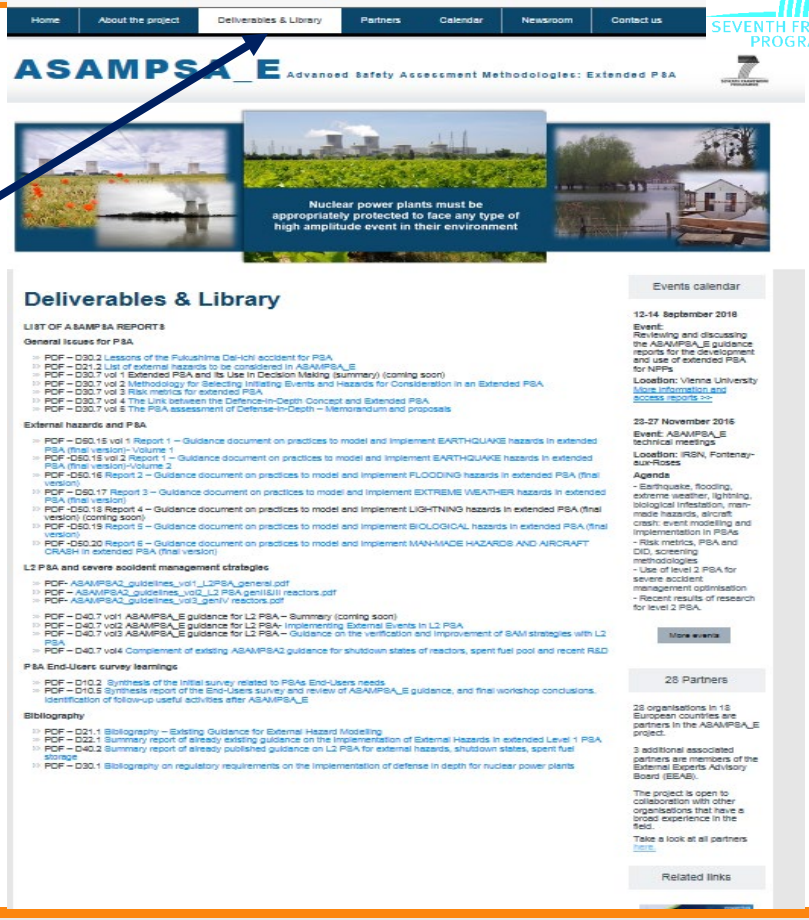
Overview of the FP7-ASAMPSA_E project (2013-2016)

Achievements:

- **All reports are publically available**

http://asampsa.eu

Area : “Deliverables and Library”



Overview of the FP7-ASAMPSA_E project (2013-2016)

- Some of the general lessons learned:
  - **Achieving an *extended PSA*: still a pending objective in 2016**

⇒ **None of the considered NPP sites** had a PSA covering all reactors initial states, all possible sources of radioactivity and all possible types of initiating events (internal / external), and accounted for a multi-unit accident management.

  - **Need for the definition and evaluation of a *global risk metrics*:**

⇒ **A challenge in case of rare extreme natural events** due to huge uncertainties affecting the annual frequency, specially in the worst cases (combined/ correlated events)

  - In case of external hazards, PSA should **model the reactor, but also *wider boundary conditions*:**
    - **neighbouring sources of threats around the site:** sources of flooding and their combinations, presence of other industrial facilities, transports, …
    - **site features**: including the case of multi-unit sites.

⇒ It is **recommended to develop firstly simplified approach** but considering **a quite large area around the reactors**.

Overview of the FP7-ASAMPSA_E project (2013-2016)

- Some of the lessons learned regarding multi-units PSA:
  - **No additional work needed:**
    - the **single unit risk measures** (core (or fuel) damage frequency, large (early) release frequency,…) can be applied
    - the **external hazards screening performed for single unit PSA** can be used
  - However:
    - **Methodological developments on event trees structure and content are needed** to limit size of event trees, introduce site human risk assessment, define multi-unit common cause failures, consider the interface between L1 & L2 PSA
    - **Risk aggregation** as difficult as for single unit PSA (due to highly uncertain data)
    - **Applicability of the same quantitative safety targets** as for single unit PSA **not clearly established**

Overview of the H2020-NARSIS project (2017-2021)

- 18 partners in Europe: academic & research organizations, operators, TSOs
- Main objectives:
  - **Identifying gaps** between practice and needs in **existing PSA methodologies for external events and multi-hazard analyses**
  - **Improving parts of these methodologies**, based on lessons learned & complementing other recent projects, e.g.:

INFRARISK
Novel indicators for identifying critical INFRAstructure at RISK from Natural Hazards

MATRIX
New Multi-Hazard and Multi-Risk Assessment Methods for Europe

ASAMPSA_E
SEVENTH FRAMEWORK PROGRAMME

  - **Considering 4 main primary hazards** & related secondary effects / combinations:
    - Earthquake & secondary effects (excluding tsunamis),
    - Riverine and coastal flooding (e.g. storm surge)
    - Extreme meteorological hazards (high winds, rainfall, droughts)
    - Tsunamis

Overview of the H2020-NARSIS project (2017-2021)

- Addressing a number of challenges:
  - **Better characterization of external hazards,** focusing on those identified as first-level priorities by the PSA end-users community, as well as the **development of a framework enabling the modelling of hazards combinations** (e.g. extreme weather correlated events) **and related secondary effects**, useful for PSA
  - **Better assessment of the fragilities of NPP SSCs:**
    - functional losses,
    - cumulative effects (aftershocks modelling in case of seismic PSA) and interactions (e.g SSI),
    - ageing mechanisms (e.g. damaging phenomena, corrosion) ,
    - human factors
  - **Better risk integration combined with a suitable uncertainty treatment**, to support the risk-informed decision making and a risk metrics comparison within extended PSA
  - **Better processing and integration of expert-based information within PSA:** investigating the applicability and benefits of using modern uncertainty theories to both **represent experts' judgments in flexible manner** and **aggregate them to be used in a comprehensive manner**.

Overview of the H2020-NARSIS project (2017-2021)

- A threefold methodology:
  - **Theoretical improvements** in scientific approach of multiple natural hazards assessment and their impacts, including advance in evaluation of uncertainties and reduction of subjectivity related to expert judgments
  - **Verification of the applicability and effectiveness of the findings** in the frame of the safety assessment for a **generic NPP**
  - **Application of the outcomes at demonstration level on a real NPP** by providing improved supporting tools for **operational and severe accident management purposes**.

Overview of the H2020-NARSIS project (2017-2021)

- Expected key achievements:
  - **Integrated multi-hazard framework** enabling probabilistic modelling of the hazards combinations
  - **Methodological framework for the derivation of multi-hazard-harmonized fragility models**, accounting for functional consequences and/or human factors, able to address the estimation of the secondary impacts in the assessment of external hazards;
  - **Dynamic BN multi-risk modelling approach** for the safety assessment purposes of NPPs, integrating plant complexity (technical, social & organisational aspects) and multi-hazards scenarios, and allowing for risk comparison considering different risk metrics;
  - **Constraining of Expert Judgment**, treatment of parameters, models and completeness uncertainties
  - **Testing the applicability, validity and robustness of the proposed advanced procedures** in the safety assessment practice in situations where empirical data are scarce, incomplete, imprecise and vague (e.g. by using an expert-based knowledge modelling tool).

Conclusions

New horizons for collaborative projects on PSAs in Europe shall be defined promoting and supporting 4 main fields of endeavor:

- **Improvement of methodologies** supporting PSAs (e.g. project such as NARSIS)
- **Extension of the range of PSAs**, to include:
  - initial operating states,
  - initiating events,
  - internal and external hazards,
  - multi-units issues,
  - site environment issues
- **Sharing the knowledge** upon the main and dominant contributions to NPP risk,
- **Improvement and harmonization of uses** of extended PSAs and decision making processes.

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THANK YOU FOR ATTENTION!

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