Severe Accident Research Network (SARNET). Level 2 PSA work package: comparison of partners methods for uncertainties assessment.

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Abstract

The PSA2 work package (PSA2 WP) is a part of the Joined Programme Activity of the European Severe Accident Network (SARNET) related to level 2 PSA methodologies. The general objectives of this work package is to provide a comparison of the different methodologies used or under development for level 2 PSA application by the partners involved in the work package and to promote their harmonization. The PSA2 WP is organized into three main topics: methodologies in general, methodologies for uncertainties assessment, and dynamic reliability methods. The different tasks initially defined for these three topics are shortly described and the partners involved identified.
Attention is then paid on the methodologies used so far by the different partners to assess the uncertainties in their level 2 PSA. A review of partners approaches to assess – as far as possible - the different sources of possible uncertainties is done for the different following topics:

- *uncertainties propagated from the level 1 PSA,*
- *uncertainties (in sense of approximation) due to the binning of the level 1 sequences in Plant Damage,*
- *uncertainties related to the structure of the Accident Progression Event Tree,*
- *uncertainties related to the probabilities of stochastic events (system failure or recovery, human actions, some physical phenomena such as ignition of hydrogen combustion or triggering of steam explosion),*
- *uncertainties elated to the modelling of the different physical phenomena,*
- *uncertainties related to the cut-off frequency used in the probabilistic quantification of the Accident Progression Event Tree;*
- *uncertainties related to the binning of level 2 sequences in Release Categories (variables not considered, values of eventual continuous variables).*

First conclusions of the comparison are given in terms of improvement needs and then of perspectives of the work for the following period of work.

1. Introduction

SARNET is a project supported by the **6th Research and Technology Framework** Programme developed by the European Commission which starts in April 2004 and is coordinated by the "Institut de Radioprotection et de Sûreté Nucléaire" (IRSN) [1].
49 European organisations network in SARNET (**Severe Accident Research Network of Excellence**) their capacities of research in order to reduce the most important remaining uncertainties for enhancing, in regard of Severe Accidents (SA), the safety of existing and future Nuclear Power Plants (NPPs). This project has been defined bearing in mind the necessity to optimise the use of the available means and to constitute sustainable research groups.
To reach these objectives, all the organizations networked in SARNET contribute to a so-called Joint Programme of Activities (JPA), which can be broken in several elements:

- Implementing an advanced communication tool for fostering exchange of information;
- Harmonizing and re-orienting the research programmes, and defining commonly new ones;
- Analysing commonly the experimental results provided by research programmes in order to elaborate a common understanding of concerned phenomena;
- Developing ASTEC integral computer code, which capitalizes in terms of models the knowledge produced within SARNET;
- Developing Scientific Databases, in which all the results of research programmes are stored;
- Developing a common methodology for level 2 Probabilistic Safety Assessment (PSA2) of NNPs;
- Developing educational courses and text/source books;
- Promoting personnel mobility between the various European organisations.

The general objective of the SARNET PSA activity is to compare, to improve and to harmonize the methodologies used for developing level 2 PSA within European countries and to share effort to develop advanced tools, as far as they are required. This objective is based on the statement that different approaches are used in Europe, more or less derived from what has been implemented in the USA.
Activities have been set up into three sub-projects performed in parallel, each of them involving some active partners and being coordinated by a project leader. Overall, 17 organizations from 13 countries are involved in this activity, 3 being from Associated Countries (see table 1)..
The program proposed for the first period has been mainly dedicated to the exchange of information and the identification of technical points, where complementary work of common interest could be performed in a second stage. First sub project (WP5.1) concerns comparison of Level 2 PSA approaches and identification of improvement needs. Second sub-project (WP5.2) deals with comparison and improvement of methodologies for the assessment of uncertainties while last one (WP5.3) aims at improving event tree methodology using dynamic reliability techniques.

Table 1: partners involved in PSA2 WP (WP 5)

Partners	WP5.1: methods	WP5.2: uncertainties	WP5.3: dynamic reliability
IRSN (France) - Institut de Radioprotection et de Sûreté Nucléaire (coordinator)	X	X	X
AVN (Belgium) - Association Vinçotte Nucléaire	X		
CEA (France) – Commissariat à l'Energie Atomique		X	X
CSN (Spain)- Consedo de Seguridad Nuclear	X	X	X
EDF (France) - Electricité de France	X	X	X
FRA ANP GmbH (Germany) - FRAMATOME ANP GmbH	X	X	X

Partners	WP5.1: methods	WP5.2: uncertainties	WP5.3: dynamic reliability
GRS (Germany) - Gesellschaft Für Anlagen und Reaktorsicherheit	**X**	**X**	**X***
INR (Romania) - National Autonomous Company for Nuclear Activities Research	**X**		**X**
JRC (Belgium) - European Commission – Directortae General Joint Research Centre		**X**	
LEI (Lithuania) - Lithuanian Energy Institute	**X**	**X**	**X**
NNC (United Kingdom) - National Nuclear Corporation	**X**	**X**	
PSI (Switzerland) - Paul Scherrer Institut	**X**	**X**	**X**
SWP (Sweden) - SWEDPOWER AB	**X**	**X**	
TUS (Bulgaria) - Technical University of Sofia	**X**	**X**	
ULB (Belgium) - Université Libre de Bruxelles			**X**
UJV (Czech Republic) - Ustav Jaderneho Vyzkumu	**X**	**X**	
VEIKI (Hungary) - Institute For Electric Power Research Co	**X**	**X**	

* Observer up to now

More precisely, objective of sub project 5.2 is to identify which types of uncertainties have been considered in existing level 2 PSA amongst the partners, to compare the methods used to assess them and, in a second stage, to improve them and to achieve a certain level of harmonization amongst the partners.
Actually, the development of level 2 PSA involves different sources of uncertainties:

- Uncertainties propagated from the Level 1 PSA, related to the frequencies of Level 1 sequences;
- Uncertainties (approximation) due to the binning of Level 1 sequences in Plant Damage States (variables not considered in the interface, values of continuous interface variables);
- Uncertainties (lack of completeness) related to the structure of the Accident Progression Event Tree (events not considered, order and chronology of events);
- Uncertainties (lack of knowledge) related to the probabilities of stochastic events (system failure or recovery, human actions, some physical phenomena such as ignition of hydrogen combustion or triggering of steam explosion);
- Uncertainties (lack of completeness) related to the modelling of physical phenomena;
- Uncertainties (lack of knowledge) related to the values of the parameters of the physical models;
- Uncertainties (approximation) related to the cut-off frequency used in the probabilistic quantification of the Accident Progression Event Tree;
- Uncertainties (approximation) related to the binning of Level 2 sequences in Release Categories (variables non considered, values of continuous variables).

Other part of the work already performed in the frame of the SARNET WP5.2 consists in reviewing and describing possible methods for uncertainty and sensitivity analysis in support to Level 2 PSA. Information on this subject may be found in [2].

To establish the status of partners methods and then to compare these methods, two questionnaires were first established:

- a general questionnaire on level 2 PSA methods addressing, concerning uncertainties assessment, the different sources of uncertainties and the methods used to assess them (to be described in general terms),

- a second questionnaire addressing specifically the different elements of methods related to uncertainties assessment on level 1 / level 2 PSAs interface, Accident Progression Event Tree (APET), releases assessment.

Answers to these questionnaires were first provided by the partners, then compiled and compared. In the following paragraphs, main conclusions of the work performed so far are summarized. Paragraph 2 gives an overview of the level of details of partners approaches. Paragraph 3 concerns propagation of level 1 PSA uncertainties to level 2 PSA. Paragraphs 4 and 5 respectively address methods used by the partners to assess uncertainties in the APET and to evaluate the radioactive releases.

2. General comparison of partners approaches

For the sake of classification of the methods used by PSA level 2 participants, two schemes have been introduced, based on different criteria. The first criteria was related to quantification methods which were qualified as:

1. None or very coarse
2. Mathematical – assignment of arbitrary distributions,
3. Physical-mathematical – process-phenomenon oriented.

The second criteria concerned propagation methods:

1. Not addressed,
2. Uncertainties are discussed in the level 2 PSA but are not quantified or are dismissed as of little consequence or interest,
3. The treatment is implicit, i.e. uncertainties are discussed but not quantified, and rather they are addressed with sensitivity analyses, mostly based on severe accident codes calculations,
4. Explicit, however, only accident progression uncertainties are addressed and quantified, and propagated to the assessment of uncertainties in release categories (RCs),
5. Explicit, quantification of uncertainties is performed also for the frequency of plant damage states (PDSs),
6. Explicit, all uncertainties are propagated from the frequencies of PDSs to the magnitude of source terms (STs).

On the basis of these classifications, the following table have shown the summary of the approaches reported by the SARNET participants to the PSA Level 2 task. The last two entries in the table are for participants who have not yet performed or reviewed a full Level 2 PSA, but are either planning one or have prepared a concrete plan/proposal.

Table 2 Approaches reported by the SARNET participants

Participant	Quantification method	Degree of complexity	Comment
AVN	1	1	Uncertainties not assessed up to now
EDF	2	2	The uncertainties are not quantified in the APET. Distributions of the split fraction assigned to each node are the average of several Solomon quantifications using for some physical variables arbitrary distributions or coming from results of some MAAP calculations

Participant	Quantification method	Degree of complexity	Comment
FRA ANP GmbH	3	5	Uncertainties considered in APET quantification originate from operator actions, branch probabilities of complex physical phenomena and availability of systems. Some branch probabilities are generated using a Monte Carlo method based on distribution functions for loads and load bearing
GRS	2	4	Uncertainties related to probabilities of stochastic events represented by a range of probabilities of the respective branching nodes. Uncertainties related to modelling of physical phenomena are taken into account in the form of uncertainty range based on experts judgments applied on MELCOR (and other codes) calculations results – including various parametric runs. Dynamic reliability methods developed and used for a specific case as a way to go beyond limitations of classical methods
IRSN	3	2 & 5	Uncertainties due to physical phenomena only assessed (only for physical phenomena leading to early containment failure). Distribution functions of physical variables values – or surface responses - included in the APET and quantified – or determined - by systematic runs of severe accident codes or specific codes (using distribution functions of uncertain parameters of these codes)
LEI	1	2	Uncertainties are considered qualitatively. Uncertainties are not quantified, but high degree of conservatism is applied to deal the uncertainty problem.
NNC	3	2	Detailed review of key sources of uncertainties with the conclusion that they could not be systematically dealt with an integrated uncertainty analysis. Systematic sensitivity analysis performed
SWP	1	2 & 3	Using Risk Spectrum, uncertainties in APET are quantified considering uncertainties on initial conditions for a specific phenomenon, on the occurrence of the phenomenon, and on its consequences in the PWR studies
TUS	1	2 & 3	Considered and discussed in the process level 2 PSA development but not explicitly quantified at the moment
UJV	1	2	Uncertainties in accident progression addressed by sensitivity analyses. No systematic propagation
VEIKI	2	4	Uncertainties of physical phenomena in APET are quantified using MAAP driven by a Monte Carlo method. Uncertainties are propagated from the frequencies of PDSs to the containment state (release category). Also are considered the uncertainty on systems recovery
INR	Note already defined	2	It would appear that uncertainties may be addressed through systematic sensitivity studies using MAAP 4
PSI	3	5	Models proposed are offspring's of NUREG-1150.

It may be concluded, from this table, that participants to this task of the SARNET project show the full spectrum of solutions which have been suggested over the years to overcome this conundrum. The sources of uncertainties, i.e. stochastic and modelling, are also dealt with by the participants at different levels.

To conclude this first global comparison of partners methods, it was considered as important to wonder if the state of the knowledge base on severe accident phenomena is still such that, according to one partner view : "The benefit of a statistical uncertainty analysis [using traditional level 2 methodologies] for the level 2 PSA [may be] investigated but the results [are probably] not sufficiently convincing". An orientation to answer, at least partly to this question, would be to compare the results obtained respectively with dynamic reliability methods and with classical approaches and this is the purpose of another task undertaken in the frame of SARNET.

3. Uncertainties propagated from level 1 PSA

The following table summarizes the partners methods for level 1 PSA uncertainties propagation to level 2 PSA.

Table 3: summary of partners approaches to assess level 1 PSA uncertainties and to propagate them into level 2 PSA

Partner	Level 1 uncertainties	Level 1 to level 2 propagation
EDF	Uncertainties on input data considered	Uncertainties on PDS frequency available but not propagated
FRA ANP GmbH	Normal procedure at Framatome is integrated level 1/level 2 PSA. Uncertainties considered in level 1 PSA concern component failure, initiating events, operator actions and are propagated to level 2 PSA	
GRS		Uncertainties on PDS frequency propagated to level 2 analysis. Effect of the selection of PDS attributes not investigated
IRSN	Uncertainties on input data (components reliability, initiating events, human reliability) considered	Uncertainties on PDS frequency available but not propagated
LEI	Uncertainties on reliability data considered. Effect of use of generic data rather than specific ones investigated. Probability of human errors also considered	Uncertainties on PDS frequency available (not for last level 1 PSA version) but not propagated
NNC	Several sensitivity analysis performed	Review of NUREG 1150 methods. Key sources of uncertainties investigated - modelling, parameter values and completeness uncertainties - and estimated not to be systematically dealt with within an integrated uncertainty analysis. Sensitivity analysis were then performed
SWP	Uncertainties in the present interface due to - parameter distribution uncertainty not totally addressed due to a partly manual process, - lack of knowledge and simplifications not taken into account Integrated level 1 / level 2 study under development	
TUS	Uncertainties on parameters value (data), modelling components and human errors considered.	Uncertainties propagation considered relevant to assess the availability of safety systems considered in the event sequences, for operator actions and human reliability analysis related to the PDS.

Partner	Level 1 uncertainties	Level 1 to level 2 propagation
UJV	Uncertainty on components failure and human errors considered. Epistemic uncertainty addressed using sensitivity studies	Different levels of refinement of the interface attributes used for the different revisions of the study. Uncertainties on CDF not propagated to level 2
VEIKI	Uncertainties on components failure and human actions considered	Uncertainty on PDS frequency determined using the minimal cut sets. Distributions for component failure rate taken from level 1 PSA with extension to systems not considered in level 1 PSA. Sensitivity analysis on primary bleed at 550°C core outlet action (introduced in level 1/level 2 interface)

From table 3, it appears that:

- most of the partners:
    - perform separate level 1 / level 2 PSAs using different probabilistic software,
    - take into account in level 1 PSA uncertainties on components failure and human actions,
    - but didn't propagate the uncertainties to level 2 PSA.
- for partners who propagate the level 1 PSA uncertainties to level 2 PSA, this may be done:
    - automatically in case of an integrated level 1/level 2 PSA,
    - by the mean of PDS frequency distribution in the other cases.

No partner tries to estimate the uncertainty due to the binning of level 1 sequences into PDS (selection of different PDS attributes effect). This uncertainty may arise due to a coarse discrimination of interface variables.
The modelling uncertainties which seem an important issue for level 2 PSA do not appear, according to the different partners approaches, a relevant issue for level 1 PSA.

4. Uncertainties considered in the Accident Progression Event Tree (or Containment Event Tree)

Different elements of the first questionnaire concern uncertainties that could be considered in the APET (or CET – Containment Event Tree) quantification:

- physical phenomena omitted or neglected,
- uncertainty on human actions,
- effect of cut off frequency during APET quantification.

Also general questions on methods were addressed such as physical phenomena considered as aleatory or not.
Concerning the issue of physical phenomena, partners' answers lead to the following list of phenomena that have not been always considered in the APET or CET:

- primary pumps operating during the initial phase of the accident,
- accident management other than reactor cooling system (RCS) depressurisation,
- large initial loss of containment isolation or failure of containment penetration and hatches, liquid leak from the containment,
- hydrogen burn in the primary system,
- core recriticality in BWR after core melt due to core flooding (including in case of cooling by non borated water),
- late core reflood,
- structural behaviour of the steam generator tubes,

- in vessel steam explosion (generally neglected because considered as leading to containment damage with a very low probability),
- DCH after vessel lower head rupture due to an in vessel steam explosion,
- vessel breach after core melt (cooling of the vessel from outside),
- ex vessel steam explosion,
- sump or wall heat up due to fission products.

The corresponding uncertainties have not been quantified. It is also interesting to point out that, for the same physical phenomena, different consequences may be investigated and then considered in the APET. A typical example of such phenomenon is the vessel breach at high or intermediate pressure, phenomenon for which different kinds of consequences have been identified by the partners such as:

- Direct Containment Heating (DCH) and associated consequences,
- Hydrogen burning (linked or not to DCH),
- Ex vessel steam explosion and associated consequences,
- Vessel rocketing,
- Containment failure (due to RCS displacement),
- Fission products re-suspension.

Another approach to establish similar list of phenomena would be to compare the list of phenomena considered by one of the partners and not the other ones. For example, one partner considers as important the following issue: "*containment threat due to direct core melt attack regarding ventilation ducks and sump design*" which has not been considered by other partners. Another example is the influence of initial defaults on steam generator tubes on the failure of these tubes which has been reported to have been analyzed only by one partner. So, the list above must be, of course, considered very carefully and probably not complete.

Another issue, still concerning physical phenomena, is the aleatory character of some phenomena. According to one partner, the "*aleatoric uncertainty of physical processes considered in the event trees appears when the actual probabilistic values of the occurring events (branching) are specified in the course of the event tree quantification*". In another partner approach, two physical phenomena were considered as aleatory: steam explosion triggering and initiation of hydrogen burning (hydrogen passive auto catalytic recombiners not already installed for the version of the level 2 PSA considered) and a probability has been associated to the corresponding APET events. Sensitivity analyses were performed to evaluate the impact of the corresponding probabilities. In another partner approach also, two uncertainties have been included directly in the APET in the form of probability distribution: in-vessel hydrogen source distribution for each scenario and containment and cavity strength (random variables with distribution functions).

The uncertainty (in sense of approximation) introduced by the cut off frequency during APET quantification has been estimated by some partners. All of them agree that the corresponding uncertainty is low. This statement is due to the use of a low cut-off frequency (generally equal of less than 10^{-10} reactor year) which is enabled by the probabilistic software performances.

Concerning the uncertainty (still in sense of approximation or lack of completeness) due to time management in the APET or more generally to the coarse structure of the APET, it is clear that the APET is a model which is always incomplete. According to one partner experience, "*decisions have to be made where to neglect and to simplify parts of the real word situation… because of limited time and knowledge*". Up to now, the corresponding uncertainty, which is related to dynamics – stochastic interactions and dependencies poorly addressed by the classical event tree method has not been quantified. A way to quantify it – or at least part of it for specific situations or phenomena - is to use dynamic reliability methods and to compare the results obtained by the two approaches. This would allow an assessment of the quality of the results from classical methods. On the other side, some partners try to limit the corresponding uncertainty repeating questions – like hydrogen combustion at different moments and under different conditions - in the APET.

The question of uncertainty on systems behaviour has been addressed in detail by only two partners:

- For one of them, the availability of systems is assessed in a similar way than done for level 1 PSA (integrated level 1 / level 2 PSA),
- in the case the other partner approach (for safety injection and spray systems recovery), the failure probability of recovery includes the probability that a minimal cut-set for a given PDS contains non-recoverable failure and the probability that personnel fails to recover the system. As the context dependency of this last probability was not taken into account, sensitivity analysis were performed to assess its influence.

No separate assessment of corresponding uncertainty has been provided.

Some conclusions have been drawn from the previous considerations and also considering table 1:

- the diversity of partners approaches to assess (or not) the uncertainties in APET quantification,
- the partners' interest for the uncertainties due to physical phenomena, but no quantification of the relative importance of uncertainties due to human actions or systems reliability is given,
- the feasibility of a rather systematic assessment of the uncertainties for recently developed level 2 PSA using:
  - systematic severe accident code calculations,
  - may be complementary expert judgments interpretation,
- nevertheless, there is no clear estimate of the importance of uncertainty due to the completeness of the study.

Also, partners definitely agree that two sources of uncertainties are to be considered: uncertainties due to the aleatoric nature of some phenomena or events (typically human actions) and uncertainties due to lack of knowledge (also called epistemic uncertainties).

5. Uncertainties considered for the releases assessment

Similarly to physical phenomena that should be included in the APET and have not yet been considered, partners also gave information on phenomena not considered for the releases assessment:

- release of low volatile species from the fuel in the late phase,
- air entrance inside the vessel and associated consequences (ruthenium release),
- iodine chemistry modelling uncertainties,
- influence of hydrogen combustion or recombination on the iodine and aerosol behaviour,
- releases during Molten Corium Concrete Interaction,
- fission products re-vaporisation from the boiling sumps,
- all re-suspension mechanisms,
- limitation of filters efficiency in case of large amount of steam,
- releases paths ways in the environment (through surrounding buildings).

From this list partners generally agree that the most important uncertainty concerns the volatile iodine behaviour which is considered as unknown or at least poorly modelled so that several partners estimated that the corresponding uncertainty cannot be determined.

Following table summarizes partners approaches to assess uncertainties on releases for those who have addressed, at least partly, this issue.

Table 4: summary of partners approaches to assess uncertainties on releases

<table>
<tr><td>Partner</td><td>Uncertainties due to binning of level 2 sequences into releases categories</td><td>Uncertainties in source term assessment for a given Release Category (RC)</td></tr>
<tr><td>EDF</td><td colspan="2">Uncertainties not assessed. Consistency of the releases for the different scenarios with the different release categories investigated</td></tr>
<tr><td>FRA ANP GmbH</td><td colspan="2">Sensitivity analysis performed (for one PSA) to determine
- the impact of the choice of a specific scenario to represent a release category (considered as binning uncertainty),
- the impact of some MAAP code parameters,
- the impact of the filter efficiency, the condition of spray system activation, the retention in adjacent building (case of interfacing LOCA).
Uncertainties on source term due to the choice of a specific scenario estimated of an order of magnitude while uncertainties on source term assessment for a given scenario estimated of a factor 5 (excluded some phenomena effect (re-suspension) or lack of knowledge on iodine behaviour)</td></tr>
<tr><td>GRS</td><td>No direct assessment. It is considered that corresponding uncertainties are included in bandwidth associated to the releases fractions of the different release categories</td><td>For some of the 10 RC, MELCOR calculations performed to assess releases fractions, other ones estimated by experts' judgments. About an order of magnitude uncertainty expected. Uncertainty of gaseous and organic forms of iodine estimated not quantifiable</td></tr>
<tr><td>IRSN</td><td>Analysis of binning uncertainties:
- specific "uncertain parameters" (duration of the different phases), introduced and their effect quantified (one order of magnitude effect),
- two levels of binning used (about 1000 of detailed RCs gathered in about 25 main RCs) Two orders of magnitude may separate releases of different RCs associated to a same main RC</td><td>Analysis of uncertainties on source term:
Several uncertain parameters introduced in a simplified dedicated model coupled with the APET. Parameter distribution reflects lack of knowledge (containment break size, fission production emission, deposition and resuspension during the different phases, gaseous iodine behaviour). Very large dispersion of the volatile iodine releases distribution obtained (two orders of magnitude).</td></tr>
<tr><td>NNC</td><td colspan="2">Same approach as for APET phenomena (review of key sources of uncertainties estimated to be impossible to be systematically dealt with an integrated uncertainty analysis and then systematic sensitivity analysis performed)</td></tr>
<tr><td>SWP</td><td>Uncertainties not assessed. For one level 2 PSA, it was estimated that an order of magnitude may be obtained between LOCA and other sequences grouped in the same RC.</td><td>Two different types of release categories defined: sequence based and source term based RC. Uncertainties were estimated only for first ones and divided in two parts (combined to define uncertainty of releases for each RC):
- parametric uncertainties (variation of MAAP parameters effect)
- "lack of completeness" uncertainties assessed by performing runs of varied sequences</td></tr>
<tr><td>UJV</td><td colspan="2">Uncertainties not assessed. Particular points investigated (releases from fuel, MELCOR prediction of retention in RCS and the containment, selection of decontamination factors.</td></tr>
</table>

From this table, it may be concluded that only a limited number of partners assess the uncertainties on source term. Both binning uncertainty (here in the sense of approximation) and uncertainty in source term prediction are considered rather high (estimated generally of more than one order of magnitude). Gaseous iodine behaviour is estimated to be the most important contributor to the source term uncertainty.

6. Conclusions, perspectives

As a general conclusion of the work performed, it should be pointed out, first, that a clear evidence of the interest of the uncertainty assessment should be provided. As previously reported, most participants belong to countries, where the two IAEA guidelines for performance and review of level 2 PSA are or have been the basis for acceptance of PSA. In both these guidelines the importance of addressing and quantifying all levels of uncertainties is stressed. Nevertheless, only a small number of institutions fully comply with this requirement, if at all uncertainties are addressed.
It is interesting to note also, that, generally, the objectives of level 2 PSAs development in the different countries do not refer to requirements concerning methods (including uncertainties assessment methods) or results.

Other main elements of conclusions may be summarized as it follows:
- the diversity of partners approaches to assess (or not) the uncertainties in APET quantification and releases assessment and thus the difficulty of harmonization,
- the partners' interest for the uncertainties due to physical phenomena, but no quantification of the relative importance of uncertainties due to human actions or systems reliability is given,
- the feasibility of a rather systematic assessment of the uncertainties (mainly centred on physical phenomena aspects) for recently developed level 2 PSA using:
  - systematic severe accident code calculations,
  - may be complementary expert judgments interpretation,
- nevertheless, there is no clear estimate of the importance of uncertainty due to the completeness of the study no more to the limitations of the classical methodologies,
- the high level of uncertainties on releases (both due to binning uncertainty and to source term prediction),

Considering the difficulty of the task to achieve a certain level of harmonization amongst the partners on all aspects of a level 2 PSA, it has been decided to concentrate the efforts of the group in the near future on the research of best estimate methods to assess the following physical phenomena and the corresponding uncertainties in a level 2 PSA:
- hydrogen distribution and combustion,
- melt corium concrete interaction
- iodine releases.

This orientation will lead to more exchanges with the other groups of SARNET in charge of R and D on those phenomena. Besides, the development of dynamic reliability methods will be continued and the choice of an example of application will be done considering particularly the same physical phenomena.

References

1 SARNET public web site: http://www.sar-net.org/

2 Nicolas DEVICTOR, Commissariat à l'Energie Atomique (CEA), France and Ricardo BOLADO LAVIN, European Commission (EC), Joint Research Centre, the Netherlands. Uncertainty and Sensitivity Methods, Including PSA L2 Applications
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