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European expert network for the reduction of uncertainties in severe accident safety issues (EURSAFE)

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Abstract

EURSAFE thematic network was a concerted action in the sixth framework programme of the European Commission. It established a large consensus among the main actors in nuclear safety on the severe accident issues where large uncertainties

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still subsist. The conclusions were derived from a first-of-kind phenomena identification and ranking tables (PIRT) on all aspects of severe accident also realised in the frame of the project. Starting from a list of all severe accident phenomena containing approximately 1000 entries and established by the twenty partner organisations, 106 phenomena were retained eventually as both important for safety and still lacking sufficient knowledge. Ultimately, 21 research areas for addressing these phenomena regrouped according to their similarities were identified. A networking structure for implementing and executing the necessary research was proposed, which promotes integration and harmonisation of the different national programmes. A severe accident database structure was proposed to ensure preservation of experimental data and enhanced communication for data exchange and use for severe accident codes assessment. The final product, named EURSAFE, is a website network, http://asa2.jrc.it/eursafe, connecting nodes located at partner sites. As the result of an action involving R&D governmental institutions, regulatory bodies, nuclear industry, utilities and universities from six EU Member States (Finland, France, Germany, Spain, Sweden, UK) plus JRC, three European third countries (Czech Republic, Hungary, Switzerland), and USA, EURSAFE represents a significant step towards harmonisation and credibility of the approaches, and resolution of the remaining severe accident issues.

1. Introduction

The physics of severe accidents is very complex. It addresses multi-phase, multi-component (and often multi-time scale) phenomena at very elevated temperature involving different disciplines (mainly thermal-hydraulics, physico-chemistry and mechanics). In recent years it has been found out that mastering these disciplines (and couplings between them) is certainly necessary, but still not sufficient to master hypothetical severe accidents in nuclear reactors. The mastering of the chaining between phenomena, in a realistic way, as imposed by real accident scenarios, is an important input to safety demonstrations.

Important progress towards the resolution of severe accident issues has been accomplished in the past, especially in the fourth and fifth framework programmes of the European Commission by promoting discussion and work between the experts in specific domains, and the International Phebus FP program (FISA, 1999, 2001; Schwarz et al., 2001). However, still large uncertainties exist in some areas and/or the disparity in the approaches to address these issues sometimes challenges the credibility of the conclusions. In addition, new safety requirements are emerging as the result of the evolution of fuels, plant lifetime and reactor concepts.

For existing reactors, in addition to the requirements for developing appropriate Severe Accident Management (SAM) tools, the evolution of fuel management towards higher burn-up and the use of MOX fuel, makes it necessary to assess the possible consequences of severe accidents.

The lifetime extension of existing reactors, which is envisaged by the utilities, as it is beginning in the US, could be the occasion for the Safety Authorities to ask for a re-evaluation of the safety studies. Consequently, the use of PSA level 2 should generalise. The reliability of such analyses and the appropriateness of the counter-measures are strongly dependent on the knowledge of major physical phenomena and of the level of uncertainties in coupling all the phenomena.

For future reactor designs, assessing the possible consequences of severe accidents is also necessary, as in Europe the Safety Authorities require that severe accidents be considered in the design of future power plants.

In order to decrease the uncertainties and therefore strengthen the credibility of scenario analyses, the project put together the European experts in severe accidents, whatever their organisations, R&D, utilities, regulatory, industries, universities, to work in a network structure. The objective of this thematic network was to establish a large consensus on the severe accident issues where large uncertainties still subsist, and to propose a structure to address these uncertainties by appropriate R&D programmes making the best use of the European resources. The proposed network is supposed to be the embryo of a future Severe Accident Network of Excellence.

2. Work programme

To achieve the objective required obtaining among all the major European actors in nuclear safety sufficient convergence on severe accident issues and phenomena, and on their importance in terms of safety and knowledge, such as to arrive to a consensual approach to resolve the remaining uncertainties. Establishing phenomena identification and ranking tables (PIRT) has been proved in other areas (e.g. loss-of-coolant accidents, LOCA) to be an efficient and unbiased way to reach such a consensus (Phenomena Identification and Ranking Tables, 2004).

A PIRT covering all the aspects of severe accident has been realised as an initial step towards the objective. It integrates all the severe accident issues from core degradation up to release of fission products in the containment, taking into account any possible countermeasures and the evolution of fuel management.

As a second step, PIRT implications have been deduced taking into account existing and planned European facilities, codes and programmes. This included: (i) defining R&D needs in terms of objectives and priorities; (ii) identifying the required R&D tasks in terms of experimental programmes and codes; (iii) reviewing the European facilities and codes which could be used for these tasks, taking into account the existing and planned programmes.

As third step proposed a conceptual organization for a possible future European Network of Excellence for Severe Accidents. The mission of this network would be to address the remaining uncertainties on the key safety issues according to the implications deduced from the PIRT by optimising the use of resources available in Europe.

Lastly, the problem of data conservation system for both existing and future experimental data was addressed and a possible unified system proposed.

3. PIRT on severe accidents

3.1. PIRT extend

The PIRT addresses severe accident situations for LWRs, covering LWRs available or in project, mainly in Europe (several containment types, different accident management measures). The initial situation is core uncovery and onset of debris formation. The final situation is long-term corium stabilisation, long-term containment integrity, and fission product retention or release to the environment.

3.2. PIRT organisation and methodology

The aim of this phenomena identification and ranking tables was to identify R&D priorities for severe accidents of LWRs. The methodology consisted basically in:

- establishing lists of phenomena covering the whole spectrum of severe accident situations and events;
- ranking these phenomena according to their relevance to reactor safety (safety-oriented groups) and
- ranking the phenomena according to their degree of knowledge (phenomena-oriented groups).

The final ranking takes into account both safety and knowledge aspects and is the basis for the elaboration of R&D programmes (see Section 4).

The PIRT tasks were performed by three safety-oriented sub-groups, namely, primary circuit, containment and source term, and five phenomena-oriented sub-groups, namely, in-vessel phenomena, ex-vessel phenomena, dynamic loading, long-term loading, fission products. A chairman and a vice-chairman, one specialist of reactors, one specialist of phenomena leads each sub-group.

First, a list of all phenomena of concern for severe accidents, classified according to the five phenomena-oriented sub-groups was established. The list was then used for voting (1) on safety importance for each safety-oriented sub-domains, and (2) on knowledge level. Voting was made by each partner and a synthesis established through averaging the votes.

3.3. List of severe accident phenomena

The list of phenomena was established according to the following generic topics:

- in-vessel phenomena
  - core degradation
  - reflooding
  - corium behaviour in the bottom head
  - integrity of primary and secondary circuits
- ex-vessel corium behaviour
  - vessel failure and corium release
  - molten core–concrete interaction
  - core-catchers, corium–ceramic interaction

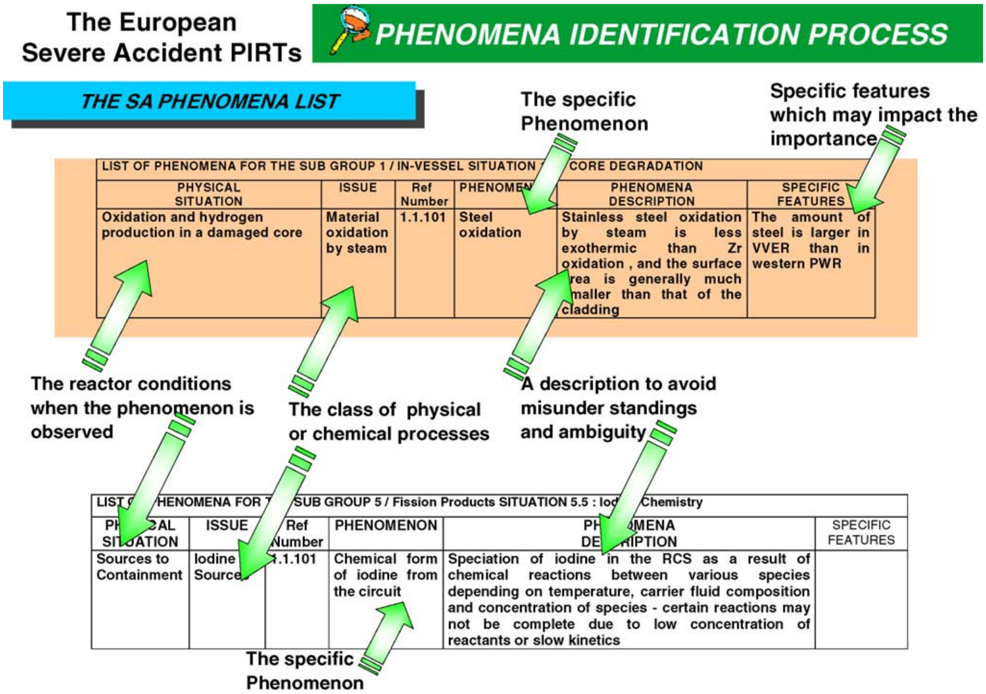

Fig. 1. Illustration of the identification process of severe accident phenomena.

- dynamic loading
  - vapour explosion
  - steam spikes from melt quenching
  - hydrogen combustion and detonation
  - dynamic behaviour of pressure vessel and primary circuit
  - dynamic behaviour of containment and equipment
- long-term loading
  - containment thermalhydraulics
  - mechanical static behaviour of containment and basemat
  - melt ejection and direct containment heating
- fission products
  - release of fission products, actinides and structure material from the core
  - transport in the RCS including deposition, resuspension, retention in complex structures
  - ex vessel release and by-pass paths
  - aerosol behaviour in the containment
  - iodine chemistry
  - other FP's behaviour.

Fig. 1 gives an illustration of the phenomena identification process. It is noted that the list includes a short description of all phenomena to avoid misinterpretation of the definitions and mismatching in the expert's votes. The full list is found in (Seiler et al., 2003).

3.4. Safety importance voting

Rationale for voting on safety importance was as follows:

- *Vote level 3 (high priority)*: The phenomenon (or the aspect) is highly important for safety and the probability of occurrence is high, medium or unknown. The uncertainties on this phenomenon should be reduced to the minimum possible.
- *Vote level 3L (high priority but low probability)*: The phenomenon (or the aspect) has important consequences and the probability of occurrence is low.
- *Vote level 2 (medium priority)*: The phenomenon (or the aspect) is important for safety and the probability of occurrence is medium or unknown.

- *Vote level 1 (low priority)*: The phenomenon (or the aspect) has low importance for safety, or has medium importance for safety and its probability of occurrence is low.
- *Vote NO*: No opinion.
- *Vote NA*: Not applicable (phenomenon not relevant for the considered S/o situation).
- "–": No participation.

A classification based on vote averages was established as follows:

- <1.66: Low importance ranking.
- ≥1.66 and ≤2.33: Medium importance ranking.
- >2.33: High importance ranking.

Any phenomena for which the number of votes was less than five, whatever was the average value of the votes, was disregarded. On the other hand, phenomena having more than five votes "3" were selected as highly important anyway.

A first list of so-called "selected phenomena" being those phenomena for which average was more than 2.33 was established. Applying this criteria, the list was scaled down from 916 phenomena initially to 229.

3.5. Phenomena knowledge voting

Voting for level of knowledge was required only for the 229 phenomena selected in the safety-oriented round. Rationale for voting on phenomena knowledge was as follows:

- *Vote level 1*: The phenomenon/aspect is *well* understood. The processes are adequately modelled and well verified in general on an extended experimental basis. Needs little or no R&D.
- *Vote level 2*: The phenomenon/aspect is on the whole understood, uncertainties remain for unexplored parameter ranges or extrapolation to reactor scale. The main processes are described by adequate models but the verification is not complete due to a limited understanding and to limited number of data.
- *Vote level 3*: The phenomenon/aspect is *only partly* understood. The models are *rudimentary*. The model verification is insufficient due to a significant lack of experimental data. Needs significant R&D effort.
- *Vote NF*: (No fit) none of the suggested votes fits (provide explanation in the comments).
- *Vote NE*: Problem unknown (no expertise).
- "–": No participation.

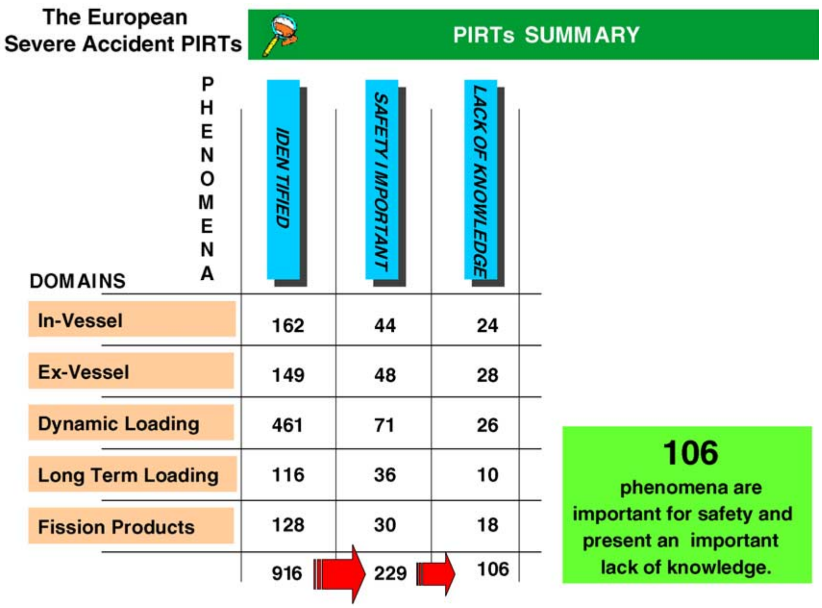

Fig. 2. PIRT summary.

A classification based on vote averages was established as follows:

- *List 1*: Phenomena with a vote average ≥ 2.3: selected as most significantly lacking knowledge.
- *List 2*: Phenomena with a vote average ≥ 2.1 and bi-modals: re-discussed on the basis of the rationales summarised by the chairpersons of the various groups, and either not considered or put in the list as still lacking knowledge for some aspects.

3.6. PIRT list

Applying the above criteria to the 229 phenomena of the safety-riented list, 106 were retained as both important for safety and lacking sufficient knowledge: 57 in list 1 and 49 in list 2. Fig. 2 illustrates this selection process. The list of the 106 phenomena retained either in list 1 or list 2 is reported in Table 1. The list includes the short description of the phenomena, the original reference number of the full list (see FISA, 1999), the safety importance averaged votes for primary circuit (SoV P.C), containment (SoV Cont.) and source term (SoV S.T.), respectively, the phenomena knowledge averaged votes (PoV), and whether it belongs to list 1 or list 2 (“b” after a number stands for bi-modal distribution). In addition, the last three columns refer to PIRT implications as is explained in the next section.

As integrating the results of both the safety oriented and the phenomena oriented rounds, this list of phenomena is actually the PIRT phenomena list.

4. PIRT implications

As a further step, the research needs to address each selected phenomena of the PIRT list were identified.

First, the objectives of research and the description of programmes and codes needed (including existing capabilities) to address each selected phenomena of the PIRT list were reviewed. A list was established assigning to each selected phenomena the relative research needs and programmes. The result is summarised in the last two columns of Table 1. In the column “objectives of needed research ” of Table 1, the key is as follows:

- A: perform experimental work to produce the missing information;
- B: perform analytical work to integrate the existing data in best estimate codes;
- C: develop a conservative approach;
- D: perform R&D work for the development of new accident management procedures and
- 1, 2, 3. . . indicate a chronological order for performing the research.

Second, the phenomena were regrouped into a limited number of research items according to their similarities in terms of research needs/physical processes, with the scope of being able to set up a limited number of coherent R&D programmes. A rationale for these research needs was established based on safety relevance and lack of knowledge (Traubauer and Magallon, 2003). The outcome of this process is summarised in Table 2, which gives the 21 items of needed research and relative rationales drawn from the 106 phenomena selected in the PIRT. The numbers of the research items are also reported in column “Item N.R.” of Table 1 to indicate which research item each selected phenomenon belongs to.

5. Proposal for a network of excellence

An efficient way to resolve the remaining severe accident safety issues as established by the PIRT and the PIRT implications tasks is certainly to address them within an integrated structure, which optimise the use of resources available in Europe, regroups the efforts of the researchers in the various domains, and helps converging towards a common understanding of severe accident phenomena. Succeeding would reinforce the confidence in and credibility of severe accident analyses. A conceptual organisation of such an integrated structure as a European Network of Excellence for Severe Accidents is proposed in this section.

5.1. Network of excellence objectives

The general objectives of a network should be to:

- tackle the fragmentation that exists between the different R&D organizations, notably in defining research programmes and developing/qualifying computer tools;
- harmonize the methodologies applied for assessing risk and improve Level 2 PSA tools;

Table 1
Severe accident PIRT list (see Section 3.6)

Physical situation	Issue	Phenomenon	Phenomena description, other specific features	Reference no.	SoV P. C.	SoV Cont.	SoV S. T.	PoV	List	Item N. R.	Objectives of needed research	Description of experimental program or computer code
In-vessel				1,0,000								
Core degradation				1,1,000								
In-vessel heat transfers in a damaged core	Dry core Validation of 2D–3D models and experimental benchmarking	Natural convection within RPV	The natural circulation flow patterns will form in the vessel as a direct result of the variation in temperature within the core and vessel. These flow patterns can be initially influenced by the ballooning and rupture in the fuel elements, and over the longer term by the formation of blockages within the core. The impact of in-vessel natural circulation is to delay the overall heating of the core because of the more effective removal of heat from the hotter regions of the core to the colder structures within the vessel. As a result, radial temperature gradients in the core are reduced and the heating of the core is much more uniform. *More significant in low pressure*.	1,1,040	2,31	1,63	2,00	2,25	2	1,5	B1: assessment of codes on existing exp. (like Westinghouse exp.) and reactor plants B2: improvements of 3D model A3: 3D exp. under prototypical conditions	Model oriented, simple structures, heating and inflow/outflow conditions, subsequently introduction of complications i.e. in homogeneities (IKE-experiment); (see also Westinghouse exp.; UPTF)
Oxidation and hydrogen production in a damaged core	Fluid composition	Oxidation by air	The oxidation by air is more exothermic than that by steam but without hydrogen generation. Nitriding of zirconium may occur particularly if the oxygen content of the air is exhausted. Fuel oxidation by air results in hyperstoichiometric urania.	1,1,111	2,08	1,45	2,50	2,13	2	5,1	A1: small-scale exp. to clarify conclusions on kinetics and support integral exp. A2: integral exp. B3: model improvement	See exp. CODEX-RU, MADRAGUE, QUENCH, RUSET Phébus 2K: planned
In-core molten pool behaviour	Pool configuration	Spatial growth of the pool	Without reflooding, the molten pool will continue to grow gradually because of inner heat sources. Its axial or radial propagation will make it reach first either the lower or lateral structures, depending on the heat transfers at its boundaries.	1,1,200	2,38	1,14	1,33	2,35	1	1,3	A1: to clarify the initial and boundary conditions for further core melt down sequence B2: improvements of existing models	Related phenomena will be investigated in the LIVE and RIT facilities, using simulant materials. Decay heat will be simulated Benchmark to Phébus, ACRR-MP
Special fuel issues	High burn-up fuel phenomena	Fuel oxidation	Oxidation and hydrogen production: impact on fuel oxidation.	1,1,233	1,45	1,29	2,38	2,36	1	5,1	A1: analytical exp. to clarify kinetics, surface increase	Exp. at very high temperatures (VERCORS exp.)

Table 1 (*Continued*)

Physical situation	Issue	Phenomenon	Phenomena description, other specific features	Reference no.	SoV P. C.	SoV Cont.	SoV S. T.	PoV	List	Item N. R.	Objectives of needed research	Description of experimental program or computer code
											B2: improvements of existing models (ELSA)	Validation of codes, benchmark to Phébus etc.
											A3: integral exp.	Phébus 2K: planned
	MOX fuel phenomena	Fuel oxidation	Oxidation and hydrogen production: impact on fuel oxidation.	1,1,243	1,50	1,20	2,45	2,62	1	5,1	Same as 1,1,233	
Reflooding				1,2,000								
Damaged core	Hydrogen generation	Oxidation of metal-rich mixtures	The oxidation of Zr-rich mixtures (especially U–Zr–O), either liquid when relocating or frozen after relocation, could start again under the action of the strong steam flow rates following reflooding. It could be an important source of hydrogen and renewed heat-up.	1,2,021	2,46	2,58	1,88	2,40	1	1,1	A1: more analytical exp. with liquid mixtures	Small-scale exp. to obtain basic data (effective surface available for oxidation), well-instrumented so that transient effects can be quantified MADRAGUE planned
											A2: integral exp. B3: model improvement	QUENCH, Phébus 2K: planned
	Mechanical failure	Fuel rod collapse	The thermal shock may cause the fuel columns to collapse, especially the parts where the cladding had disappeared or was totally oxidized (insufficient time for the molten zircaloy to penetrate into the pellet interfaces and cracks, fuel break-up on grain boundaries due to UO_2 oxidation). In both cases above, this will lead to formation of a debris bed.	1,2,033	2,00b	1,50	1,57	2,63	1b	1,2	A1: analytical exp. on real rod segments B2: improvements of models, check existing data (LOFT, LP-FP2) B3: simplified approaches in core degradation and system codes/heuristic criteria;	Possibly fulfilled by a further stage of the MADRAGUE incl. Quench
											A4: integral exp.	Phébus 2K: planned
Degraded core	Coolability	Coolability of a molten pool	Corium/water interaction (thermal and mechanical) at the boundaries of the pool will depend on the critical heat flux. Cracking of the corium crust may increase the exchange surface. *The critical heat flux depends also on the characteristics of the damaged configuration* (*geometry, debris, remnants of rods, etc.*)	1,2,060	2,67	2,11	2,00	2,24	2	1,2	A1: large-scale analytical exp. B2: dev. of simplified models, check existing data	COLIBRI, RIT facility Coolability under reflooding, depending on configuration of pool, and heat removal from boundaries, CHF in presence of debris

		Coolability of a particulate debris bed in case of bottom reflooding	The velocity of water entering the debris bed limits the progression of the quench front. 2D effects may be very important because of non uniformities in the bed or because of its shape	1,2,061	2,33	2,11	1,88	2,35	1	1,2	A1: 3D analytical exp. in simulant materials including oxidation B2: improvement of 2D/3D models, check existing data, important: debris characteristics A3: integral exp.	See IKE-DEBRIS; RENOIR SILFIDE(EdF); STYX(VTT) POMECO(KTH) Phébus 2K considered
		Coolability of a particulate debris bed in case of top reflooding	The velocity of water entering the debris bed limits the progression of the quench front. In case of top reflooding, the counter-current flow of steam reduces significantly the ability of water to penetrate into the debris bed. 2D effects may also be very important because of non-uniformities in the bed or because of its shape.	1,2,062	2,33b	2,00	2,18	2,50	1b	1,2	See 1,2,061	
	Failure of structures	Crust failure	The thermal stresses due to reflooding will favour the mechanical failure of the crusts, which support the corium molten pool. This would lead to the downward progress of corium in the core region.	1,2,080	2,29	1,67	1,38	2,38	1	1,2	B: use of simplified models, uncertainty: crust support; check existing data (MACE)	Mechanical failure or failure by melt-through depends on crust stability
Corium behaviour in bottom head				1,3,000								
Corium relocation to lower head	Initial conditions	Molten pool failure modes	The various failure modes of the molten pool in the core region, as well as the failure location and the initial size of the crust break, are the initial conditions for the relocation to the lower head. The flow rate of corium leaving the pool will depend on the initial size of crust break, on hydrostatic head of molten pool, etc. The size of the break will increase due to corium heat transfer.	1,3,010	2,50	1,75	1,57	2,53	1	1,3	B1: dev. of models, uncertainty: debris characteristics, check existing data A2: analytical exp.	Melt progression, accumulation, cooling conditions, 3D effects, crust formation, hole ablation Related phenomena will be investigated in the LIVE facility, using simulant materials; decay heat will be simulated

Table 1 (*Continued*)

Physical situation	Issue	Phenomenon	Phenomena description, other specific features	Reference no.	SoV P. C.	SoV Cont.	SoV S. T.	PoV	List	Item N. R.	Objectives of needed research	Description of experimental program or computer code
											C3: dev. simplified model (e.g. HARAR) See 1,1,200; 1,2,060; 1,2,080	Parameter studies on consequences
		Characteristics of corium arrival in lower plenum	The characteristics of corium arrival into the lower head are the chronology of successive slumps, the temperatures, masses and composition of corium flows, etc. . . *The timing and mode of the corium relocation process will modify the further behaviour of corium in the lower head. It will also affect the risk of steam explosion*.	1,3,011	2,50	1,78	1,57	2,38	1	1,3	See 1,3,010; 3,1,022	
	Corium flow through the internals—wet lower head	Steam explosion	Vapor explosion in case of corium contact with water in the lower head.	1,3,033	2,40	1,92	1,60	2,50	1	3,2	See 3,1,022	
	Oxidation and hydrogen production	Corium oxidation at arrival in lower head	The metallic components of the melt that slumps into the residual water pool in the lower head and breaks up could be oxidized by steam, which is intensively produced. *Melt–water interaction will only occur with residual water pool in lower plenum*.	1,3,040	2,07	2,36	1,56	2,20	2	1,1	A1: analytical exp. for kinetic data B2: improvement of models, use existing data (FARO, ZREX, SSEX) See also 3,1,022	 Uncertainties: melt jet break-up, flow pattern. Depends on reactor design
Lower head debris bed behaviour	Heat transfer	Thermal-hydraulics within the debris bed	The heat-up or cooling of the debris depends on the external heat transfer and the debris porosity. If the debris bed is embedded in water and critical heat flux and porosity are not limiting, the debris does not heat up or will be quenched. If the convective heat transfer from the debris to the coolant is less than the heat generation, the debris will dry out and may melt. In this case, the debris porosity decreases. *Importance of non-uniform debris distribution*.	1,3,061	2,33	1,57	1,60	2,38	1	1,2	See 1,2,061	

Lower head molten pool behaviour	Pool configuration	Molten pool formation	The molten pool is formed by molten debris or by relocation of melt from the core region without significant fragmentation and its accumulation in the lower plenum. The relocation is either continuous or intermittent. Molten structure material might contribute to the melt pool. *A molten pool in the lower plenum behaves in principle similarly to that in the core region but its size might be much larger due to the crucible-like pressure vessel wall and to supplementary material coming from internal structure melt-through. It might be below or/and above a debris bed*.	1,3,080	2,36	1,25	1,88	2,44	1	1,3	See 1,1,200 B: code simulation should consider history of melt pool formation due to relocation	
		Segregation and stratification of materials	Depending on the relative density of the different materials and their relative miscibility (existence of miscibility gaps), liquid phases (such as metallic and ceramic materials) may separate and form different layers. Metals may also come atop from melt-through of core structures. *It depends on physical and chemical properties as well as thermal and flow conditions and affects slightly the heat source distribution but significantly the heat flux distribution to the boundary in case that the heat conductivity varies a lot*.	1,3,081	2,57	1,56	1,88	2,63	1	1,3	A1: analytical exp. for oxide–metal pools to study material behaviour B2: dev. of detailed models (incl. thermochemical equilibrium), use existing data B2: dev. of simplified models	Cont. MASCA/COLIMA Consider also ‘layer switches’
Lower head molten pool behaviour	Heat transfer	Pool heat transfers to boundaries	The pool heat transfers include the phenomena: focussing effect, radiative upward heat transfer in case of dry lower head, heat transfer to a dry or wet particle bed, and heat transfer to possibly overlying water. It also includes the downward heat transfer by conduction.	1,3,091	2,57	1,44	1,67	2,25	2	1,3	B1: improve models based on existing data (ANAIS, COLIMA)	Effect of steam and aerosol on radiative heat transfer SIMECO exp.

Table 1 (*Continued*)

Physical situation	Issue	Phenomenon	Phenomena description, other specific features	Reference no.	SoV P. C.	SoV Cont.	SoV S. T.	PoV	List	Item N. R.	Objectives of needed research	Description of experimental program or computer code
											A2: analytical exp. with water above the pool	
											B3: code development and validation	Relevant phenomena: stratification, convection, conduction, radiation, impact of overlying water and melt/structure addition from RPV internals
											D4: assessment of the potential and risk to retain the melt within the RPV by flooding of the reactor pit	
		Vaporisation of pool materials	In a large corium pool, heat-up due to decay heat could lead to a significant vaporisation of metals and/or fuel. *Impact on fission product source term*.	1,3,093	1,85	1,22	2,27	2,29	2	1,3	A1: analytical exp.	Determination oft the vaporization rate according to the composition and the thermodynamic conditions of the corium (with FP simulants) COLIMA
											B2: dev. of models	Codes: ELSA(IRSN), FPPOOL(IKE), RELOS(RUB)
Vessel external cooling	Wet cavity	Effect of lower head penetrations	Lower head penetrations like in TMI or BWRs may have a substantial impact on RPV wall external cooling by affecting the external convection flow and the steam formation. *Special case of BWR and of some PWR*.	1,3,145	2,36	1,89	2,00	2,38	1	1,4	B1: dev. model based on existing data	
											A2: reactor design specific exp.	To resolve concerns related to scaling and design impacts on heat transfer, SULTAN.

			Recently performed experiments indicate that penetrations do not significantly hinder the heater transfer to the water.								D3: assessment of the potential and risk to retain the melt within the RPV by flooding of the reactor pit	
Thermal and mechanical loadings and behavior of structures including the lower head	Lower head	Thermal and mechanical loadings	If different corium layers form by stratification in the lower head (oxide, metals, debris), this will induce axisymmetrical thermal loadings of the lower head with various distributions. In the absence of stratification, the 3D distribution of the mixture of debris and molten corium in the lower plenum will induce local hot spots, and thus asymmetrical thermal loadings on the vessel. The mechanical loadings will be the primary pressure and the dead weight of vessel and corium. *Important for 3D effects*.	1,3,161	2,50	1,60	1,50	2,20	2	1,3	B1: model development based on existing data (ANAIS, FOREVER) B2: use of 3D codes with layer formation A3: integral exp. to study effects of thermal gradients See also 1,3,081, 1,3,091	Various uncertainties accumulated, esp. thermal loads depending on stratification and on history of melt accumulation in lower head. Thus, emphasis on scenario aspects. FOREVER
		RPV mechanical failure	RPV modes of mechanical failure: plasticity, damage, creep.	1,3,168	2,58	2,42	1,86	2,15	2	1,6	A1: finalise semi-integral exp. A2: integral exp. B3: simplified 2D model (time, failure location and lower head deformation at failure time) A4: analytical exp. (to complete model validation on failure criteria), additional steel specific data	OLHF final report FOREVER Main uncertainty: thermal loading. Apart from 3D aspect reasonably covered. Improve treatment of penetrations Analytical tests on plate fissuration

Table 1 (*Continued*)

Physical situation	Issue	Phenomenon	Phenomena description, other specific features	Reference no.	SoV P. C.	SoV Cont.	SoV S. T.	PoV	List	Item N. R.	Objectives of needed research	Description of experimental program or computer code
Integrity of primary and secondary circuits				1,4,000								
Integrity of primary and secondary circuits	Thermo-mechanics of structures	SG tube failure and SG plenum failure	Effect of very high thermomechanical loads on SG craked tubes, bolted manway closure, tubes plugs, etc. additional thermal loads due to fuel or fission products. *Uncertainties on boundary conditions to be considered.*	1,4,023	2,46	1,88	2,73	2,08	2	1,5	B1: analytical studies to solve the issue, based on validated codes A2: analytical exp. for special materials/weldings A3: exp. under prototypical conditions with used tubes C4: dev. conservative approach based on detailed calculations using finite element codes	 MECI exp. Reasonable scaled experiment (similar to the Westinghouse one) is required for validation.
Ex-vessel				2,0,000								
Vessel failure and corium release				2,1,000								
Vessel mechanical failure and corium release	Opening process	Dynamic failure induced by in-vessel FCI	Weak vessel situation: vessel failure in case of energetic corium water interaction in case of water injection on top of corium pool. Phenomena detailed in sub-group no. 3 (dynamic loading).	2,1,031	2,11	2,38	1,71	2,36	1	3,3	A1: pressure loads after water injection on top of corium pool C2: risk assessment in the framework of Level 2 PSA C3: justification of the melt retention strategy for future plants. See also 1,3,161, 1,3,168, 2,5,010	ANAIS: metallic layer with increasing Zr fraction and with oxidation Analytical simplified models exist in IRSN. They will be used with loads issued from M3CD calculations

	Mass transfer to reactor pit	Mass flow rate and pouring history	Depends on vessel failure mode, on breach location and opening, on pool configuration ⇒ input conditions for MCCI. The vessel failure mode depends strongly on the melt relocation behaviour from the core to the lower plenum.	2,1,040	1,29	2,62	1,75	2,24	2	1,6	B1: assess model by exp. data (FOREVER) A2: analytical exp. on lower head failure phenomena B3: model development to predict break opening See 1,3,010; 1,3,011; 1,3,081 1,3,168	Main uncertainty: thermal loadings, creeping and mechanical support by cavity. Determine transient behaviour of mass flux dependent on failure mode.
		Corium composition and physical state	Depends on in-vessel pool configuration and on breach location: metal phase, oxide phase, liquide state or solid particles, temperature. . . The corium composition and physical state depends strongly on the melt relocation behaviour from the core to the lower plenum.	2,1,041	1,86	2,69	2,38	2,27	2	1,6	B1: developments: core relocation, pool stratification, segregation and solidification models to be improved and extended A2: analytical exp. C3: dev. conservative approach to cover all possible, physically reasonable conditions See 1,3,010; 1,3,011; 1,3,081 1,3,168; 2,1,040	Strongly linked to scenario aspects. Layering in the pool; 3D effects to be considered. MASCA/COLIMA Define reference compositions for different failure modes, determine state and properties of the corium.
Vessel mechanical failure and corium release	Mass transfer to reactor pit	Breach location and flow path	The corium release to reactor pit may be disturbed by external device such as numerous RIC tubes for example. *Depends on reactor design*.	2,1,042	1,71	2,38	1,67	2,27	2	1,6	B1: integrate the existing data in models	Use of simulant material (FOREVER)

Table 1 (*Continued*)

Physical situation	Issue	Phenomenon	Phenomena description, other specific features	Reference no.	SoV P. C.	SoV Cont.	SoV S. T.	PoV	List	Item N. R.	Objectives of needed research	Description of experimental program or computer code
											A2: plant-specific experiments C3: determine most probable breach location and breach dimension for reference failure modes See 1,3,168; 2,1,040	
Molten corium concret interaction				2,2,000								
Power distribution and concrete ablation	Pool formation, geometry and heat exchange surface	Debris bed and melt cake formation (detailed in 2.5.6)	Interaction between corium and water in the reactor pit, particles bed formation and melt cake formation depending on fragmented part of the corium jet, particle size distribution. . . FCI risk detailed in sub-group no. 3 Effect of FCI on particle size distribution has to be considered for debris bed coolability. *Depends on reactor design and on SAM procedures*.	2,2,050	2,00	2,46	1,60	2,43	1	3,1	B1: modelling of melt–water interaction (jet break-up) based on exp. data (FARO, PREMIX) A2: large-scale exp. with corium C3: risk assessment in the framework of Level 2 PSA See also 3,1,022	Interaction determines development of coolable states Debris and cake formation with large mass and long pour (FARO-type) MC3D, IKEJET/IKEMIX code for parametric studies
		Layers configuration	Existence of two or more immiscible liquids, which induced different layers due to their density difference. Include also debris layer from concrete on top of metallic layer.	2,2,052	1,00	2,42	1,67	2,46	1	2,1	B1: improve 0D models using exp. data A2: analytical exp to define pool configurations during MCCI with special attention to compositions with potential of layer formation A3: integral exp. B4: improve 2D models using exp. data	To be integrated in TOLBIAC-ICB, MEDICIS See PERCOLA, VULCANO, COLIMA, MACE To prove scale effects 2D CROCO

		Layers stability under sparging gas	Is stratified pool configuration stable under sparging gas? Depends on density ratio between the different layers, on layers viscosity, on bubble size and on surface tensions; mass transfer between liquid layers with or without crust at interface entrainment by gas bubble rise and settling phenomena	2,2,053	1,00	2,45	1,60	2.43	1	2,1	B1: improvement of 0D–2D model A2: analytical exp. to study effect A3: integral experiment See also 2,5,052	MEDICIS, WEX, 2D CROCO Exp. with simulant materials with visual observation (ARTEMIS?) VULCANO
	Heat sources (decay heat distribution/recriticality risk/chemical reactions)	Fission products remaining in the pool	Variation of decay heat as a function of time (related to sub-group no. 5). Fission product entrainment by sparging gas.	2,2,060	1,50	2,38	2,25	2,15	2	2,1	B1: validate simplified models with exp. data (ELSA) C2: use conservative approach, no credit to be taken from decay heat reduction (redistribution) for retention concepts	
Power distribution and concrete ablation	Heat transfer	Convection induced by sparging gas	Lateral, downward and upward heat transfer coefficient for wall with gas injection (lateral or downward) or gas release (upward) ⇒ extension to multi layers pool with crust at two layers interface.	2,2,070	1,50	2,33	1,86b	2,14	2	2,1	B1: check whether existing models are adequate and determine whether current uncertainties have significant impact on AM B2: dev. of simplified 0D models A3: analytical exp. to reduce uncertainties for heat transfer correlations used in MCCI codes. A4: integral exp. See also 2,2,053	Simulant material with small solidification interval in contact with a cooled wall with gassing device. BALI-ex-vessel, ARTEMIS MEDICIS OECD-MCCI, VULCANO
		Liquid/liquid heat transfer in presence of sparging gas	In case of miscibility gap, heat transfer at liquid–liquid interface under sparging gas. Interface temperature	2,2,072	1,50	2,42	1,50	2,14	2	2,1	Same as 2,2,070	
Late phase of basemat erosion	Containment pressurisation, increase of source term	Axial melt-through	Interaction of corium with water in the cavity underneath the basemat, FP release through possible additional path. *Depending on reactor design*.	2,2,100	2,00	2,77	2,11	2.33	1	3,1	B1: check whether available models are sufficient	Specific reactor problem. Important for SAM implementation and emergency considerations

Table 1 (*Continued*)

Physical situation	Issue	Phenomenon	Phenomena description, other specific features	Reference no.	SoV P. C.	SoV Cont.	SoV S. T.	PoV	List	Item N. R.	Objectives of needed research	Description of experimental program or computer code
											A2: integral experiment? D3: related to specific reactor design	COMET?
Core catcher: spreading phenomena				2,3,000								
Corium and substrate properties	Thermodynamic properties	Δ*H*, liquidus and solidus temperatures. . .	Not really a phenomena, it is also a generic item. The question is more about the validity of thermodynamic bases in reactor composition domain.	2,3,020	1,00	2,60	1,67	2,13	2	2,3	A1: small-scale exp. to measure thermodynamic, thermochemical data, particularly viscosity	High temperature mass spectrometry measurements, ISABEL tests, ENTHALPY project, MASCA, COLIMA facility
											B2: consolidate recent studies, particularly from MASCA, evaluate existing database, link database to MCCI codes	Develop look up tables for reactor safety codes, ensuring consistency of treatment. NTD (nuclear thermodynamic database), CHEMAPP, GEMINI, THERMOCAL or FACTSAGE
Heat transfer during spreading	Heat transfer and boundary conditions	Heat transfer to the upper water layer	Heat transfer between upper crust and water if spreading under water	2,3,045	2,50	2,60	2,67	2,13	2	2,2	B: development of heat transfer model, evaluate existing data (MACE, RIT spreading exp.) or new data (OECD-MCCI) to be implemented in THEMA and CROCO	Main uncertainty: crust fracture and water ingression.
Core catcher: corium ceramic interaction				2,4,000								
Corium and ceramic properties	Thermodynamic properties	Δ*H*, Liquidus temperature. . .	Not really a phenomena, it is also a generic item. The question is more about the validity of thermodynamic bases in reactor composition domain.	2,4,020	0	2,50	1,00	2,15	2	2,3	Same as 2,3,020	

Corium–ceramic interaction; heat transfer and dissolution mechanism	Dissolution mechanism	Ceramic dissolution by oxide	Ceramic dissolution by oxide. Situation related to stratified pool configuration. Density ratio between metallic and oxidic phase depends on previous phase.	2,4,060	0	2,44	1,00	2,17	2	2,3	B1: model dev. 0D approach, based on existing data (ISABEL, CIRMAT)	MEDICIS
											B2: improve 2D models using exp. data	CROCO, TOLBIAC
											A3: analytical exp.	ARTEMIS, confirmatory research for specific core catcher
		Effect of O_2 potential on dissolution mechanism	Effect of atmosphere composition on oxygen potential gradient and consequences on dissolution mechanism	2,4,062	0	2,67	1,00	2,33	1	2,3	B1: model dev. 0D/2D approach, based on existing data	MEDICIS, CROCO, TOLBIAC
											A2: assess the stabilization of interaction with stratified (oxide/metal) corium	COLIMA: determination of ceramic dissolution in stratified pool, control of the atmosphere conditions, prototypic materials
Corium coolability				2,5,000							See also 2,4,060	
Top flooding of melt	Bulk cooling (transient or unstable situation)	Heat transfer mechanism	Bulk cooling mechanism, heat transfer between water and liquid corium with a solid crust at interface, which is not enough thick to be stable.	2,5,010	2,00	2,50	2,17	2,31	1	2,2	A1: integral exp to study heat transfer, crust behaviour, water ingression with real materials	OECD-MCCI, COMET: clarification of related phenomena is necessary for assessment of melt coolability
											B2: assessment of success of melt stabilisation by post cavity flooding and the risk of containment failure due to steam explosion.	
											A3: small-scale exp. (COMECO) to study effect of melt properties on heat transfer	
											B4: development of simplified 0D/enhanced 2D models	MEDICIS/WEX, CROCO-0D, TOLBIAC-ICB

Table 1 (*Continued*)

Physical situation	Issue	Phenomenon	Phenomena description, other specific features	Reference no.	SoV P. C.	SoV Cont.	SoV S. T.	PoV	List	Item N. R.	Objectives of needed research	Description of experimental program or computer code
	Water ingression into to crust	Cracks formation in crust	Cracks formation in upper crust due to thermal constraint applied, water may penetrate the cracks and improve the heat transfer.	2,5,020	2,00	2,42	2,00	2,47	1	2,2	Same as 2,5,010	
	Melt ejection into overlying water	Melt entrainment by sparging gas	Liquid corium ejected with gas flow through openings in upper crust	2,5,030	1,00	2,38	2,00	2,33	1	2,2	A1: analytical test to study effect of properties and gas velocity B2: model development A3: integral exp. link to layer configuration and crust behaviour See also 2,5,010	PERCOLA, COMECO, simulant material MEWA-IKE/MEDICIS/WEX/CROCO, TOLBIAC OECD-MCCI, COMET
		Crust anchorage	Melt ejection mechanism is different if upper crust is floating (ejection mechanism) or if it is anchored to the reactor pit wall (extrusion mechanism).	2,5,033	1,00	2,36	2,25	2,24	2	2,2	B1: development of simplified models based on existing data from OECD-MCCI A2: analytical exp. A3: integral test to determine if the crust is anchored or not in reactor configurations with real materials.	MEDICIS OECD-MCCI Demonstrative large scale test (more than 3 m) especially: pressure build-up under, ejection paths and modes
Debris bed formation and debris bed coolability eneric item	Melt jet break-up in water pool	Jet break-up in deep water pool (>4 m)	Complete fragmentation reached by deep water pools depending on melt jet/stream conditions same condition as for in-vessel situation but under sub cooling and deeper water pools and low pressure	2,5,041	1,00	2,69	2,00	2,21	2	3,1	See 3,1,022	
		Fragmentation and dynamic loading due to FCI	Mixing may lead to steam explosions with critical loading for cavity walls (especially with deep water pools and related confinement, i.e. most critical is a mixture deep in water pool, but solidification against) and part of fine fragments	2,5,043	2,33	2,57	2,00	2,46	1	3,2	See 3,1,022	
	Particulate debris formation	Local and global size distribution and particle shapes	Local size distribution: multigrain configurations with reduced porosity; irregular shapes (granulate)	2,5,052	1,50	2,50	2,25	2,23	2	3,1	See 3,1,022	

			Global size distribution: e.g. stratification with small particles at top									
Bottom injection of water into melt (e.g. COMET core catcher concept)	Water injection by pressure difference	Hydrostatic head in COMET and down comers	Initial conditions: water injection depends on hydrostatic head vs. pressure build-up by interaction (steam production) and freezing. Bottom injection of water in the melt is a very promising option for melt stabilization	2,5,070	1,00	2,38	1,50	2,09	2	2,4	B1: model development on the basis of existing data A2: confirmatory tests including down comer concept	MEWA/WABE-IKE, RIT porosity model COMET, DECOBI, COMECO
	Porosity formation in melt	Fragmentation and mixing between melt and water	Feedback between strong evaporation and related expansions, pressure build-up, resulting motions and fragmentation (surface increase) determines porosity formation; driving pressure build-up vs. axial steam release	2,5,082	2,00	2,50	1,67	2,45	1	2,4	See 2,5,070	
	Short-term cooling (quenching)	Rapid quenching and solidification	Reached by porosity formation and water penetration from below	2,5,100	2,00	2,30	1,50	2,20	2	2,4	See 2,5,070	
		Strong steam production	Consequence: pressure build-up in containment	2,5,101	1,00	2,36	1,67	2,10	2	2,4	See 2,5,070	
Melt pool in partial enclosure with external water	Core catcher with external cooling: EPR, Tian-wan, multicrucible concept. . .	Heat transfer at corium pool boundaries	Pool convection, stratification etc. (similar to in-vessel corium pool behaviour see sub-group no. 1)	2,5,120	1,00	2,67	1,50	2,10	2	1,3	B: review existing data See 1,3,080; 1,3,081; 1,3,091; 1,3,161	
Core catcher: other specific phenomena				2,6,000								
Corium gathering in a dedicated cavity	Gate opening	Effect of non homogeneous ablation on gate ablation	Crust instability may introduce heterogeneity in concrete ablation above the gate. Concept EPR, depends also on gate material.	2,6,021	0	2,57	1,00	2,18	2	2,3	B1: model dev. based on existing data (KAPOOL) B2: dev. simplified model to be implemented in system codes (MAAP)	

Table 1 (*Continued*)

Physical situation	Issue	Phenomenon	Phenomena description, other specific features	Reference no.	SoV P. C.	SoV Cont.	SoV S. T.	PoV	List	Item N. R.	Objectives of needed research	Description of experimental program or computer code
Dynamic loading				3,0,000								
Vapour explosion				3,1,000								
(A) In-vessel vapour explosion with melt into water	Melt relocation from core region into water filled space	Location/orientation of melt flow path	Downward through lower grid plate or sideways and then downward through core former or further sideways through core barrel into down comer.	3,1,011	2,09b	1,40	1,20	2,4	1b	3,1	B: scenario analyses and modelling See 1,1,200; 1,3,010; 1,3,011; 1,3,033	ASTEC, ATHLET-CD, ICARE/CATHARE (planned)
		Type/shape of relocation flow	Either one big jet downwards (very improbable), multitude of jets downward or flow through core former or down the vessel wall. Very important for relocation rate.	3,1,012	2,18	1,20	1,20	2,6	1	3,1	Same as 3,1,011	
		Flow cross-section	Important for relocation rate.	3,1,013	2,00b	1,20	1,20	2,4	1b	3,1	Same as 3,1,011	
		Relocation rate	Very important for premixed mass.	3,1,014	2,25	1,20	1,20	2,6	1	3,1	Same as 3,1,011	
		Composition of relocating corium	Very important: oxidic/metallic, solidification temperature.	3,1,015	2,00b	1,00	1,25	2,3	1b	3,1	Same as 3,1,011	
(A) In-vessel vapour explosion with melt into water	Premixing	Break-up of corium jets/flows	Creates coarse fragments. Influences penetration depth of continuous jets/flows.	3,1,022	2,44	1,25	1,25	2,1	2	3,2	B1: detailed model dev. and validation on the basis of existing data (FARO, KROTOS, PREMIX, BILLEAU) A2: analytical experiment A3: semi-integral exp. Sub-cooling and low pressure to be considered for vapor explosion in PWR cavity.	IKE-JET, IKE-MIX, MC3D, MATTINA MIRA 20L, MIRA 3L Data pre-mixing due to internal structure with large size and multi-jet pours as well as fine fragmentation, extension of parameter range: SERENA-OECD, KROTOS, TROI-KAERI, ALPHA-JAERI, PREMIX

		Duration	Of the order of seconds. Most important for masses of corium and water in premixture.	3,1,026	2,11b	1,00	1,25	2,2	2b	3,2	See 3,1,022	
	Explosion expansion	Pressure build-up (high-level)	Most important primary consequence of steam explosion. Strongly depends on details of case.	3,1,067	2,00b	1,50	1,50	2,3	1b	3,2	B: detailed model dev. and validation on the basis of existing data (FARO, KROTOS) A: analytical experiment A: semi integral exp. Sub-cooling and low pressure to be considered for vapor explosion in PWR cavity.	IDEMO-IKE, MC3D MICRONIS, DROPS, MISTEE-RIT Data pre-mixing due to internal structure with large size and multi-jet pours as well as fine fragmentation, extension of parameter range: SERENA-OECD, KROTOS, TROI-KAERI, ECO
		Energy conversion	Consequence of explosion expansion.	3,1,068	2,27	1,50	1,25	2,4	1	3,2	See 3,1,067	
	Material effects on premix-ing/triggering/explosion	Effects of solidification	No further fine scale fragmentation.	3,1,072	2,22b	1,25	1,25	2,2	2b	3,2	See 3,1,022; 3,1,067	
(C) Vapour explosion in PWR reactor cavity (with melt into water)	Premixing	Similar to 3.1 A with cavity in place of RPV	In PIRT, first issue after reference number 3,1,228. A strong steam explosion in the reactor pit is very improbable, although possible except if there is not enough water in the pit.	3,1,400	1,00	2,25	1,20	2,13	2	3,2	Sub-cooling and low pressure to be considered See 2,1,040; 3,1,022	
	Propagation	Similar to 3.1 A	In PIRT third issue after reference number 3,1,228. Possible to allow a low quantity of water to be present in the pit. It might contribute to quench the corium.	3,1,410	1,00	2,25	1,20	2,3	1	3,2	Sub-cooling and low pressure to be considered See 3,1,067	

Table 1 (*Continued*)

Physical situation	Issue	Phenomenon	Phenomena description, other specific features	Reference no.	SoV P. C.	SoV Cont.	SoV S. T.	PoV	List	Item N. R.	Objectives of needed research	Description of experimental program or computer code
	Explosion expansion	Similar to 3.1 A	In PIRT fourth issue after reference number 3,1,228	3,1,420	1,00	2,25	1,20	2,07	2	3,2	Sub-cooling and low pressure to be considered See 3,1,067	
	Effects of premixing/explosion (general)	Pressure load on corium retention devices (if any)	In PIRT reference number 3,1,232	3,1,432	1,00	2,44	1,40	2,27	2	3,2	Sub-cooling and low pressure to be considered See 2,1,031; 3,1,022; 3,1,067	Dependent on reactor design
Hydrogen combustion and detonation				3,3,000								
(A) Local hydrogen combustion and explosions in compartments near H_2 release location	Propagation of combustion and explosion waves	Flame acceleration	By orders of magnitude due to turbulence and growth of flame surface. Determines hydrogen risk. Important to ensure containment integrity. Flame propagation, detonation and combustion waves are not well known. Experiments are necessary in this field, especially concerning detonation, and DDT, which is the only threatening phenomenon for the containment integrity. Nevertheless, the uses of recombiners limit strongly the risks.	3,3,022	1,00	2,69	1,40	2,20	2	3.4	B1: evaluate existing database, and code capability by benchmarking A2: analytical experiments, esp. for non-uniform conditions B3: detailed code improvement. Criteria available. May be evaluated from detailed gas distribution calculation B4: simplified 0D code development See also 3,3,112	HICOM-project, REACFLOW, CFX, BO5, FLAME-3D, COM-3D ENACCEF-CNRS and spherical bomb experiments CNRS. TONUS: coupling between turbulence and combustion, COM3D. Establish link between mixture and geometric conditions: CFX, COCOSYS, GASFLOW. ASTEC (planned)
		Transition to detonation (DDT)	3,3,029	2,00	2,69	1,40	2,4	1	3,4		Same as 3,3,022	
	Pressure loads	Pressure loads on equipment, including safety equipment	The hydrogen concentration in the compartments can be obtained from CFD codes. If the concentrations are suspected to be too high, an engineering solution as recombiners could be chosen.	3,3,043	1,33	2,31	1,29	2,13	2	3,4	A1: analytical experiments	ENACCEF-CNRS and spherical bomb experiments CNRS.

											B2: detailed code improvement. Needs detailed 3D studies.	TONUS, COM3D, DET3D, CFX, COCOSYS, Needs consolidation, acceleration, improved user interface.
											B3: simplified 0D code development	ASTEC (planned)
(B) Global hydrogen combustion and explosions in containment	Ignition	Ignition by PARs		3,3,094	1,50	2,45	1,80	2,36	1	3,4	B1: evaluate database B2: improvement of detailed model. D3: evaluate AM	CFX, COCOSYS
	Propagation of combustion and explosion waves	Flame acceleration	As 3,3,022	3,3,102	1,00	2,77	1,60	2,21	2	3,4	Same as 3,3,022	
		Transition to detonation (DDT)		3,3,109	2,00	2,83	2,29	2,33	1	3,4	Same as 3,3,022	
		Quenching of detonations by geometrical constrains		3,3,112	1,00	2,45	1,50	2,21	2	3,4	A1: analytical experiments	ENACCEF-CNRS and spherical bomb experiments CNRS. Ongoing activities at FZK for quantification of this process
											B2: detailed code improvements and validation.	TONUS: coupling between turbulence and combustion. CFX, COCOSYS, GASFLOW
											See also 3,3,043	
Dynamic behaviour of containment and equipment				3,5,000								
(B) Concrete containments	Dynamic response of pressure bearing shell on non-uniformly distributed transient pressure loading	Crack development		3,5,044	3,00	2,14	2,33	2,10	2	3,5	A1: integral exp.	Last MAEVA exp. ADINA

Table 1 (*Continued*)

Physical situation	Issue	Phenomenon	Phenomena description, other specific features	Reference no.	SoV P. C.	SoV Cont.	SoV S. T.	PoV	List	Item N. R.	Objectives of needed research	Description of experimental program or computer code
											B2: finite element code (mechanics): model validation and improvement for cracks development	CASTEM: static quasi loading and application to reactor cases
											B3: detailed thermal hydraulics code: model improvement of flow rates	TONUS and CASTEM
											B4: 0D model: development and integration of containment leak model	ASTEC: considered
		Role of flaws and imperfections in both, concrete and liner		3,5,047	2,00	2,43	2,00	2,27	2	3,5	B1: analytical work to assess the behaviour of metallic pipes and liners by a code of mechanics for given pressure loads	
											A2: analytical exp. on liners	Exp. on mechanical behaviour of liners and of welding zones of liners: planned.
											A3: analytical exp. on concrete	Exp. on concrete specimens: permeability measurements under traction constraint with different temperature and humidity conditions
	Behaviour of composite liners	Leakage at pene-trations		3,5,059	2,00	2,00	2,50	2,11	2	3,5	C1: develop a conservative approach	No ongoing or planned activities
	Behaviour of steel liners	Leakage through locally failed steel liner		3,5,067	2,00	2,17	2,43	2,10	2	3,5	B1: validation of models based on existing data	
											A2: analytical exp. on liners	Exp. on mechanical behaviour of liners and of welding zones of liners.
											See also 3,5,059	
		Leakage at pene-trations		3,5,068	2,00	2,43	2,57	2,10	2	3,5	B1: validation of models based on existing data See also 3,5,059	

Long-term loading				4,0,000	4,0,000								
Containment thermal-hydraulics				4,1,000	4,1,000								
Containment atmosphere mixing	Heat transfer and internal flow rates	Jet/plume gas interaction and entrainment effects	*Needed for global validation.*	4,1,070	1,00	2,58	1,29	2,14	2	3,4		B1: detailed code improvement and validation. Validate CFD for general applications.	CFX, COCOSYS, GASFLOW, TONUS, ESTET, SATURNE. Review experimental database for model validation. Guidance on model creation and nodalisation
												A2: analytical experiments	TOSQAN, MISTRA, PANDA, ThAI: thermal hydraulics phenomena studies inside containment: heat transfer, condensation, stratification, steam and helium jet effects in simple and complex geometry
		Thermal and mass stratification inside containment compartments	*Needed for global validation.*	4,1,071	1,00	2,58	1,57	2,13	2	3,4		Same as 4,1,070	
Melt ejection and direct containment heating				4,2,000									
High or intermediate pressure melt ejection	Lower head failure	Break position	The break position is dependant on the in vessel phenomena addressed in the in vessel phenomena list: stratification of different corium layers, hot spot loadings, critical heat fluxes. . .. For DCH, it is a boundary condition which determines first the corium mass able to be ejected and then dispersed, but also the mechanism of ejection: particularly the break position will change the relative durations of the different phases flow (corium discharge, multiphase (corium + gases discharge), single phase gases discharge) and the velocity vector of liquid film	4,2,013	2,25	2,64	1,86	2,38	1	4,1		See 1,3,168, 2,1,042	
	Multi phase liquid Jet	Corium/steam two phase jet	Two different phases are distinguished for the corium ejection: the single liquid corium phase and then the multiphase steam/corium phase discharge. The item addresses the second one.	4,2,030	1,33	2,50	2,29	2,33	1	4,1		A1: semi-integral exp.	DISCO-H facility: alumina–iron melt and steam, RPV, cavity, sub-compartments and the containment in a 1/18 scale.

Table 1 (*Continued*)

Physical situation	Issue	Phenomenon	Phenomena description, other specific features	Reference no.	SoV P. C.	SoV Cont.	SoV S. T.	PoV	List	Item N. R.	Objectives of needed research	Description of experimental program or computer code
			The highly transient DCH process consists of a complex sequence of events, which must be adequately modeled to enable extrapolation.								B2: development and validation of simplified dispersal and entrainment models (CERSY test data available) A3: separate-effect tests on two-phase steam/corium discharge	RUPUICUV-0D (ASTEC): Planned in connection with AFDM meshed code validation at FZK; COCOSYS-DCH, MAAP
		Corium entrainment out of the reactor primary vessel with lateral breaches	In case of lateral breaks, the initial level of the corium melt in the lower head of the primary vessel may be above or not of the hole initial position.	4,2,031	1,00	2,42	2,29	2,50	1	4,1	Same as 4,2,030	Same as 4,2,030
Reactor cavity phenomena	Corium particles generation	Corium particles generation from the corium pool	Interaction between the corium pool and the high speed surrounding gases	4,2,060	1,00	2,44	1,67	2,42	1	4,1	Same as 4,2,030	Same as 4,2,030
		Corium particles generation from the two phases jet	The corium may be fragmented in side the corium/steam two-phase jet, phenomena considered here.	4,2,063	1,00	2,33	2,33	2,58	1	4,1	Same as 4,2,030	Same as 4,2,030
	Corium particles transfer	Corium particles entrainment	Entrainment of the corium particles along the reactor pit. *The corium particles entrainment depends on the cavity geometry* (*rather horizontal or vertical entrainment in case of an annular space around the vessel*).	4,2,070	0	2,50	2,00	2,38	1	4,1	Same as 4,2,030	Same as 4,2,030
		Corium particles trapping	Particles trapping are the result of singularities in the particles flow due to geometrical aspects. *The corium particles trapping depend on the cavity geometry and on pathes between cavity and containment geometry. Specific devices may be added to trap the corium particles*.	4,2,071	0	2,58	1,88	2,31	1	4,1	Same as 4,2,030	Same as 4,2,030
Mechanical static behaviour of containment and basemat				4,3,000								
Steel containment	Leakage	Leakage at penetrations		4,3,071	0	2,50	2,20	2,25	2	3,5	Same as 3,5,068	
Fission products				5,0,000								
In-vessel release				5,1,000								

Release mechanisms for FPs and actinides from solid fuel	Release mechanisms for FPs and actinides from solid fuel	Release in highly oxidising environment	Important increase of the volatility of certain elements due to a high state of oxidation, e.g. in the situation of air ingress in the core	5,1,026	1,67	1,00	2,36	2,69	1	5,1	B1: review of existing data	
											B2: analysis of reactor scenarios to define the test conditions	ATHLET-CD, ASTEC
			Containment filtered pressure relief is a likely measure to achieve severe accident final safe state.								A3: small-scale exp. to examine the speciation and aerosol behaviour of Ru under different oxidising environments, temperatures etc. with simulants and real FPs and other materials	Transport (thermal gradient tube etc.) and speciation (mass spectrometry, UV–vis spectroscopy etc.) experiments would be conducted under a range of conditions relevant to severe reactor accidents with involve identification of the dominant vapour-phase and condensed-phase (aerosol) species of ruthenium and simulant FPs.
			The issue is important for assessing containment by-pass scenarios.									RUSET, (AEKI): separate effect tests on the oxidation and release of Ru and other simulant FPs (1 rod segment) VERDON, MADRAGUE, real FP materials
			Knowledge base during refuelling outages, when the reactor vessel is open, should be increased. Chemistry in the containment is an important issue for long-term accident management.									CODEX-RU bundle (7–9 rods) tests with fission product simulant materials.
											B4: modelling improvement for FP release induced by fuel oxidation	ICARE/ELSA, DIVA/ELSA (ASTEC)

Table 1 (*Continued*)

Physical situation	Issue	Phenomenon	Phenomena description, other specific features	Reference no.	SoV P. C.	SoV Cont.	SoV S. T.	PoV	List	Item N. R.	Objectives of needed research	Description of experimental program or computer code
											B5: modelling effort for Ru transport including necessary kinetic effects	SOPHAEROS (ASTEC)
											A6: integral exp. to complement existing data from separate effect tests—coupling between fuel degradation and FP release	PHEBUS 2K planned mid 2007
Release of structure materials	Release of structure materials	Releases from silver-indium cadmium control rods	Silver indium and cadmium release at the time of control rod rupture and later on. *Modelling effort needed.*	5,1,041	1,00	1,00	2,36	2,09	2	5,2	B1: refined modelling of control rod degradation and its coupling with silver indium cadmium release	ATHLET-CD, ICARE/ELSA, DIVA/ELSA (ASTEC)
Core reflooding	Core reflooding	Interaction with water	Source term associated to the interaction between intact fuel, core debris, molten corium and water	5,1,050	1,75	1,67	2,23b	2,69	1b	5,5	B1: adaptation of existing release models	ATHLET-CD, ICARE/ELSA, DIVA/ELSA (ASTEC)
			The temporary increase of fission products during reflooding needs more test data. (Depending on the temperature and structure of the damaged core.)								A2: integral exp. with coupling of phenomena	PHEBUS 2K planned to study FP release during reflooding
			Only very few und very uncertain data from LOFT and TMI2								A3: small-scale exp. to examine the effect of release during boiling and long-term leaching of FPs	Simulant corium with sintered metal- or oxide-rich mixtures of UO2, Zircaloy with representative quantities of simulant FPs. Heat-up and cool-down phase. (Followup of LPP)
Transport in primary and secondary system				5,2,000								
Vapour phase phenomena	Vapour phase phenomena	Gas phase chemistry	Chemical reactions between various species depending on temperature, carrier fluid composition and concentration of species	5,2,014	1,33	1,17	2,40	2,38	1	5,2	B1: evaluation of existing database under consideration of prototypical conditions.	

											A2: small-scale exp. to examine the species formed in the gas phase under RCS. Data would be produced on speciation under representative RCS.	Highly reactive simulant fission product species, high-temperature conditions etc. of RCS conditions for iodine, caesium, tellurium and ruthenium species. Analysis: on-line mass spectrometry, filter and grab samples.
											A3: small scale exp. for gaseous iodine in the RCS especially for kinetic aspects	CHIP planned to address different plant situations
											B4: modelling effort starting by the identification of key species and reactions. Implementation of prelim. Kinetics data	IMPAIR, SOPHAEROS
											See also 5,1,026	
Aerosol phenomena	Resuspension	Re-volatilisation	Vaporisation of a deposited species, due to changes in temperature (including the effect of decay heat), vapour concentration or gas composition as well as abrupt pressure changes	5,2,042	1,67	1,17	2,33	2,45	1	5,3	Al1 integral tests with representative real materials	PHEBUS 2K planned—air ingress and quench tests
											A2: analytical experiments with simulants and/or samples from integral experiments.	
											B3: improvement of existing codes	
											See also 5,1,026, 5,1,050	IMPAIR, SOPHAEROS
Retention in complex structures	Retention in complex structures	Secondary side of steam generator	Aerosol retention by various mechanisms in the secondary side of a steam generator in case of steam generator tube rupture and possible containment bypass.	5,2,050	2,33	1,50	2,64	2,54	1	5,3	B1: analyses of reactor conditions A2: integral and separate effect test	ATHLET-CD, ICARE/CATHARE ARTIST (PSI) program

Table 1 (*Continued*)

Physical situation	Issue	Phenomenon	Phenomena description, other specific features	Reference no.	SoV P. C.	SoV Cont.	SoV S. T.	PoV	List	Item N. R.	Objectives of needed research	Description of experimental program or computer code
			No prototypical data exists under realistic boundary conditions and obtained using the real components. Available models for retention as a result of obstacles cannot be used under steam generator secondary side conditions and geometry.								B3: model development and implementation based on SGTR and ARTIST data B4: achieve realistic estimations of the source term	SOPHAEROS
Aerosol behaviour in containment				5,4,000								
Aerosol behaviour in containment	Retention in complex structure	Retention in containment leakage flow paths	Aerosol retention as they pass through various containment leakages (wall cracks, equipment hatch)	5,4,060	1,00	1,88	2,47	2,42	1	5,3	B1: evaluate existing data (MAEVA)	Exp. with well-defined cracks in representative concrete and standard aerosol sources and with on-line detection (AEA and DRAGON-PSI)
			Impact of water condensation is not well known, as tortuosities in cracks								A2: small-scale exp. to estimate degree of aerosol leakage See 3,5,044	
Iodine chemistry				5,5,000		0	0					
Chemistry in containment	Gas phase phenomena	Adsorption/desorption on/from surfaces	Transport of iodine species to (adsorption) or from (desorption) surfaces (metallic, paints, aerosol particles)	5,5,021	0	2,00	2,87	2,38	1	5,4	B1: review of existing data	Define objectives »> action on CEA
											A2: small-scale exp with metallic surface	IODE (ASTEC), IMPAIR
											B3: derive correlations of adsorption/desorption rates from existing data.	
		RI heterogeneous formation	Organic iodide formation in gas phase due to reaction of deposited iodine and iodide with paints	5,5,023	0	1,75	2,60	2,27	2	5,4	B1: review of existing data	
											A2: small-scale exp with relevant conditions	EPICUR: measure kinetics data
											B3: model improvement	IODE (ASTEC), IMPAIR

										See also 5,5,021	
	RI radiolytic destruction	Decomposition of organic iodide due to radiation in the gas phase	5,5,024	0	1,75	2,67	2,18	2	5,4	B1: review of existing data	
										A2: small scale exp. to identify the compounds generated by I2 and CH3I decomposition and rates	EPICUR planned—could provide information
										B3: incorporate decomposition rates from ICHEMM in models	IODE (ASTEC)
										B4: interpretation of new exp. data with mechanistic models and extrapolation to reactor conditions—derive simplified models See also 5,5,021	IODE (ASTEC)
	Effect of steam condensation	Volatile iodine trapping in water condensed from steam	5,5,025	0	1,75	2,29	2,31	1	5,4	A: small-scale exp. of steam condensation on paints in gaseous phase, without sump. See also 5,5,021	Initially iodine in gaseous phase, or deposited on paints.
Mass transfer	Mass transfer between sump and atmosphere	Phenomena governing the iodine flux between the liquid and the gas phase, assuming that thermodynamic equilibrium is reached at the interface	5,5,030	1,00	2,00	2,73	2,36	1	5,4	B1: update review of EPRI–ACEX project (1994–1996).	
										B2: define reactor typical conditions	PSIODINE, IMPAIR3
		Iodine partitioning between aqueous and gas phases is not only a function of the rate of production of volatile iodine species in aqueous phase but also depends on the mass transfer rate of iodine species crossing the water–gas interface.								A3: small-scale exp. for quantitative speciation data, also to provide information on mass transfer	FENRIS(PSI) with prototypical conditions for irradiation of aqueous solutions, containing iodine, organic components; fast speciation analysis

Table 1 (*Continued*)

Physical situation	Issue	Phenomenon	Phenomena description others specific features	Reference no.	SoV P. C.	SoV Cont.	SoV S. T.	PoV	List	Item N. R.	Objectives of needed research	Description of experimental program or computer code
											B4: implement improved models using exp. data (SISYPHE)	CPA/IODE (ASTEC)
	Liquid phase phenomena	Boundary conditions	Influence of thermal-hydraulics, Ag oxidation, pH development, concentrations of additives, mass transfer and radioactive boundary conditions on iodine chemistry	5,5,040	0	2,00	2,80	2,42	1	5,4	B1: define reactor typical conditions	IMPAIR, ASTEC
											A2: analytical exp. for Ag oxidation	PARIS provides data (only partial)
		Oxidation and reduction of iodine species	Various oxydo-reduction reaction leading to interconversion between I^-; I_2 and $IO_3{}^-$	5,5,043	0	2,00	2,36	2,33	1	5,4	B1: model improvement (exist. data)	IODE (ASTEC)
											B2: define reactor typical conditions	PSIODINE, IMPAIR3
			Iodine speciation is a function of oxidation or reduction of iodine species depending on the presence of radiation products of water, dose, solution pH, impurities, etc.								A3: small-scale exp. with complex composition of sump water and impurities	FENRIS(PSI) with prototypical conditions for irradiation of aqueous solutions, containing iodine, organic components and impurities
											See also 5,5,040	
		Homogeneous organic iodide formation	Organic iodide formation in aqueous phase initiated by radiolytic decomposition of organic material	5,5,047	0	2,00	2,47	2,67	1	5,4	B1: define reactor typical conditions	PSIODINE, IMPAIR3
											A2: small-scale exp.	Get data on organic material release from atmospheric paints and their transfer to sump water, CAIMAN
			No consensus on the mechanism of formation of organic iodide exists.								A3: small-scale exp. with real old paints (older than 15 years)	FENRIS(PSI) with prototypical conditions for irradiation of aqueous solutions, containing iodine, organic components

											See also 5,5,040	
		RI formation on submerged paints	Organic iodide formation by surface reactions with submerged paints. *Model validation needed.*	5,5,048	0	1,75	2,40	2,25	2	5,4	See 5,5,040; 5,5,047	
		Iodine release from drying pools	Release of iodine from a pool when it dries.	5,5,04C	0	1,67	2,36	2,60	1	5,4	A1: small-scale exp. with reactor typical conditions to renew incomplete database from 1980.	New exp. with prototypical conditions for irradiation of aqueous solutions
			A sudden surge of volatile iodine release is expected at the time when the pool is very close to dryness.								See also 5,5,040	
Transfer out of containment	Transfer by leaks	Retention in leakage paths	Fractions of molecular and organic iodine retained in the leakage paths of the containment	5,5,080	2,00	1,75	2,50	2,40	1	5,3	C1: conservative approach, especially for organic iodine	
											See also 3,5,044; 5,4,060	

- regularly updated PIRT as a function and a measure of the progress performed in the network;
- diffuse the knowledge to Associated Candidate Countries more efficiently and associate them to the definition and the conduct of our research programmes more closely;
- bring together top scientists in severe accident to be a world leader in advanced computer tools for severe accident risk assessmentl;
- train students and researchers in experimental techniques, in risk evaluation and in code development, and facilitate their mobility and
- develop advanced communication links and user-friendly databases to facilitate capitalization and diffusion of knowledge.

5.2. *Network proposed structure*

The network should be organised on the basis a joint programme of activities divided in sub-domains: scientific (as corium, containment, source term, plus an integrated severe accident code), Level 2 PSA, Education and training, Databases, Information system. It might be organised with a two management level structure. On the first level, a Governing Board involving all members will be in charge of strategic decisions and will be advised by an Advisory Committee and an Ad-hoc Scientific Committee. On the second level, a Management Team will be entrusted with the task of the day-to-day management of the network.

5.2.1. *The Governing Board*

A Governing Board should review the progress made by the network, in particular in terms of progressive integration, and make recommendations on future orientations. It will decide upon the allocation of the financial contribution of the commission and approve the joint programme of activities. The Governing Board is composed of:

- one member designated by each network partner and
- one representative of the Commission as observer.

5.2.2. *The Advisory Committee and the Ad-hoc Review Committee*

The role of the Advisory Committee will be to provide the Governing Board with advice on strategic orientations of the research activities. It will involve end-

Table 2
Items for still needed research in severe accidents as deduced from the PIRT

No.	Items for needed research	Rationale for selection
1,1	Hydrogen generation during reflood or melt relocation into water	Rapid generation of hydrogen, which may not be accommodated by recombiners and the risk of early containment failure. Improve knowledge about the magnitude of hydrogen generation.
1,2	Core coolability during reflood and thermal-hydraulics within particulate debris	Termination of the accident by re-flooding of the core while maintaining RCS integrity. Increase predictability of core cooling during re-flood.
1,3	Corium coolability in lower head and external corium catcher device	Improve predictability of the thermal loading on RPV lower head or corium catcher devices to maintain their integrity.
1,4	Integrity of RPV due to external vessel cooling	Improve database for critical heat flux and external-cooling conditions to evaluate and design AM strategies of external vessel cooling for in-vessel melt retention.
1,5	Integrity of RCS	Improve predictability of heat distribution in the RCS to quantify the risk of RCS failure and possible containment bypass.
1,6	Corium release following vessel failure	Improve predictability of mode and location of RPV failure to characterise the corium release into the containment.
2,1	MCCI: molten pool configuration and concrete ablation	Improve predictability of axial versus radial ablation up to late phase MCCI to determine basemat failure time and loss of containment integrity.
2,2	Ex-vessel corium coolability, top flooding	Increase the knowledge of cooling mechanisms by top flooding the corium pool to demonstrate termination of accident progression and maintenance of containment integrity.
2,3	Ex-vessel corium catcher: corium ceramics interaction and properties	Demonstrate the efficiency of specific corium catcher designs by improving the predictability of the corium interaction with corium catcher materials.
2,4	Ex-vessel corium catcher: coolability and water bottom injection	Demonstrate the efficiency of water bottom injection to cool corium pool and its impact on containment pressurisation.
3,1	Melt relocation into water and particulate formation	Determine characteristics of jet fragmentation, debris bed formation and debris coolability towards maintenance of vessel and respectively containment integrity.
3,2	FCI incl. steam explosion: melt into water, in-vessel and ex-vessel	Increase the knowledge of parameters affecting steam explosion energetics during corium relocation into water and determine the risk of vessel or containment failure.
3,3	FCI incl. steam explosion in stratified situation	Investigate the risk of weakened vessel failure during reflooding of a molten pool in the lower head.
3,4	Containment atmosphere mixing and hydrogen combustion/detonation	Identify the risk of early containment failure due to hydrogen accumulation leading to deflagration/detonation and to identify counter-measures.
3,5	Dynamic and static behaviour of containment, crack formation and leakage at penetrations	Estimate the leakage of fission products to the environment.
4,1	Direct containment heating	Increase the knowledge of parameters affecting the pressure build-up due to DCH and determine the risk of containment failure.
5,1	Oxidising environment impact on source term	Quantify the source term, in particular for Ru, under oxidation conditions/air ingress for HBU and MOX.
5,2	RCS high-temperature chemistry impact on source term	Improve predictability of iodine species exiting RCS to provide the best estimate of the source into the containment.
5,3	Aerosol behaviour impact on source term	Quantify the source term for aerosol retention in the secondary side of steam generator and leakage through cracks in the containment wall as well as the source into the containment due to revolatilasation in RCS.
5,4	Containment chemistry impact on source term	Improve the predictability of iodine chemistry in the containment to reduce the uncertainty in iodine source term.
5,5	Core re-flooding impact on source term	Characterise and quantify the FP release during core re-flooding.

user organisations, including vendors, utilities and regulatory bodies from Europe and Associated Candidate Countries.

The role of the Ad-hoc Scientific Review Committee will be to review, on behalf of and at the request of the Governing Board, the scientific and technical activities performed by the network and the knowledge acquired.

5.2.3. The Management Team

The Management Team should be in charge, on behalf of the Governing Board, of the day-to-day management. The Management Team is composed of the coordinator heading the team, of scientific coordinators, who will coordinate the scientific activities of the project leaders in a sub-domain (corium, containment, source term), of an Education and Training Coordinator, of a Database Manager, and of an Information System Manager. Administrative experts will assist the Management Team.

The Management Team should monitor the progress made in the joint programme of activities, examine any difficulty, which may arise and examine with the corresponding project leaders the possible actions to overcome them, examine the new projects, promote collaborations and make proposals to the Governing Board for updating the programme of activities, manage the communication system and the databases of the network, organise the training and education activities, and disseminate information inside and outside the network, in particular by organizing annual conferences and topical seminars, and by setting a web site.

The coordinator acts under the control of the Governing Board, and reports to it on his duty, by pproviding technical and financial reports to the Governing Board, coordinating the annual joint programme of activities updates for approval by the Governing Board and implementing the decisions of the Governing Board, notably the joint programme of activities.

Further details about the network organisation and definition of research fields are found in (Mailliat and Magallon, 2003).

5.2.4. Implementation of the network

The proposal for implementing such a Severe Accident Research Network of Excellence, called SARNET, has been accepted by the European Commission for the sixth framework programme. The project is being started and has initial duration of 4 years.

6. Severe accident database structure

Working in a network structure addressing all severe accidents issues requires an efficient tool to ensure that everyone has equal and easy access to all the shared data for an optimised use. This objective can be reached through using advanced hardware and software computer technologies (e.g., web-based techniques) able to ensure a distributed repository of the data (presently stored in variety of forms and format, e.g., paper support, tapes, CD, magnetic media) taking into account data access and retrieval requirements for code development and assessment, and storage and retrieval of supporting information (such as data reports, data analysis reports, test facility drawings, pictures and/or video film). At the same time, it is necessary that participating organisations can establish themselves and independently from each other adequate levels of access to their own information for preserving copyright.

In the frame of EURSAFE a database network was developed for demonstration purpose essentially. Five EURSAFE partners having already produced a significant amount of data participated, namely CEA, FZK, IRSN, JRC and RIT. Extension to all severe accident data is envisaged in the frame of the SARNET Network of Excellence. The basis is the STRESA structure developed by JRC (Annunziato et al., 2001). Designing the platform was made after assessing current practices for the preservation and maintenance of severe accident data (Meyer et al., 2003) and identifying data access requirements by code developers and users (Piluso et al., 2003). The final product, named EURSAFE, is a network connecting five different STRESA nodes located at each partner site (Annunziato et al., 2003). Each partner manages the access level to the data stored on his node.

A preliminary version of the EURSAFE website is available at http://asa2.jrc.it/eursafe. It is composed of a number of facilities organised by thematic arguments (FCI, spreading, vessel behaviour, etc.). Experiments and data which have been included in the database so far are the following:

- CEA: facilities from PLINIUS platform: VULCANO (VE-U7), VITI, COLIMA, KROTOS;
- IRSN: PHEBUS FPT-0, FPT-1;
- FZK: QUEOS, PREMIX, ECO, DISCO and possibly KJET (two tests of each facility);

- RIT: FOREVER, KMFCI, POMECO and
- JRC: FARO, KROTOS.

7. Conclusions

The objectives of this joint venture project have been fully reached. All the major European actors in nuclear safety worked together in the project, whatever they are R&D organisations, utilities, regulatory bodies, industries, universities. Non-European entities like US–NRC were also participating.

EURSAFE thematic network has demonstrated that the major actors in nuclear safety representing a large spectrum of different economic and safety interests could reach a common agreement on severe accident issues and phenomena, on their importance in terms of safety and knowledge, on where are the remaining major uncertainties and on the necessary actions to undertake to resolve them. This of course reinforces the credibility of the conclusions on the state-of-the-art of severe accident issues.

By this diversity and close collaboration, all the pending uncertainties on severe accident issues could be identified and ranked according to commonly established and unified rules. The PIRT realised in EURSAFE was a first-of-a-kind exercise encompassing all severe accident safety issues and represents a major outcome of the project in this respect.

EURSAFE was the starting point towards an extended harmonized effort in developing and securing the existing data for the mitigation of severe accidents. The natural continuation of this effort will be the SARNET Network of Excellence proposed in FP6 to implement and perform the required research programmes and integrated actions to resolve the remaining severe accident issues.

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