EUROPEAN NETWORK FOR THE REDUCTION OF UNCERTAINTIES IN SEVERE ACCIDENT SAFETY ISSUES (EURSAFE)

CO-ORDINATOR

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3.	EDF	Electricité de France, Pôle Industrie, Chatou (F)
4.	TVO	Teollisuuden Voima Oy, Olkiluoto (FIN)
5.	AEAT	AEA Technology plc, Nuclear Technology, Dorchester (UK)
6.	SERCO	SERCO Assurance, Risley (UK)
7.	NRI	Nuclear Research Institute plc, Rez (CZ)
8.	FZK	Forschungszentrum Karlsruhe, Karlsruhe (D)
9.	IKE	Institut für Kernenergetik und Energiesysteme, Stuttgart (D)
10.	GRS	Gesellschaft fuer Anlagen und Reaktorsicherheit, Garching (D)
11.	FANP	FRAMATOME ANP GmbH, Erlangen (D)
12.	KTH	Royal Institute of Technology, Stockholm (S)
13.	AEKI	KFKI Atomic Energy Research Institute, Budapest (HU)
14.	CSN	Consejo de Seguridad Nuclear, Madrid (E)
15.	UPM	Universidad Politecnica de Madrid, Madrid (E)
16.	JRC	Joint Research Centre, Petten (NL)
17.	VEIKI	Institute for Electric Power Research Co, Budapest (HU)
18.	HSE	Health Safety Executive (UK)
19.	PSI	Paul Scherrer Institut, Villigen (CH)
20.	NRC	Nuclear Regulatory Commission (USA)
21.	CIEMAT	Department of Nuclear Fission (E), *Observer*
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EXECUTIVE SUMMARY

The objective of the EURSAFE network was to establish a large consensus on the Severe Accident issues where large uncertainties still subsist and to propose a Severe Accident Networking of Excellence structure to address these issues through concerted and optimised Research programmes. The project was a thematic network of duration two years starting 1st December 2001 and finishing 30 November 2003.

First, a PIRT (Phenomena Identification and Ranking Tables) was established for each phase of a severe accident from core degradation up to release of fission products in the containment, taking into account any possible counter-measures and the evolution of fuel management. Second, the PIRT implications and actions were determined taking into account existing and planned European facilities, codes and programmes. Third, recommendations were made for the structure of a future Networking of Excellence. Fourth, a consolidated framework for the preservation of integral severe accident data used for the assessment of computer codes performance in nuclear reactor conditions data was proposed.

The PIRT phenomena list was successfully established by consensus among the twenty organisations in the project representing the mains actors in Nuclear Safety in Europe and beyond, which legitimates its validity. Starting from a list of all severe accident phenomena established by the project partners and containing more than 1000 entries, 105 phenomena were retained eventually as both important for safety and still lacking sufficient knowledge.

PIRT implications included identifying the research needs to address each selected phenomena of the PIRT list and regrouping the phenomena 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 list of 21 items for needed research resulted, representing a common European view of the needs.

Defining the best networking structure for implementing and executing the necessary research to address the remaining severe accident issues was established in parallel with developing a proposal for such a network in FP-6. Practically, the activities in the frame of EURSAFE were devoted to the organisation of the network and the definitions of the research fields according to the PIRT and PIRT implications results, having the aim of promoting the integration of different national programmes.

A possible structure for data conservation and exchange in a network environment was experimented in EURSAFE with five participating partners. The work included assessing current practices for preservation and maintenance of SA data, identifying data access requirements by code developers and users, designing and creating the network. The existing STRESA web structure originally developed by JRC-Ispra was used as the starting point. One week training on STRESA was organized for each partner and a network connecting five different STRESA nodes located at each partner site was set up and assessed. A EURSAFE Web site is available at http://asa2.jrc.it/eursafe. It is composed of a number of facilities organized by thematic arguments (FCI, spreading, Vessel behaviour, etc.).

A. OBJECTIVE AND SCOPE

Important progress towards the resolution of severe accident issues has been accomplished in the 4th and 5th framework programmes by promoting discussion and work between the experts in specific domains [1-2]. At this stage, it has been found that a network regrouping all the severe accident domains, and bringing all the actors in nuclear energy to work together, was an appropriate structure to identify those areas where large uncertainties still subsist as well as integrated programmes to reduce these uncertainties.

The objective of the EURSAFE thematic network is 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. It incorporates issues related to existing plants (PWR, BWR and VVER), lifetime extension of these plants, evolutionary concepts (higher burn-up and MOX fuels), and safety and efficiency of future systems.

In order to reach the objective 20 partners representing R&D governmental institutions, regulatory bodies, nuclear industry, utilities and universities from 6 EU Member States (Finland, France, Germany, Spain, Sweden, United Kingdom) plus JRC, 3 European third countries (Czech Republic, Hungary, Switzerland), and the USA were brought to work together in a network structure, which is supposed to be the embryo of a future Severe Accident Network of Excellence.

B. WORK PROGRAMME

B.1. Project Management

This work-package includes the overall project management, monitoring and coordination activities. These activities are organising the meetings, defining the working methodology, setting up the technical sub-groups, editing and distributing the contractual deliverables, reporting to the Commission.

B.2. PIRT

To achieve the objectives requires obtaining among all the major European actors in Nuclear Safety sufficient convergence on 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 [3].

A PIRT is realised here for the first time for severe accidents as an initial step towards the objective (WP2. WP1 is management of the project). It integrates all the severe accident issues from core degradation up to release of fission products in the containment, taking into account any possible counter-measures and the evolution of fuel management.

B.3. PIRT Implications

PIRT implications are then deduced taking into account existing and planned European facilities, codes and programmes (WP3). The work package includes:

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.

B.4. Networking of Excellence Structure

The following phase is proposing a conceptual organization for a possible future European Network of Excellence for Severe Accidents (WP4). The mission of this network would be to address the remaining uncertainties on the key safety issues according to the conclusions of WP3 by optimizing the use of resources available in Europe.

B.5. Severe accident database structure

Having the prospective of becoming a network of excellence, it is important that the EURSAFE network address the problem of finding a possible unified data conservation system, for both already existing experimental data and those which might be produced (WP5). This task is conducted in parallel with the other WPs.

C. WORK PERFORMED AND RESULTS

C.1. C.1 PIRT (*Leader J.M. Seiler, CEA*)

For realising the PIRT, a list of severe accident phenomena, classified in five groups (Ex-vessel phenomena, In-vessel phenomena, Dynamic loading, Long term loading, Fission products), was first established. The list was then used by each partner for voting 1)- on safety importance using partner's own safety analysis criteria, including level-2 PSA, and 2)- on knowledge level. Voting and ranking were established through well-defined procedures and finalised after checking their consistency during plenary sessions at PIRT meetings.

First, three safety-oriented groups of experts scrutinized the definitive list of phenomena and ranked them according to their importance for primary circuit safety, containment safety and source term. Then, the five previously mentioned phenomena-oriented groups ranked in terms of knowledge those phenomena selected as important for safety.

Practically, numerical values were assigned to the phenomena which could be either High (H=3), Medium (M=2) or Low (L=1) for Safety Importance and Known (K=1), Partly Known (PK=2) or Unknown (UK=3) for Knowledge. According to the number of H, M and L votes assigned to a phenomenon, an Importance Ratio (IR) was deduced from:

$$IR = \frac{(3n_H + 2n_M + n_L)}{(n_H + n_M + n_L)} \qquad IR \in [1,3]$$

For IR greater than 2.32, a phenomenon was flagged as highly important for safety.

The same method, applied to the knowledge votes, allowed to define, using a similar formula, a Knowledge Ratio KR. Phenomena associated with a KR greater than 2.32 present a significant lack of knowledge.

After completion of the two ranking phases, this procedure clearly emphasized the phenomena being simultaneously highly important for safety and significantly lacking of knowledge. Such phenomena are obviously candidates for further R&D work, which will be specified in the PIRT's implications work package.

Starting with 916 identified phenomena, the list was reduced to 229 important for safety, of which 106 were found lacking sufficient knowledge. The list was in turn divided into two categories: phenomena most significantly lacking knowledge (57 phenomena) and those still lacking knowledge for some aspects (49 phenomena). Figures 1 and 2 illustrate the phenomena identification process and summarise the PIRT work, respectively.

A PIRT report will be made available, which details all the phases of the work, and explains in more details the criteria used for voting, ranking and establishing the lists. Besides the consensual conclusions, the report contains also the votes and comments of all partners individually in order to keep trace of technical aspects, which justify the PIRT conclusions, and to provide a reference for future updating of the PIRT.

C.2. PIRT Implications (*Leader K. Trambauer, GRS*)

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 (Table I). In the column "Objectives of needed research " of Table I, 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,

1, 2, 3… indicate a chronological order for performing the research.

Next, 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. The outcome of this process is summarised in Table II, which gives the 21 items of needed research and relative rationales drawn from the 106 phenomena selected in the PIRT.

C.3. Proposal for a Network of Excellence (*Leader A. Mailliat, IRSN*)

In order to optimise the use of resources available in Europe and reinforce the credibility of severe accident analyses, the remaining issues have to be addressed within an integrated structure. A proposal has been submitted to implement such a structure as a network of excellence in FP6. This network, named SARNET (Severe Accident Research Network), is a natural continuation of the EURSAFE network, and will now bring together the European organisations around a joint programme of research activities to satisfy the needs identified in EURSAFE.

The ultimate objective is to elaborate a virtual laboratory based on national resources, know-how and expertise, and having a strong coordinating structure. This laboratory will have the mission to carry out the commonly agreed research programmes in an optimised way in order to resolve the above remaining safety issues and produce highly validated and qualified tools for Level-2 PSA studies for any kind of NPPs in Europe. It should be one the major objective of the Network to re-orientate progressively the existing national programmes and contribute to launch new ones in a coordinated way and in accordance with the research priorities identified by the Network, eliminating duplications and developing complementarities.

It will be necessary to integrate the current knowledge and all the future knowledge generated by the research activities performed within the network in a unique severe accident code. Most of the ongoing research activities will have the ultimate objective to provide this code with appropriate physical modelling. In addition, the tool will be adapted, through mostly co-operative actions, so as to be used for any reactor applications in Europe.

Integration of the experimental research capacities will be more progressive, to account for the need to raise funding at national and extra-national levels in order to support the cost of the experimental programmes, notably in case of large ones. Nevertheless, most of the ongoing national experimental research programmes should be proposed as part of the network in view of providing the critical mass of competence needed to resolve the remaining issues as identified in EURSAFE. A clear policy in terms of access rights to experimental data produced within the network is proposed to preserve the interests of the different organizations. Progress reports on restricted experimental programmes will be widely disseminated in order to promote extension of existing collaborations within other members of the Network.

To be sure that the research is efficient and well focused, the PIRT exercise will have to be regularly updated. In parallel, actions will be taken for training students and researchers in experimental techniques, in risk evaluation and in code development, and for facilitating their mobility into the corresponding teams.

Advanced communication links and user-friendly databases will be developed to facilitate the capitalization and the diffusion of knowledge, and the joint execution of the programme of research activities together with reducing rapidly the number of meetings and amount of travel: e-learning, on-line assistance to code users, access to experimental databases and thermodynamic databases, work flow between co-developers, co-development and management of technical documentation, multi-site videoconference, etc… Actions will be taken to normalize and secure the scientific and technical information produced by the Network.

C.4. Proposal for a Data Conservation Structure (*Leader A. Annunziato, JRC*)

This task includes: i) Assessing current practices for the preservation and maintenance of severe accident data; ii) Identifying data access requirements by code developers and users; iii) Formulating guidelines for the preservation of and access to the data; iv) Designing a platform for the preservation of the data.

It is proposed to use advanced hardware and software computer technologies (e.g., web-based techniques) 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. This allows also storage and retrieval of supporting information such as data reports, data analysis reports, test facility drawings, pictures and/or video film. A the same time it is necessary that participating organisations can establish themselves independently each other the level of access to their own information preserving possible copyright prerogatives.

In the frame of EURSAFE this activity was essentially developed for demonstration purpose and thus limited to five EURSAFE partners (CEA, FZK, IRSN, JRC, RIT,). It is envisaged to be extended to all severe accident data in the frame of the SARNET Network of Excellence. The basis is the STRESA structure developed by JRC [4]. The final product, named EURSAFE, is a network connecting five different STRESA nodes located at each partner site. Each partner manages the access level to the data stored on his node.

EURSAFE website is available at http://asa2.jrc.it/eursafe. The site is still in construction. It is composed of a number of facilities organized by thematic arguments (FCI, spreading, Vessel behaviour, etc.). At present, it contains data from selected tests of the PLINIUS, PHEBUS, DISCO, FOREVER, MISTEE, PREMIX, QUEOS, ECO, POMECO, KJET, FARO and KROTOS programmes. Figure 3 shows a picture of the home page of the site.

CONCLUSION

EURSAFE thematic network has demonstrated that the major European 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 results 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.

REFERENCES

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[3] Phenomena Identification and Ranking Tables (PIRT's) for Loss-of-Coolant Accidents in Pressurized and Boiling Water Reactors Containing High Burnup Fuel, NUREG/CR-6744, LA-UR-00-5079.

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Table I: Severe Accident PIRT list (see key Section C.2)

Physical Situation	*Issue*	*Phenomenon*	*Phenomena Description others Specific Features*	*Ref. N.*	*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	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	Validation of 2D-3D models and experimental benchmarking Model oriented, simple structures, heating and inflow/outflow conditions, subsequently introduction of complications i.e. inhomogeneities (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 B2: improvements of existing models (ELSA) A3: integral exp.	exp. at very high temperatures (VERCORS exp.) Validation of Codes, Benchmark to Phebus ect. 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 A2: integral exp. B3: model improvement	small-scale exp. to obtain basic data (effective surface available for oxidation), well-instrumented so that transient effects can be quantified MADRAGUE planned QUENCH, Phébus 2K: planned

Physical Situation	*Issue*	*Phenomenon*	*Phenomena Description others Specific Features*	*Ref. N.*	*SoV P. C.*	*SoV Cont.*	*SoV S. T.*	*PoV*	*List*	*Item N. R.*	*Objectives of Needed Research*	*Description of Experimental Program or Computer Code*
Damaged core	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 A4: integral exp.	possibly fulfilled by a further stage of the MADRAGUE incl. Quench 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. 2-D 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. 2-D 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 flowrate 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. C3: dev. simplified model (e.g. HARAR) See 1,1,200, 1,2,060, 1,2,080	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. Parameter studies on consequences
Corium relocation to lower head	Initial conditions	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	

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	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) A2: analytical exp. with water above the pool. B3: Code development and validation D4: Assessment of the potential and risk to retain the melt within the RPV by flooding of the reactor pit	Effect of steam and aerosol on radiative heat transfer SIMECO exp. Relevant phenomena: stratification, convection, conduction, radiation, impact of overlying water and melt/ structure addition from RPV internals

Physical Situation	*Issue*	*Phenomenon*	*Phenomena Description others Specific Features*	*Ref. N.*	*SoV P. C.*	*SoV Cont.*	*SoV S. T.*	*PoV*	*List*	*Item N. R.*	*Objectives of Needed Research*	*Description of Experimental Program or Computer Code*
		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. B2: dev. of models	Determination oft the vaporization rate according to the composition and the thermodynamic conditions of the corium (with FP simulants) COLIMA 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.* Recently performed experiments indicate that penetrations do not significantly hinder the heater transfer to the water.	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. D3: Assessment of the potential and risk to retain the melt within the RPV by flooding of the reactor pit	To resolve concerns related to scaling and design impacts on heat transfer, SULTAN.
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 3-D 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 3-D aspect reasonably covered. Improve treatment of penetrations Analytical tests on plate fissuration
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.

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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 Subgroup n°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 A2: Plant specific experiments C3: Determine most probable breach location and breach dimension for reference failure modes see 1,3,168, 2,1,040	Use of simulant material (FOREVER)
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 subgroup n°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

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		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 transfert between liquid layers with or without crust at interface entrainment by gas buble 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 subgroup n°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 throughpossible 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 A2: Integral experiment? D3: Related to specific reactor design	Specific reactor problem. Important for SAM implementation and emergency considerations COMET?

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Core Catcher: Spreading Phenomena				*2,3,000*								
Corium and substrate properties	Thermodynamic properties	ΔH, 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 B2: Consolidate recent studies, particularly from MASCA, evaluate existing data base, link data base to MCCI codes	High Temperature Mass spectrometry measurements, ISABEL tests, ENTHALPY project, MASCA, COLIMA facility 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	ΔH, 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) B2: improve 2D models using exp. data A3: analytical exp.	MEDICIS CROCO, TOLBIAC ARTEMIS, confirmatory research for specific core catcher
Corium - ceramic interaction Heat transfer and dissolution mechanism	Dissolution mechanism	Effect of O2 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 A2: Assess the stabilization of interaction with stratified (oxide/metal) corium see also 2,4,060	MEDICIS, CROCO, TOLBIAC COLIMA: Determination of ceramic dissolution in stratified pool, control of the atmosphere conditions, prototypic materials
Corium Coolability				*2,5,000*								
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 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	OECD-MCCI, COMET: Clarification of related phenomena is necessary for assessment of melt coolability MEDICIS / WEX, CROCO-0D, TOLBIAC-ICB
	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	

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	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 meters) especially: pressure build-up under, ejection paths and modes
Debris bed formation and debris bed coolability eneric item	Melt jet breakup in water pool	jet breakup in deep water pool (> 4m)	complete fragmentation reached by deep water pools depending on melt jet/stream conditions same cond. 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	
Debris bed formation and debris bed coolability eneric item	Melt jet breakup in water pool	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); - global size distribution: e.g. stratification with small particles at top	2,5,052	1,50	2,50	2,25	2,23	2	3,1	see 3,1,022	
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 buildup 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 buildup, resulting motions and fragmentation (surface increase) determines porosity formation; driving pressure buildup 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 buildup 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 subgroup n°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)	

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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 downcomer.	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 premixing/ 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 1st 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 3rd 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	

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	Explosion expansion	similar to 3.1 A	In PIRT 4th 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 wawes are not weel known. Experiments are necessary in this field, especially concerning detonation and DDT which is the only threatening phenomenon for the containment integrity. Nevertheless, the use of recombiners limit strongly the risks.	3,3,022	1,00	2,69	1,40	2,20	2	3,4	B1: evaluate existing data base, 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 B2: detailed code improvement. Needs detailed 3D studies. B3: simplified 0D code development	ENACCEF-CNRS and spherical bomb experiments CNRS. TONUS, COM3D, DET3D, CFX, COCOSYS, Needs consolidation, acceleration, improved user interfac. 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 data base 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 B2: detailed code improvements and validation. see also 3,3,043	ENACCEF-CNRS and spherical bomb experiments CNRS. Ongoing activities at FZK for quantification of this process TONUS : coupling between turbulence and combustion. CFX, COCOSYS, GASFLOW

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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. B2: finite element code (mechanics): Model validation and improvement for cracks development B3: detailed thermal hydraulics code: Model improvement of flow rates B4: 0D model: Development and integration of containment leak model	Last MAEVA exp. CASTEM: static quasi loading and application to reactor cases ADINA TONUS and CASTEM 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 A3: analytical exp. on concrete	 Exp. on mechanical behaviour of liners and of welding zones of liners: planned. Exp. on concrete specimens: permeability measurements under traction constraint with different temperature and humidity conditions
	Behaviour of composite liners	leakage at penetrations		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 see also 3,5,059	 Exp. on mechanical behaviour of liners and of welding zones of liners.
		leakage at penetrations		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	
Longterm Loading				**4,0,000**								
Containment Thermal-hydraulics				*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. A2: analytical experiments	CFX, COCOSYS, GASFLOW, TONUS, ESTET, SATURNE Review experimental database for model validation. Guidance on model creation and nodalisation 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	

Physical Situation	*Issue*	*Phenomenon*	*Phenomena Description others Specific Features*	*Ref. N.*	*SoV P. C.*	*SoV Cont.*	*SoV S. T.*	*PoV*	*List*	*Item N. R.*	*Objectives of Needed Research*	*Description of Experimental Program or Computer Code*
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 The highly transient DCH process consists of a complex sequence of events, which must be adequately modeled to enable extrapolation.	4,2,030	1,33	2,50	2,29	2,33	1	4,1	A1: semi-integral exp. B2: development and validation of simplified dispersal and entrainment models (CERSY test data available) A3: separate-effect tests on two-phase steam/corium discharge	DISCO-H facility: alumina-iron melt and steam, RPV, cavity, subcompartments and the containment in a 1/18 scale. 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 is the result of singularities in the particles flow due to geometrical aspects. *The corium particles trapping depends on the cavity geometry and on pathes between cavity and containment geometry. Specific devices may be added to trapp 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	Leackage at penetrations		4,3,071	0	2,50	2,20	2,25	2	3,5	same as 3,5,068	

Physical Situation	*Issue*	*Phenomenon*	*Phenomena Description others Specific Features*	*Ref. N.*	*SoV P. C.*	*SoV Cont.*	*SoV S. T.*	*PoV*	*List*	*Item N. R.*	*Objectives of Needed Research*	*Description of Experimental Program or Computer Code*
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 Containment filtered pressure relief is a likely measure to achieve severe accident final safe state. The issue is important for assessing containment by-pass scenarios. 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.	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 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 B4 modelling improvement for FP release induced by fuel oxidation B5 modelling effort for Ru transport including necessary kinetic effects A6 integral exp. to complement existing data from separate effect tests - coupling between fuel degradation and FP release	ATHLET-CD, ASTEC 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. RUSET, (AEKI): separate effect tests on the oxidation and release of Ru and other simulant FPs (1 rod segment) VERDON, MADRAGUE, real FP materials CODEX-RU bundle (7-9 rods) tests with fission product simulant materials. ICARE/ELSA, DIVA/ELSA (ASTEC SOPHAEROS (ASTEC) 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 The temporary increase of fission products during reflooding needs more test data. (Depending on the temperature and structure of the damaged core). Only very few und very uncertain data from LOFT and TMI2	5,1,050	1,75	1,67	2,23b	2,69	1b	5,5	B1: adaptation of existing release models A2: Integral exp. with coupling of phenomena A3: Small scale exp. to examine the effect of release during boiling and long term leaching of FPs	ATHLET-CD, ICARE/ELSA, DIVA/ELSA (ASTEC) PHEBUS 2K planned to study FP release during reflooding 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)

Physical Situation	*Issue*	*Phenomenon*	*Phenomena Description others Specific Features*	*Ref. N.*	*SoV P. C.*	*SoV Cont.*	*SoV S. T.*	*PoV*	*List*	*Item N. R.*	*Objectives of Needed Research*	*Description of Experimental Program or Computer Code*
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 data base 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. A3: Small scale exp. for gaseous iodine in the RCS especially for kinetic aspects B4: modelling effort starting by the identification of key species and reactions . Implementation of prelim. kinetics data see also 5,1,026	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. CHIP planned to address different plant situations IMPAIR, SOPHAEROS
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	A1 Integral tests with representative real materials A2 analytical experiments with simulants and/or samples from integral experiments. B3 improvement of existing codes see also 5,1,026, 5,1,050	PHEBUS 2K planned - air ingress and quench tests 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. 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.	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 B3: Model development and implementation based on SGTR and ARTIST data B4: Achieve realistic estimations of the source term	ATHLET-CD, ICARE/CATHARE ARTIST (PSI) program 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) Impact of water condensation is not well known, as tortuosities in cracks	5,4,060	1,00	1,88	2,47	2,42	1	5,3	B1: evaluate existing data (MAEVA) A2: Small scale exp. to estimate degree of aerosol leakage see 3,5,044	Exp. with well-defined cracks in representative concrete and standard aerosol sources and with on-line detection (AEA and DRAGON-PSI)

Physical Situation	*Issue*	*Phenomenon*	*Phenomena Description others Specific Features*	*Ref. N.*	*SoV P. C.*	*SoV Cont.*	*SoV S. T.*	*PoV*	*List*	*Item N. R.*	*Objectives of Needed Research*	*Description of Experimental Program or Computer Code*
Iodine Chemistry				*5,5,000*					*0*	*0*		
Chemistry in containment	Gas phase phenomena	Adsorp-tion/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 A2: Small scale exp with metallic surface B3: derive correlations of adsorption/ desorption rates from existing data.	 Define objectives >>>action on CEA IODE (ASTEC), IMPAIR
		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 B3: model improvement see also 5,5,021	 EPICUR: measure kinetics data IODE (ASTEC), IMPAIR
		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 B3 incorporate decomposition rates from ICHEMM in models B4 interpretation of new exp. data with mechanistic models and extrapolation to reactor conditions - derive simplified models see also 5,5,021	 EPICUR planned - could provide information IODE (ASTEC) 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 experiment 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 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.	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 A3: small scale exp. for quantitative speciation data, also to provide information on mass transfer B4: implement improved models using exp. data (SISYPHE)	 PSIODINE, IMPAIR3 FENRIS(PSI) with prototypical conditions for irradiation of aqueous solutions, containing iodine, organic components; fast speciation analysis CPA/IODE (ASTEC)

Physical Situation	*Issue*	*Phenomenon*	*Phenomena Description others Specific Features*	*Ref. N.*	*SoV P. C.*	*SoV Cont.*	*SoV S. T.*	*PoV*	*List*	*Item N. R.*	*Objectives of Needed Research*	*Description of Experimental Program or Computer Code*
Chemistry in containment	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 A2: analytical exp. for Ag oxidation	IMPAIR, ASTEC PARIS provides data (only partial)
		Oxidation and reduction of iodine species	Various oxydo-reduction reaction leading to interconversion between I-; I2 and IO3- 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.	5,5,043	0	2,00	2,36	2,33	1	5,4	B1: model improvement (exist. Data) B2: Define reactor typical conditions A3: small scale exp. with complex composition of sump water and impurities see also 5,5,040	IODE (ASTEC) PSIODINE, IMPAIR3 FENRIS(PSI) with prototypical conditions for irradiation of aqueous solutions, containing iodine, organic components and impurities
		Homogeneous Organic iodide formation	Organic iodide formation in aqueous phase initiated by radiolytic decomposition of Organic material No consensus on the mechanism of formation of organic iodide exists.	5,5,047	0	2,00	2,47	2,67	1	5,4	B1: Define reactor typical conditions A2: small scale exp. A3: small scale exp. with real old paints (older than 15 years) see also 5,5,040	PSIODINE, IMPAIR3 Get data on organic material release from atmospheric paints and their transfer to sump water, CAIMAN FENRIS(PSI) with prototypical conditions for irradiation of aqueous solutions, containing iodine, organic components
		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 A sudden surge of volatile iodine release is expected at the time when the pool is very close to dryness.	5,5,04C	0	1,67	2,36	2,60	1	5,4	A1: small scale exp. with reactor typical conditions to renew incomplete data base from 1980. see also 5,5,040	New exp. with prototypical conditions for irradiation of aqueous solutions
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	

Table II: 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 (melt water interaction)	Rapid generation of hydrogen which may not be accommodated by re-combiners and the risk of early containment failure. Improve knowledge about the magnitude of hydrogen generation.
1,3	Core coolability during reflood	Termination of the accident by re-flooding of the core while maintaining RCS integrity. Increase predictability of core cooling during re-flood.
1,4	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.
1,5	External vessel cooling and Integrity of RPV	Improve data base for critical heat flux and external cooling conditions to evaluate and design AM strategies of external vessel cooling for in-vessel melt retention.
1,6	Integrity of RCS	Improve predictability of heat distribution in the RCS to quantify the risk of RCS failure and possible containment bypass.
1,7	Corium release following vessel failure	Improve predictability of mode and location of RPV failure to characterise the corium release into the containment.
2,2	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.
2,3	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.
2,4	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.
2,6	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.
3,2a	FCI incl. steam explosion in stratified situation	Investigate the risk of weakened vessel failure during reflooding of a molten pool in the lower head.
3,3	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.
3,4	Dynamic 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.

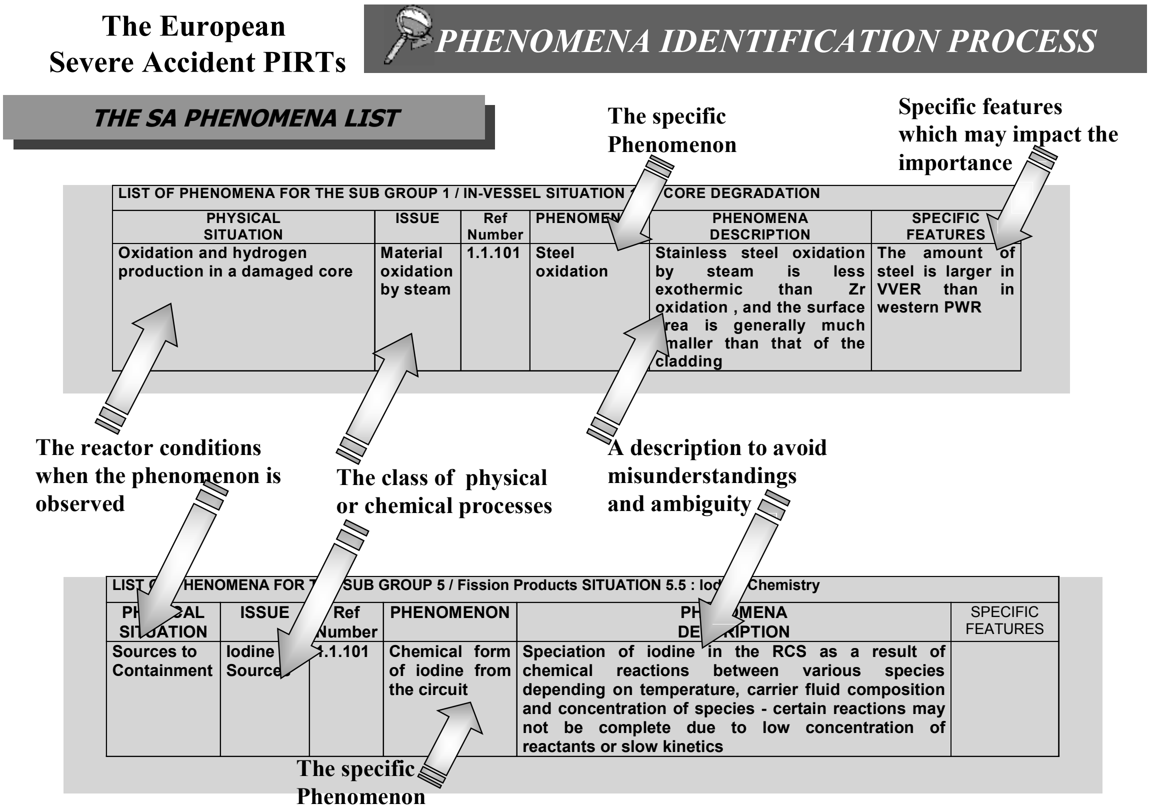

Figure 1. Illustration of the identification process of severe accident phenomena

The European
Severe Accident PIRTs

PIRTs SUMMARY

DOMAINS / PHENOMENA	IDENTIFIED	SAFETY IMPORTANT	LACK OF KNOWLEDGE
In-Vessel	162	44	24
Ex-Vessel	149	48	28
Dynamic Loading	461	71	26
Long Term Loading	116	36	10
Fission Products	128	30	18
	916	229	106

106
phenomena are important for safety and present an important lack of knowledge.

Figure 2. PIRT Summary

EURSAFE Project

Welcome into the EURSAFE Database

This is the preliminary version of the EURSAFE Project Web Site. In this inital form some of the links may not be operational and will become active as soon as the activity will progress.

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Table of content controlled area Free area

FCI Facilities			
ECO	General information	D	http://psf-nt-server.fzk.de/stresa_fzk/
FARO	General information	EC	http://asa2.jrc.it/stresa/
KROTOS	General information	EC	http://asa2.jrc.it/stresa/
MISTEE	General information	S	http://asa2.jrc.it/stresa_RIT/
PREMIX	General information	D	http://psf-nt-server.fzk.de/stresa_fzk/
QUEOS	General information	D	http://psf-nt-server.fzk.de/stresa_fzk/
SPREADING Facilities			
FARO_S	General information	EC	http://asa2.jrc.it/stresa/
VULCANO	General information	F	http://asa2.jrc.it/stresa_CEA1/
VESSEL Facilities			
FOREVER	General information	S	http://asa2.jrc.it/stresa_RIT/
POMECO	General information	S	http://asa2.jrc.it/stresa_RIT/
EURSAFE TN			
EURSAFE_Activity		EC	
MCCI Facilities			
KJET	General information	D	http://psf-nt-server.fzk.de/stresa_fzk/
Phisycal Properties Experiments			
COLIMA	General information	F	http://asa2.jrc.it/stresa_CEA1/
VITI	General information	F	http://asa2.jrc.it/stresa_CEA1/
FP Behaviour			
COLIMA_CA	General information	F	http://asa2.jrc.it/stresa_CEA1/
PHEBUS	General information	F	http://asa2.jrc.it/stresa_irsn/
DCH Facilities			
DISCO-C	General information	D	http://psf-nt-server.fzk.de/stresa_fzk/
DISCO-H	General information	D	http://psf-nt-server.fzk.de/stresa_fzk/

Figure 3. Home page of the EURSAFE website