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## SARNET : Sustainable Integration of EU Research on Severe Accident Phenomenology and Management

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**ABSTRACT:** In spite of the accomplishments reached in severe accident research, thanks notably to the EU projects carried out during previous Framework Programmes, a limited number of specific items remain where research activities are still necessary to reduce further uncertainties that are considered of importance for nuclear reactor safety and to consolidate severe accident management plans.

Facing and anticipating budget reductions, 52 European R&D organizations, including technical supports of safety authorities, industry, utilities and universities, have decided to join their efforts in a durable way by networking their research activities in the frame of a Network of Excellence proposed as a FP-6 project called SARNET, coordinated by the French “Institut de Radioprotection et de Sûreté Nucléaire”. The integral severe accident analysis code ASTEC, developed by IRSN and GRS, will provide the backbone of the integration. Actions are proposed to integrate in ASTEC the current knowledge and all the future knowledge generated within SARNET. In addition, integrating activities will be carried out as the creation of large scientific databases, the elaboration of a research priority index, education and training.

### 1 OBJECTIVES OF SARNET

The current Nuclear Power Plants (NPPs) existing in Europe are designed with the principles of defence in depth. In particular, they incorporate a strong containment and engineering systems to protect the public against radioactivity release for a series of postulated accidents. In some low probability circumstances, some severe accident sequences may result in core melting and plant damage leading to dispersal of radioactive material into the environment and thus constituting a health hazard to the public well beyond the borders of the State where the damaged plant is located.

Remarkable achievements have been obtained in the field of Water Reactor Severe accident research, thanks in particular to the numerous European actions undertaken within the 4<sup>th</sup> and 5<sup>th</sup> Framework Programmes. In spite of the accomplishments reached, a limited number of specific issues remain where research activities are still necessary in order to reduce further uncertainties that are considered of importance and to consolidate severe accident management plans: core quenching, iodine chemistry, ex-vessel melt coolability, timing of base-mat failure are examples of remaining issues underlined by the Phenomena Identification and Ranking Table (PIRT) action conducted within the EURSAFE thematic network of the 5<sup>th</sup> Framework Programme [1]. It is therefore crucial that the best state of knowledge on severe accident phenomenology, qualified computer tools and appropriate methodology should be used uniformly throughout Europe, in order to evaluate the corresponding risks and update former evaluations, taking into account notably the inevitable evolutions in reactor operations (e.g. new type of fuel, higher burn-up, extension of plant life). Additional appropriate engineering devices and/or accident management measures may have then to be developed and implemented in order to reduce the risks to an acceptably low level.

Up to now, research programmes in Severe Accident are usually decided first at national levels, though co-operation agreements are then often concluded around these national programmes, but on a case by case basis. Facing the inevitable reduction of the national budgets in this field, it is now necessary to coordinate better the national efforts to optimise the use of the available expertise and experimental facilities in order to resolve the remaining issues. This coordination will take benefits of, and strengthen, the existing complementarities between the different laboratories throughout Europe (corium/fission product chemistry experts, small scale/large scale testing, simulants/actual materials, experimenters/model developers/code developers).

Therefore, a number of European R&D organizations, including technical supports of safety authorities, industry, utilities and universities, have decided to seize the opportunity offered by the European Commission in the framework of FP6 to network in SARNET (Severe Accident Research and management NETwork) their capacities of research in the severe accident area in a durable way in order to resolve outstanding severe accident safety issues for enhancing the safety of existing and future NPPs.

The general objectives of SARNET are 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;
- 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 assessment.

The project was prepared by a Core Group comprising IRSN, CEA, GRS, FZK and VTT, and was submitted to the Commission as an offer to the first call of FP6. In overall 52 organizations decided to join the project, coming from 11 Member States (Austria, Belgium, Finland, France, Germany, Greece, Italy, the Netherlands, Spain, Sweden, United Kingdom), the Joint Research Centre of the European Community, from 6 Associated Candidate Countries (Bulgaria, Czech Republic, Hungary, Romania, Slovakia, Slovenia), Lithuania and Switzerland.

## 2 ORGANIZATION

The SARNET Network shall be organised on the basis of a two levels 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.

### ***The Governing Board***

SARNET will be steered by a Governing Board. It will 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 (JPA). The Governing Board is composed of:

- 1 member designated by each Contractor;
- 1 representative of the Commission as observer.

Members shall be of high management level and may commit the resources of their organisation for performing activities decided by the Governing Board.

### ***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 of SARNET. It will involve managers of end-user organisations, including Vendors, Utilities and Regulatory Bodies from Europe and Associated Candidate Countries. The Governing Board will appoint the participants. 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 SARNET and the knowledge acquired.

### ***The Management Team***

The Management Team shall be in charge, on behalf of the Governing Board, of the day-to-day management of SARNET. The JPA is divided in subdomains (scientific subdomains, as corium, containment, source term, plus ASTEC, Level 2 PSA, Education and training, Databases, Information system).

The Management Team is composed of the Coordinator heading the Team, of Scientific Coordinators, who will coordinate, in concert with the Coordinator, the scientific activities of the project leaders in a subdomain (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 shall notably monitor the progress made in the JPA, 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 JPA, 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 providing technical and financial reports to the Governing Board, coordinating the annual JPA updates for approval by the Governing Board and implementing the decisions of the Governing Board, notably the JPA. He will furthermore be responsible for the relations with the Commission. IRSN will act as the SARNET Coordinator for the duration of the Contract with the Commission. In each scientific sub-domain, a Scientific Coordinator, rotating among members of SARNET, will coordinate the work in his sub-domain.

### 3 THE JOINT PROGRAMME OF ACTIVITIES

To achieve the objective of SARNET a Joint Programme of Activities has been defined. All the organizations networked in SARNET will contribute to the Joint Programme of Activities (JPA), which can be, beyond management activities, broken down in 3 elements:

- Integrating activities to strengthen links between organisations;
- Joint research activities to resolve remaining outstanding issues;
- Spreading excellence activities;

The integral code ASTEC will be the main integrating component and will contribute to the diffusion of the knowledge efficiently. Activities linked to ASTEC will thus appear as “Integrating activities”, whereas some of them contribute also to the range of “Spreading excellence activities”. Furthermore, most of the “Joint research activities” will have links with ASTEC as it is one of their ultimate goals to provide physical models to be integrated in ASTEC. Furthermore, the exchange of information on the detailed models developed by the various experts through interpretation of experiments will lead at medium and long term to generic common models used in the different detailed codes (example of ICARE/CATHARE and ATHLET-CD). Besides, adequate models will be derived from these detailed models and will be included in the common reference ASTEC code.

The R&D needs will be periodically updated and the objectives of future experiments will be defined taking into account the outcome of the collaborative work on risk studies. A consensus could be reached on closure of some issues and would allow to redistribute competence and manpower on open ones in concert with other international projects (e.g. ISTCs, OECD projects...).

The programme, which is described below, may be revised, depending on the results of the negotiation with the Commission. The integrating elements of the programme are considered of highest importance and will remain the key elements of the JPA.

#### 3.1.1. Integrating activities

Most of the organisations integrated in SARNET are concerned with integrating activities. The remaining organizations are only contributing in very specific areas where their scientific competence is of very high interest for the network. Furthermore, the major part of the joint research programme will consist of the integrating elements introduced in the different national research programmes, in order to progressively reach the objective of a full integration of various research strategies. The so-called integrating activities comprise:

- Implementation of an advanced communication tool for fostering exchange of information;
- Development/qualification/maintenance of the Integral Code ASTEC;
- Harmonization of Level 2 PSA methodology and development of advanced tools;
- Implementation of scientific databases;
- Research priority assessment.

#### **Advanced communication Tool**

Advanced Communication Tool (ACT) is a key concept to achieve SARNET goals. Indeed, ACT is the unified support for efficient communication between SARNET partners (at least 30 of them, those who are involved in ASTEC and other collaborative work; more later on) to achieve the following needs:

- Access, search, publication of documents and codes (concept of knowledge storage),
- Contact and communicating with partners (interactive and collaborative services),
- Joint co-ordination of actions and programmes (co-operative management of the network),
- List of links to satellites community projects (R&D projects, related sites).

Re-use or integration of existing similar experiences within community partners should be studied to design the target tool. Of interest will be the system SINTER, which was developed in the 4<sup>th</sup> FP and is presently used in the 5<sup>th</sup> FP projects MICANET, HTR-TN and JSRI-II as well as in the IAEA project GHTRN.

### **Integral Code ASTEC**

There are 30 organisations that have expressed their willingness to collaborate on the adaptation and qualification of the Integral Code ASTEC. This code, which is developed by IRSN and GRS describes the behaviour of a whole NPP under severe accident conditions including SAM engineering systems and procedures. It is extensively used by IRSN for Level 2 PSAs regarding 900 MWe Pressurized Reactors. It will serve as the main integrator of knowledge in SARNET and contribute to diffuse it to all members. At this stage, it is important to note that it is planned to be used in 6 Associated Candidate Countries. The ASTEC project is divided into 4 sub-projects, namely: maintenance / users support / training, development and adaptation, physical model assessment, reactor application and benchmarking. IRSN and GRS will endeavour, in the limit of their financial availabilities, to offer the support to the users that such a large diffusion will imply.

### **Level 2 PSA**

Level 2 PSA is a powerful tool to assess plant specific vulnerability regarding NPP severe accidents. It aims at evaluating possible severe accident scenarios in terms of frequency, loss of containment integrity and radioactive release into the environment. It integrates the results of R&D programmes on physical phenomena involved in severe accidents, in a risk assessment perspective. In particular, it makes it possible to quantify the contribution of prevention and mitigation measures in terms of risk reduction.

Different approaches are used in Europe, derived from what has been implemented in the US. The objective of this activity is to compare, to improve and to harmonize the methodologies used for developing Level 2 PSA within European countries and to share effort to develop advanced tools, as far as they are required. Another aspect is the adaptation of methodologies for their application to the reactor types used in the Associated Candidate countries.

### **Implementation of scientific databases**

The objective is to develop and maintain an instrument that insures preservation, easy access for codes, exchange and processing of severe accident experimental data, including all related documentation. The data of concern are:

- Existing experimental data that SARNET partners are willing to share with the other partners in the network;
- All new data produced within SARNET.

The database system will be an extension of the platform developed in EURSAFE starting from the STRESA structure.

### **Research priority assessment**

The objective of this action is to provide the Governing Board of SARNET with guidelines for defining the orientations to give to the research activities of common interest and high priority. It will make use notably of:

- The outcome of the EURSAFE action (results of PIRT on severe accidents);
- The results of the qualification/benchmarking activities on ASTEC;
- The outcome of the research performed in the three thematic subdomains of SARNET (corium, containment, source term);
- The results of the national Level 2 PSA activities on the identification of knowledge improvements (risk-oriented research).

It will take into account the potential capacities of SARNET and identify the potential experimental or theoretical programmes to undertake for resolving the identified issues. This action will be performed in close collaboration within participants (those mainly involved in EURSAFE), representing TSO, industry and utilities, including organisations of Associated Candidate Countries. The results will be circulated to all participants for comment before their release. Such an assessment will be periodically conducted, and will of course make use of the results from other international projects (ISTC, OECD...) in this area.

### 3.2 Programme for jointly executed research activities

The EURSAFE actions have highlighted a number of remaining important safety issues, which need to be investigated experimentally and theoretically. The research programmes and the critical mass of competence (experimental facilities, experts) necessary to address these issues were identified. This competence was integrated in SARNET with tasks aiming at:

- harmonizing and re-orienting, if necessary, the already decided research programmes linked with the issues to be investigated;
- initiating new programmes, to be jointly carried out;
- elaborating a common understanding of concerned phenomena;
- and implementing improved models in ASTEC code.

The integration of this competence led to form promising nuclei of cooperation between some participants of SARNET, with a great potential for growing.

### 3.3 Activities designed to spread excellence

The objectives of the Education and Training sub domain in the SARNET NoE are to:

- Enhance and maintain competence in Severe Accident Research (SAR), contributing to Severe Accident Management (SAM) through education and training of students and young researchers in Europe;
- Impart additional skills to the researchers and analysts in the severe accident risk assessment;
- Foster integration of national programmes through sharing of researchers and work programmes.

The approach followed to achieve the above objectives during a relatively early part of the SARNET NoE will be to:

- Develop educational forums e.g. yearly courses, text (source) books, etc.;
- Develop training forums e.g. laboratory and reactor plant facilities, plant analyzer, etc.;
- Promote personnel mobility between the various European institutions;
- Develop user groups for important computer codes e.g. ASTEC;
- Integrate with other education and training work programmes in other networks;
- Develop links with the NEPTUNO Project in FP6.

The three elements of this sub domain are education, training and mobility.

The **education** element involves Ph. D. students and researchers, the various activities in the education element will be to provide a comprehensive course on Severe Accident Phenomenology, develop a text book or source book on Severe Accident Phenomenology, develop and provide a course on Level – 2 PSA (with description of codes, mainly ASTEC, for consequence analysis), encourage the NEPTUNO Project to set up a course on Nuclear Power Safety, including an introduction to the Severe Accidents and to Level – 2 PSA.

The **training** element involves both students and researchers but primarily the latter. The main activities will be to provide training in experimental methods and techniques, the operation, checking and debugging of computer codes, and workings of plant analysers having severe accident algorithms.

The **mobility** element involves both Ph.D. students and researchers. This element is of great importance towards the integration of the European National Programmes in Severe Accidents and in the Probabilistic Safety (Risk) Analysis. In this context, coordination of the mobility programme of SARNET with that developed in the NEPTUNO Project would be very desirable.

#### 4 MAIN RESULTS EXPECTED

A very large amount of knowledge has already been obtained in the field of Water Reactor Severe accident research, in particular within the 4<sup>th</sup> and 5<sup>th</sup> Framework Programmes (corium behaviour, melt coolability, hydrogen risks, source term). The proposed long term SARNET activity of permanently capitalizing knowledge in the integral computer tool ASTEC as well as in scientific databases, will provide the necessary conditions for preserving this knowledge and diffusing it to a large number of current and future end-users throughout Europe.

European end-users are mostly using integral computer codes developed in the United States. This results in a strong dependence on the US in code maintenance and development. Furthermore, Level 2 PSAs are based on US technology, which has been adapted differently from an organization to the other. SARNET, by fostering collaborative work in these two areas of excellence within a large number of European organizations, will create the necessary conditions for harmonizing the approaches and for Europe to become a world leader in severe accident computer code and risk assessment methodology.

A limited number of specific issues remain where research activities are still necessary in order to reduce further uncertainties that are considered of importance and to consolidate severe accident management plans: core quenching, iodine chemistry, ex-vessel melt coolability, timing of base-mat failure are examples of remaining issues underlined by EURSAFE. Whereas up to now, research programmes in Severe Accident were usually decided at national levels, it is now necessary to better coordinate the national efforts to optimise the use of the available expertise and experimental facilities in view of the reductions in the national budgets in this field.

By providing an appropriate forum of exchange of technical and scientific information between experts in various fields and by its strong coordination structure involving high management level representatives, SARNET will contribute to prioritise the research needed, to favour co-programming amongst organizations, optimise the use of the available research capacities and promote the co-operation between the different members. This will be done by taking benefits of, and strengthening, the existing complementarities between the different laboratories.

Thus, it can be expected that SARNET will modify the landscape of research on severe accident in Europe in a durable way, even after the end of the Contract with the Commission, as agreed upon by the organisation representatives. Indeed, SARNET will become a reference in terms of research priorities in the field of severe accident having impact on national programmes and fund allocations. Progressively all the research activities in this field will become strongly coordinated by the Network and ASTEC will progressively become a federative tool thereby contributing to integrate, preserve

and diffuse knowledge. In addition to ASTEC, the proposed joint programme of research activities will contribute efficiently to keeping competence and expertise in the area of severe accident management for current European water reactors, including those of Russian design, and also for future nuclear reactor designs.

An education and training programme will diffuse the excellence and knowledge in the severe accident area. This will be completed by a mobility programme under which students and researchers will be able to go into different laboratories of SARNET for training. In addition, a large conference will be organised every 12 or 18 months on the progress made in SARNET. The audience should be international and of the same level as the large conferences organised by the USNRC in this domain (CSARP, MCAP). A Web site will advertise the work performed in SARNET and the knowledge acquired, giving access to information open to the public. This communication plan will have to be approved by the Governing Board.

SARNET may also develop partnerships with other Networks of Excellence, as SAMINE (Network of Excellence in Severe Accident Management) and NEPTUNO (Network of Excellence on Education and Training in Nuclear Science). In the first case, SARNET will receive from SAMINE the needs in terms of research to address severe accident management issues and in return SARNET will provide knowledge and tools. SARNET will contribute to some of the NEPTUNO activities by providing lectures and support material, and provide some internships for students.

## **5 CONCLUSION**

By networking most of the European research organisations around a joint programme of research activities, SARNET will provide an appropriate frame for achieving within a couple of years a sustainable integration of the European research capacities on severe accident. Nuclei of co-operations already exist around some national research programmes. It is one of the missions of SARNET to promote and extend progressively the co-operations to other members of SARNET, by disseminating useful information on these programmes to potentially future partners, because they may be mutual interest for the Network and these partners.

Most of the research activities of the Network will be focused on integrating activities, as developing and validating the existing French-German code ASTEC, so as to make it the European reference for any safety studies, in particular PSA-level 2. It will be adapted, so as it can be used for any kind of water-cooled NPP existing in Europe (PWRs, BWRs, VVERs, CANDU and RBMK). Other important integrating activities will be the elaboration of large scientific databases, the definition of priorities for research of common interest to the Network, education and training.

## **6 REFERENCES**

- [1] EURSAFE thematic network - contract FIKS CT 2001-20147;
- [2] EVITA action - FIKS-CT-1999-00010.