

Severe Accident Research Network of Excellence - NUGENIA Technical Area N° 2 Newsletter N° 7 (March 2014)

An important step has been passed: since mid-2013 the SARNET network is integrated in the NUGENIA Association, created in SNETP frame for managing R&D on Gen.II-III nuclear power plants. Besides, last October in Avignon (France), the ERMSAR-2013 conference was a big success (about 140 participants) as a cornerstone between the FP7 project and NUGENIA. The next steps are now to define and launch new R&D projects in the frame of NUGENIA or to answer the calls of NUGENIA+/FP7 and H2020 EC, according to the priorities set in SARNET2 and used to define the NUGENIA Strategic Roadmap Agenda.

SARNET integration in NUGENIA

The FP7 SARNET2 project has officially ended on March 31st 2013 but the iterations with staff of EC/DG Research and Innovation needed 8 months more to finalize all project Deliverables. A complete publishable summary has been achieved in the final synthesis report: it will be put soon on the CORDIS EC site.

The SARNET network is now considered as fully integrated in the NUGENIA association (www.nugenia.org), created in SNETP frame for managing R&D on Gen.II-III nuclear power plants. This ensures the network self-sustainability that was a crucial requirement of EC since NUGENIA is a legal entity. About 30 of the SARNET2 European partners have already joined NUGENIA and a few more are ready to do so.

The Technical Area N°2 (TA2), named “Severe accidents”, includes all SARNET activities plus the issues of emergency management and SA impact on the environment. The TA2 is today coordinated by the SARNET coordinator, i.e. J.P. Van Dorsselaere (IRSN). In order to keep the efficiency of the SARNET2 management, a similar structure was kept with Sub-TAs (STA) led by different partners:

- 2.1 In-vessel Corium/Debris Coolability (A.Miassoedov, KIT)
- 2.2 Ex-vessel Corium Interactions and Coolability (C.Journeau, CEA)
- 2.3 Containment Behaviour, including H₂ explosion Risk (I.Kljenak, JSI)
- 2.4 Source Term (L.Herranz, CIEMAT)
- 2.5 Impact of SA on the Environment (F.Bréchignac, IRSN)
- 2.6 SA Scenarios (F. De Rosa, ENEA)
- 2.7 Emergency preparedness and response (O.Isnard, IRSN)

parallel, a detailed 300-page long roadmap was written in 2013. It is a working document that will be periodically updated (the next update is planned for mid-April 2014). The TA2 part of both roadmaps was directly derived from the final report of the SARP (Severe Accident Research Priorities) group in SARNET2. This report has taken into account the progress done on knowledge in the 4 last years, in SARNET but also in other frames like OECD/CSNI projects, and the preliminary analysis of the Fukushima-Daiichi accidents.

About the non-NUGENIA partners that participated to SARNET2/FP7, there are two possibilities if they wish to continue to be associated to SARNET activities:

- Either join NUGENIA as a full member (see www.nugenia.org), which will allow them to fully participate to the elaboration of new R&D projects since their beginning,
- Or only participate to the TA2 technical workshops, ERMSAR conferences and Education courses.

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General news on SARNET

In 2014, the main efforts will concern the organization of technical workshops to keep the SARNET2/FP7 momentum and the definition of new R&D projects. Links with other entities like OECD/CSNI and US.EPRI will be enhanced.

The Prof. Sandro Paci (Univ. Pisa) will continue his role of coordination of TA2 dissemination of knowledge, thus managing the future Education and

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training courses and the ERMSAR conferences. In this frame, three actions are under way:

- Preparation of the next SARNET newsletters (in continuation of the process adopted in SARNET2/FP7),
- Update of the public SARNET website that will be hosted on an IRSN server;
- Clean-up of the SARNET2 EXTRANET (named ACT) with selection of the files to be kept and transferred to the NUGENIA Huddle tool in the TA2 page.

Discussions are taking place with the few SARNET2 partners that did not join NUGENIA, as well with other organizations that expressed their interest to join SARNET (such as in Japan JAEA and NRA, the latter being ex-JNES from April 2014). CSNC (Canada) has already informed about their wish to join the TA2 activities, as well as SCK-CEN (Belgium).

Besides ERMSAR-2013, two presentations on SARNET were presented in conferences:

- “European view on severe accident research » at Jahrestagung Kerntechnik, 14-16 May 2013 at Berlin,
- “Research on the Impact of Severe Accidents and External Events on Nuclear Power Plants and on Mitigation Strategies” at EC FISA-2013 (8th European conference on Euratom research and training in reactor systems), 14-16 Oct.2013 at Vilnius.

An invitation was sent by JAEA to the SARNET coordinator to present the European R&D on severe accident and the SARNET activities at the Water Reactor Fuel Performance Meeting (WRFPM) on 14-17 September 2014 in Sendai (Japan). This meeting belongs to the series of the annual Reactor Fuel Performance Meetings jointly organized with ENS and ANS.

To date, the R&D new TA2 proposals (the ones that were uploaded in the NOIP Web tool of NUGENIA) are the following ones:

- IVMR (IRSN lead with strong UJV support): In-Vessel-Melt-Retention for medium-power NPP (VVER-1000, future NPP...),
- CORE_SOAR (IRSN lead): update of OECD SOAR on core degradation, in-kind project (no requested funding) that should start soon,

- HYCOSAM (IRSN lead): hydrogen and carbon monoxide risk management (PARs behaviour, gas combustion...)
- SFP (IRSN proposal), transverse with the TA5 dedicated to the fuel behaviour during accidents in SFP,
- FASTEC and FASTQUICK proposals for a fast-running tool for emergency centres,
- Plus in TA5 (transverse with TA2): FUEL (lead to be determined, IRSN/CEA/ITU) on a multi-scale approach on fuel & FP safety issues during any off-normal situation.



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ERMSAR 2013

The 6th European Review Meeting on Severe Accident Research (ERMSAR-2013), held six months after the end of the FP7 SARNET2 project, was hosted by IRSN in “Palais des Papes” (see picture below) at Avignon (France) on October 2-4, 2013. It gathered 137 participants from 25 countries and 61 organisations, almost at the level of the ERMSAR-2012 one. This 2013 conference, the second open one in the ERMSAR series, signed the cornerstone between 8 years of both FP6-7 SARNET projects and a future linked to NUGENIA association. The conference can be considered as a success through the number of participants and the scientific quality of papers and discussions.



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Syntheses of progress of knowledge in the different issues of severe accidents and perspectives of new R&D in the next years were presented. The subject of Fukushima accidents was highlighted with both specialists and panel presentations. The amount of acquired knowledge was huge and it will need some time to “digest” it and capitalize it through code models or state-of-the-art reports (SOAR). In fact, an essential outcome of the SARNET network has been the production of topical synthesis papers (i.e. the SOAR on MCCI) and this task will be continued (as another example an update of the OECD SOAR on core degradation is planned in the NUGENIA framework in 2014).

An important feature of this conference was also (as in ERMSAR 2012) its open characteristic; this “open” feature, consolidating ERMSAR as a major international conference on severe accidents, leaves space to presentations by specialists not directly involved in the SARNET network: 37 (including 23 out of Europe) non-SARNET participants from 32 organizations attended ERMSAR 2013 and 11 out of 52 presentations were given by non-SARNET organizations plus 5 posters (over 11). The conference was also the opportunity to hear about the SA R&D general programmes of JNES (Japan) and BARC (India).

The main sessions of the conference were addressing:

- Session 1: **Introduction and general issues** - with an overview of the severe accident research projects co-funded by DG RTD under FP7 and a presentation about NUGENIA.
- Session 2: **In-vessel corium and debris coolability** - a very present subject of lectures was the corium In-Vessel-Retention with 6 papers and 1 poster.
- Session 3: **Source term issues**
- Session 4: **Ex-vessel corium behaviour**
- Session 5: **Containment phenomena**
- Session 6: **Severe accident codes** - where the lecture on the TMI2-Like benchmark raised some discussions about the progress of computer codes in the last 20 years.
- Session 7: **Fukushima accidents**
- **Session Conclusions and Perspectives** - where the SARP lecture by GRS summarized the main R&D priorities for the next years, with the absence of strong modifications of priorities

after Fukushima but only the need to reinforce a few issues like the behaviour of spent fuel pools.

At the end of the Conference a satisfaction questionnaire was filled in by about 30% of the participants and the general feedback was very positive.

All the ERMSAR 2013 papers and presentations have been uploaded on the SARNET2 public web site (www.sar-net.eu) and a selection of the papers, jointly prepared by several SARNET2 partners and synthesizing the main scientific outcomes on some issues, will be released in a special issue of the “Annals of Nuclear Energy” journal around mid-2014.

The next ERMSAR conference is planned to be hosted by CEA in Marseille (France) on March 24-26, 2015, thus in the TA2 frame. It should be extended to emergency management issues (consistently with NUGENIA TA2 content) and possibly to PSA.

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Workshops TA 2.1 and 2.2 on corium activities in Santa Cruz, Spain



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Following the SARNET periodic technical review meetings of Work Packages 5 and 6, the sub areas on in-vessel and ex-vessel corium behaviour and coolability met successively from 17 to 21 February 2014 in Santa Cruz, Spain. It must be noted that, even though there is no more funding for these exchange meetings like in the SARNET2/FP7 project, 50 engineers and researchers from EU, Switzerland and Korea (i.e. slightly more than in previous SARNET meetings) met under the NUGENIA umbrella. This underlines the effectiveness of SARNET self-sustainability as technical exchange forum on severe accident research. Participants from utilities, industry, research centres, technical support/safety organizations and university contributed to the fruitful exchanges during these meetings.

Aside from discussing the complex physics and chemistry of corium, this week was also used to prepare several proposals that will be transmitted to the NUGENIA Executive Committee for labelling. These projects could be in-kind NUGENIA projects, NUGENIA+ projects or HORIZON2020 ones. Two side meetings were also held by EURATOM FP7 projects close to NUGENIA: SAFEST and ALISA on experimental platforms (the latter in collaboration with Chinese organizations).

The success of this event led the participants to decide to hold a next meeting in early 2015. The choice of an off-season resort has been appreciated as a valuable incentive for intense networking and collaborative work and will be maintained for 2015.

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PRELUDE-PEARL experiments

Large IRSN efforts were devoted during the last four years in the SARNET frame to the design and the construction of the PEARL facility for running experiments of debris bed reflooding in a large size configuration (540 mm diameter, 500 mm height) up to 10 bars. This size is larger than in other past or on-going experimental programs. Prior to PEARL,

experiments have been carried out in the small scale IRSN PRELUDE facility at atmospheric pressure.

The main following physical parameters have been investigated in PRELUDE: initial temperature of the debris bed, injected water flow rate, specific power maintained during the reflooding, particle size (monodispersed bed of stainless steel Ø4, Ø2 and Ø1 mm particles or polydispersed debris), presence of a bypass around the debris and finally the configuration of the water supply (bottom or top injection) to be more representative of the reactor situations.

The main outcomes have been presented in the ERMSAR-2013 conference. These numerous experiments (roughly 150) increase significantly the database on the reflooding process and are useful to develop and to validate models in numerical simulation codes such as ICARE/CATHARE and ASTEC at IRSN or MEWA-2D at IKE. This is particularly true for bottom reflooding configurations where the thermal-hydraulics conditions (temperature of the debris, water and steam flow rates) are better known compared to top reflooding configurations.

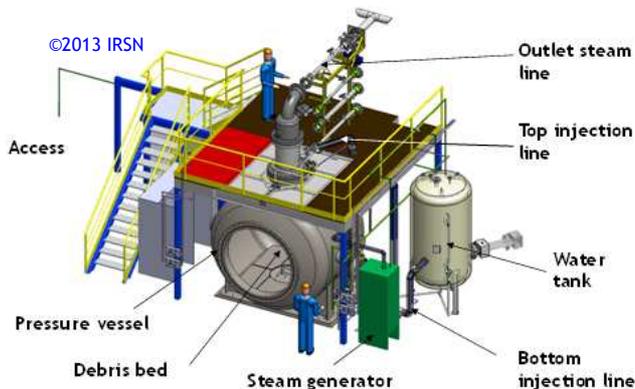
The experiments led to improve knowledge mainly on steam production, quench front propagation, cooling rate and efficiency of the reflooding. The effects of pressure drop on the stability of the quench front and on the stability of the debris bed itself (possible fluidisation) have been observed and constitute new quantitative results in this field.

Complementary activities have been done in the frame of the qualification of the heating process of a large debris bed up to 500 kg by means of induction process. The heating of large debris bed containing 4 mm particles and small particles down to 2 mm up to 900°C was reached with a rather flat power distribution up to 300 W/kg, which was not obvious at the beginning of the project.

In parallel to the conduction of PRELUDE experiments, IRSN has designed the PEARL facility for which the construction at Cadarache is now finalized since the end of 2013.

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Source term activities



PEARL facility schematic description

The recent activities focused on qualification tests, mainly on the tightness of the circuits, the pressure vessel, the water tank, the regulation of the injected water flow rate, the pressure control, the steam generator and the heaters. For instance, heaters are needed to obtain 200°C on the components and avoid steam condensation which is very important for the outlet steam flow measurement.



PEARL facility as constructed ©2013 IRSN

The PEARL facility is now ready to be yielded by the manufacturer to the owner IRSN. The experimental program is planned to start in the first half of 2014, after a final qualification campaign.

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A meeting was organized at Aix-en-Provence on January 31st 2014 by L. Herranz (CIEMAT), who leads the TA 2.4 "Source term" in collaboration with the coordination team (T. Haste, IRSN, T. Kärkeela, VTT and F. Parozzi, RSE) and few other IRSN specialists involved in EURATOM and NEA projects related to source term. The main objective was to prepare the transition of Source Term R&D research from SARNET2 to NUGENIA framework. To do so, there were detailed presentations regarding the major conclusions drawn from the WP8 of SARNET 2 and other projects such as PASSAM, STEM and BIP2. Those presentations were preceded by a general TA2 presentation given by J.P. Van Dorsseleere.

As a result of the meeting, several decisions were made:

- To prepare a synthesis paper wrapping up the major activities and conclusions accomplished in SARNET2; the paper was planned to be submitted to a journal before summer 2014.
- To hold a workshop on Source Term gathering the specialists so that a first push can be given in terms of projects proposals for NUGENIA and H2020. This should be held during the coming fall 2014.
- To organize a joint workshop with OECD/WGAMA on iodine chemistry, since many projects on the matter end up along 2014 and 2015. Discussion with OECD/WGAMA should start as soon as possible to also clarify the potential use of NEA projects within NUGENIA.

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Phébus FPT3 benchmark

One important SARNET2 task was the code benchmark focused on the last Phébus FPT3 experiment. Sixteen organizations from 11 different countries used 8 computer codes, three of which of an integral nature (ASTEC, MELCOR and MAAP). The benchmark, coordinated by IRSN, was articulated in 5 areas for comparison: bundle, circuit transport, containment, iodine chemistry and integral aspects.

The most generic observations highlighted the significant user effect and the large deviations incurred by integral calculations when modelling the

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last stages of the test sequence (i.e. iodine chemistry). In addition, it was concluded that most deviations found between data and estimates were in areas in which experimental work is presently ongoing and/or their results under discussion (i.e. VERDON, CHIP, PARIS experiments etc...).

Specific observations have been also settled, such as for example:

- Although cumulative fission product release has been reasonably predicted, an under-prediction has been noted for semi- and low-volatiles,
- The measured high iodine gas concentration at the cold leg has not been captured by the codes,
- In-codes models for containment thermal-hydraulics and aerosols seem to be suitable in the Phébus vessel arrangement,
- And the predictability of iodine gas fraction in containment remains being a challenge.

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On-going FP7 projects: CESAM and PASSAM

CESAM (Code for European Severe Accident Management), coordinated by GRS (Germany), involves 18 partners: IRSN and AREVA NP SAS (France), GRS, KIT, USTUTT and RUB (Germany), CIEMAT (Spain), ENEA (Italy), VUJE and IVS (Slovakia), LEI (Lithuania), NUBIKI (Hungary), INRNE (Bulgaria), IJS (Slovenia), VTT (Finland), PSI (Switzerland), JRC (EC) and BARC (India).

It started in April 2013 for 4 years and aims at the improvement of the European reference code ASTEC for use in Severe Accident Management (SAM) analysis. The Fukushima-Daiichi accidents highlighted that the overall understanding of such accidents and the development or improvement of adequate SAM measures is essential in order to increase the safety of nuclear power plants (NPP) operated in Europe. After a review of SAM measures in the existing European NPPs, based on what was already done in the frame of the ENSREG stress tests, CESAM is focused on the SAM analyses for the diverse European NPPs (PWR, VVER, CANDU) and on source term evaluations. Code validation will be done in parallel vs. available or new experiments,

especially relevant for SAM and for BWR (in close link with the Fukushima accidents).

PASSAM (Passive and Active Systems on Severe Accident source term Mitigation), (<https://gforge.irsn.fr/gf/project/passam>), coordinated by IRSN, involves 9 partners: IRSN, EDF and Université de Lorraine (France), CIEMAT and CSIC (Spain), PSI (Switzerland), RSE (Italy), VTT (Finland), AREVA NP GmbH (Germany).

It started in January 2013 for 4 years and concerns mainly experimental programmes to enhance existing systems and work on innovative systems for mitigation of atmospheric release to the environment. The corresponding facilities are EPICUR (IRSN), TRISTAN (PSI), PECA (CIEMAT), SCRUPOS (RSE) and JAVA (AREVA GmbH). The main outcomes will be a better understanding of fission product trapping phenomena and checking of their long term retention (or revolatilization) under severe accident conditions leading to correlations/models for implementation in simulation codes (such as ASTEC). A state-of-the-art report has been written end of 2013 on several mitigation systems used (pool scrubbing, sand filters plus metallic pre-filters) or potentially usable.

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Recent and forthcoming events

February 17-21, 2014: TA2.1 and 2.2 workshops organized by KIT and CEA at Tenerife (Spain)

February 17-21, 2014: ASTEC training course in the ENSTTI frame, hosted by IRSN in Cadarache castle (France)

February 25-26, 2014: PASSAM workshop, hosted by CIEMAT in Madrid (Spain)

March 18-21, 2014: CESAM workshop, hosted by JSI in Ljubljana (Slovenia)

April 6-9, 2014: ICAPP conference in Charlotte (USA)

April 7, 2014: special meeting (upon invitation) on the IVMR NUGENIA proposal at Madrid (Spain)

April 8-10, 2014: NUGENIA general Forum, Madrid (Spain)

July, 2014: ICONE-2014, Prague (Czech Rep.)

Sept.14-17, 2014: WRFPM meeting in Sendai (Japan)

Sept.17, 2014: deadline for answers to the H2020 Call on Fission R&D

Sept.2014: release of the NUGENIA+ Pilot call

March 10-12, 2015 (dates to be yet confirmed): ERMSAR 2015, hosted by CEA in Marseille (France)