

SARNET, a success story.

Survey of major achievements on severe accidents and of knowledge capitalization within ASTEC code



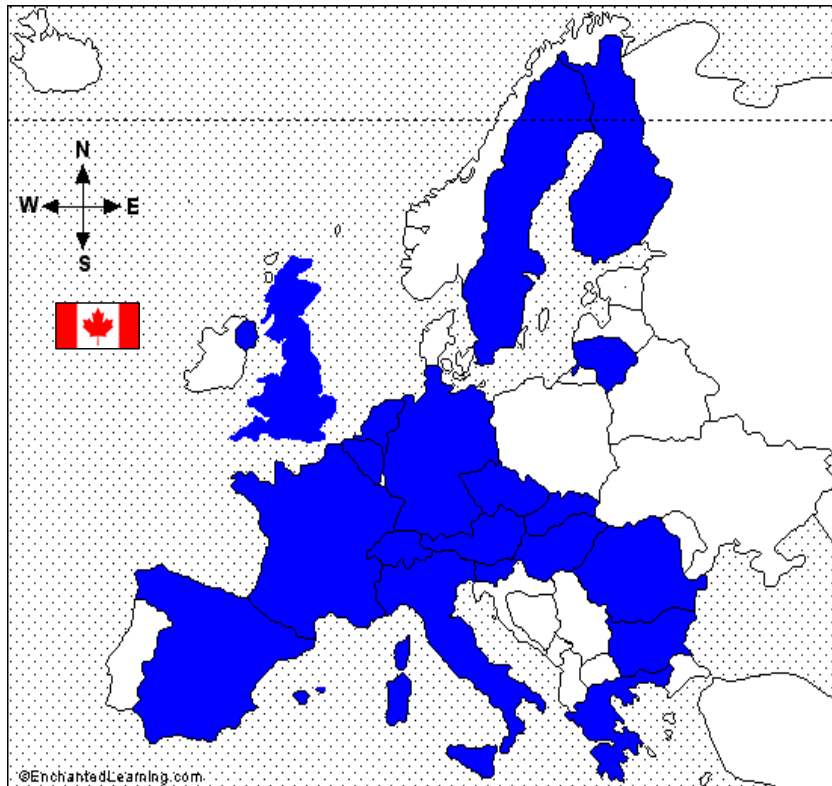
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- Knowledge capitalisation into the ASTEC integral code
- SARNET2 Network of Excellence (2009-12)
- Conclusions

SARNET main objectives

- Tackling the fragmentation that exists between the different European R&D organisations, notably in **defining common research programmes** and developing/qualifying computer tools, in particular the ASTEC IRSN-GRS integral code;
- **Harmonizing** the methodologies applied for assessing risk and improve **Level 2 Probabilistic Safety Analysis** (PSA) tools;
- **Disseminating the knowledge** to Newcomers to the European Union more efficiently and associating them with the definition and the conduct of research programmes more closely;
- Bringing together top scientists in SA research to **constitute a world leadership.**

SARNET general features



**Severe
Accident
Research**

NETwork of excellence

20 Countries (Europe plus Canada)

- 51 partners
 - 19 Research organizations
 - 10 Universities
 - 11 Industry organizations
 - 4 Utilities
 - 7 Safety authorities and Technical Safety Organizations
- More than 230 researchers
- About 20 PhD students

- Work of about 70 persons per year
- 10M€ efforts per year → 1.4M€ per year funded by the EC (6th FP, April 2004 - September 2008)

SARNET main achievements: WEB, ACT and DATANET

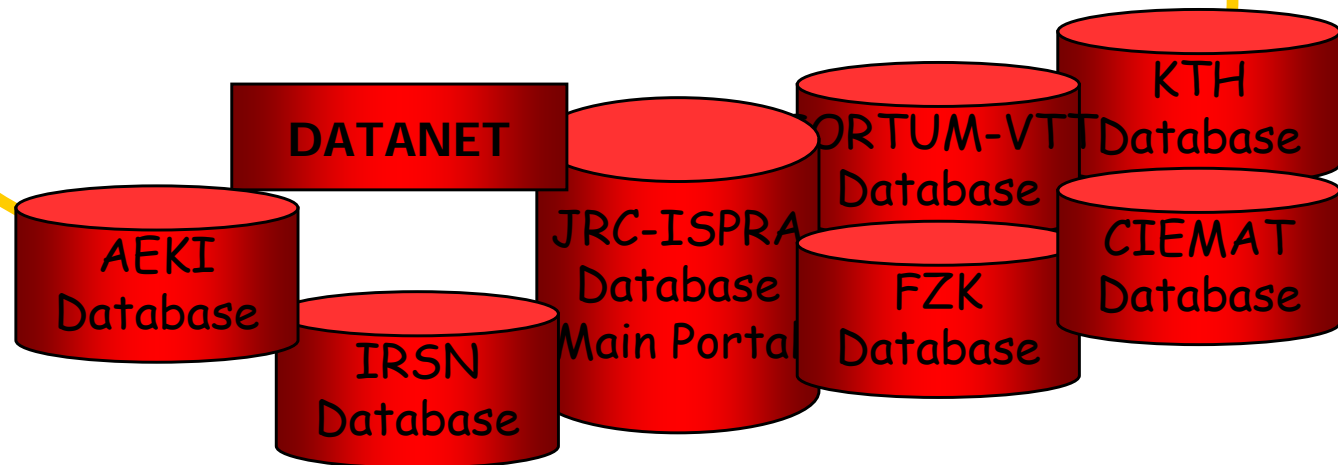
A WEB portal supplies SARNET partners with an access (reading and or writing) to:

- **networking tool** (document, management, meeting organisation, forum, questionnaire...)
- **experimental data bases**,
- ASTEC code,
- links
- ...



ACT (WP1) Status

- 200 users
- 500 to 1000 accesses per month
- 6000 items stored
- 11 Topical sites



DATANET (WP 6) Status

- 7 nodes are open (JRC, FZK, IRSN, CEA, AEKI, KTH, CIEMAT, FORTUM-VTT)
- Implementation of more than 100 test results from 20 experimental facilities is underway

SARNET main achievements: Level 2 PSA

- Comparison of the main PSA2 methods used by the partners.
- Harmonization of methods:
 - Definition of steps based on partners' answers to questionnaires,
 - Some level of harmonization was reached on specific issues leading to relevant recommendations (H₂ combustion, iodine chemistry, MCCI, large early releases, reactor safe state definitions, PSA1 to PSA2 interfaces).
- Dynamic Reliability methods:
 - State-of-The-Art Report release,
 - Benchmark exercise with classical reliability methods.
- Precise definition of ASTEC requirements for PSA2 needs (*ASTEC V1 fits most of them but needs of improvements of code documentation, in particular input data*) and work on ASTEC coupling with probabilistic tools.

SARNET main achievements: Integration of Research Activities

- Collaborations on pre- and post- calculations of experiments (e.g. PSI on FZK QUENCH tests),
- Joint realization of experiments (e.g. VTT experimentalists on IRSN CHIP experiments),
- Joint definition and interpretation of experiments → many “interpretation circles” created and really active, with benchmarking of codes, in order to achieve a common understanding of experimental phenomena (using e.g. ASTEC modules),
- Yearly technical meetings in each of the three topical areas (corium behaviour, containment integrity and source term), complemented by a large number of specialists’ meetings.

SARNET main achievements: Spreading of Excellence

- Three 5-day **courses** for students and young researchers or SA specialists. 40 to 100 attendees.
- **Mobility** programme for training of students and researchers in SARNET laboratories: 33 delegations, average of 3 months.
- Three **conferences** (European Review Meetings on Severe Accident Research – ERMSAR) organized in France, Germany and Bulgaria as a forum to the SA community. About 100 attendees → *These conferences are becoming one of the major events in the world on the SA topic.*
- LWR **Severe Accident Safety Book** = text book of about 450 pages. Final version to be issued in 2009.
- SARNET WEB site.
- **About 300 SARNET papers** in conferences and/or journals.

SARNET main achievements: Research Priorities

- Selection of 6 issues remaining open with **high priority**:
 - Core coolability during reflooding and debris cooling,
 - Ex-vessel melt pool configuration during MCCI & ex-vessel corium coolability by top flooding,
 - Melt relocation into water & ex-vessel FCI,
 - Hydrogen mixing and combustion in containment (flame acceleration),
 - Oxidising impact on source term (Ru oxidising conditions or air ingress for HBU and MOX fuel elements),
 - Iodine chemistry in RCS & in containment.
- Assessment of other issues:
 - 4 were re-assessed with **medium priority**,
 - 5 were assessed with **low priority**,
 - 3 were marked as **'issue could be closed'**.

ASTEC key role in SARNET

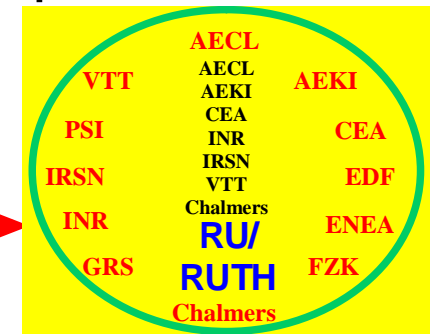
- ASTEC integral code (**A**ccident **S**ource **T**erm **E**valuation **C**ode) jointly developed by IRSN-GRS for SA in LWR: Source Term, Severe Accident Management, PSA level 2.
 - Intensively used for current PSA2: in IRSN on French PWR 1300 MWe and in GRS for German Konvoi 1300 MWe.
- ASTEC has progressively become the **reference European SA integral code** through work in SARNET:
 - Release by IRSN-GRS of 3 successive versions V1 (latest V1.3rev2 in Dec.07), users' training, intensive code maintenance and users' support through 3 Users Clubs and web tools,
 - Code assessment by 29 partners (\approx 50 users): validation vs. experiments, benchmarks on plant applications,
 - Integration of knowledge generated by SARNET Topics (Corium, Source Term and Containment) through improved models.

ASTEC model developments: Examples for Source Term domain

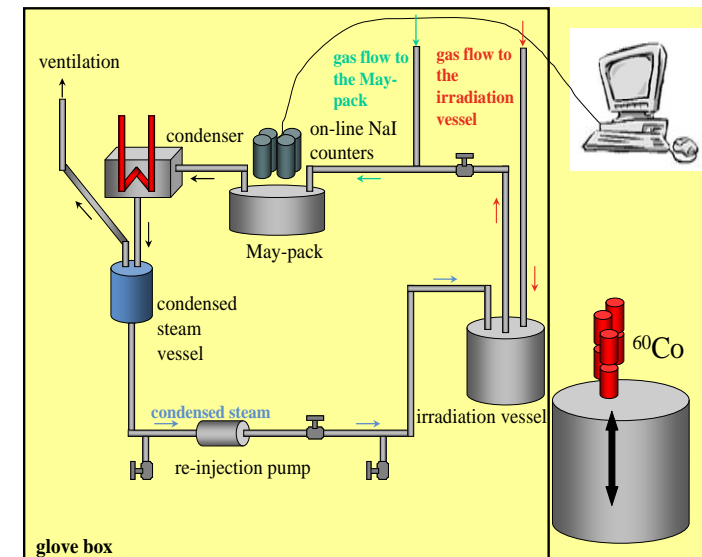
- Effect of **air ingress** on FP release/transport → Experiments showed that **Ruthenium** release occurs in oxide form; after full oxidation of fuel & cladding, the oxides can be transported to the containment atmosphere and can persist there.

- Models were devised for ASTEC dev. version.

“Interpretation circle”: experiments in black



- **Iodine behaviour in the containment** → **Improved models for ASTEC** on radiolytic oxidation in the sump (based on ISTP/EPICUR data: see right picture) and on sump/atmosphere mass transfer (SISYPHE data).



ASTEC model adaptation to all European reactor types

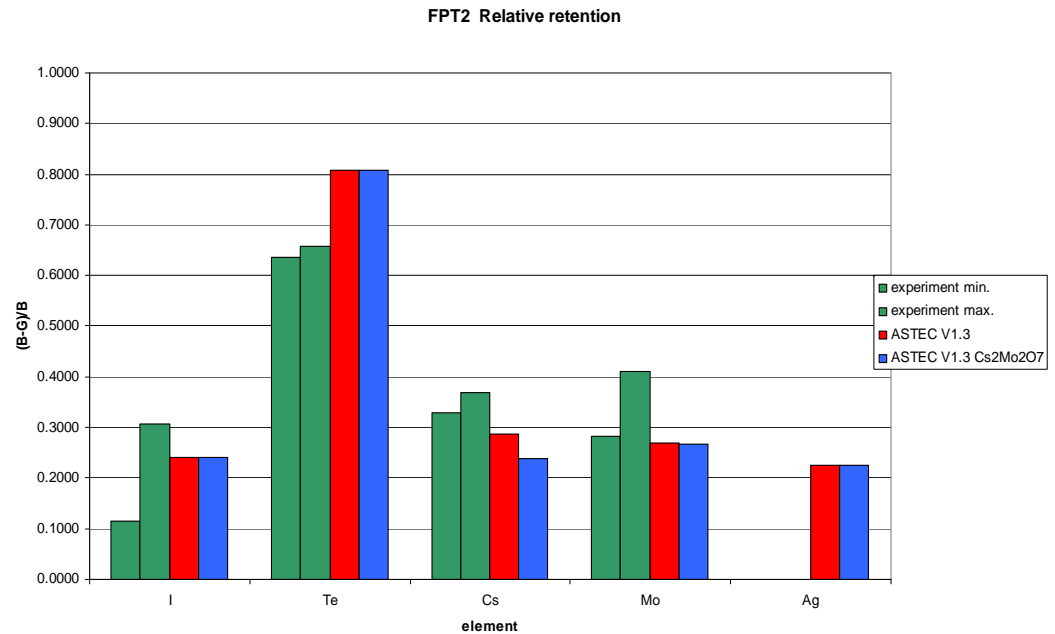
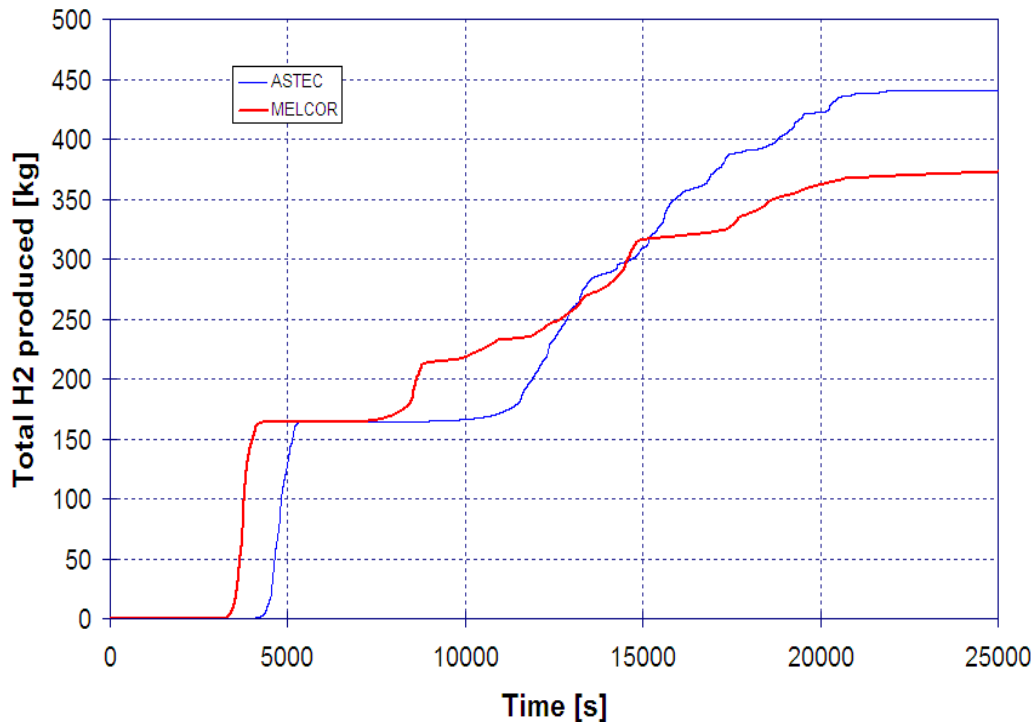
Identification/ranking of needs by partners, up to general specifications and scoping calculations (including validation) with ASTEC V1 models.

- VVER-440 and -1000: full code applicability of V1 versions and good level of validation (already many code applications since several years),
- BWR and CANDU: all models already applicable, except core degradation,
- RBMK: applicability to the early-phase of core degradation and to most other phenomena, including confinement behaviour.

⇒ *Work will focus in SARNET2 on adaptation for BWR and CANDU.*

ASTEC assessment (1/2)

- **Large validation efforts on 65 experiments** ⇒ *In general good results, most models at the State of the Art, except for core reflooding (esp. for H_2 production and degraded cores, like all codes).*
 - **Benchmarks on diverse scenarios** with integral or detailed codes for PWR900-1300, Konvoi 1300, West.1000, VVER-440, VVER-1000, CANDU and BWR.
 - Comparable trends and orders of magnitude of results with integral codes MELCOR or MAAP4,
 - Good agreement with core degradation detailed codes such as ATHLET-CD or ICARE/CATHARE.
- ⇒ *Significant feedback on ASTEC models, numerical robustness, documentation.*
- **Volume of work (out of IRSN-GRS) ≈ 15 persons/year**



- Benchmark ASTEC/MELCOR for during a SBLOCA 2" in the cold leg of a Westinghouse 1000 reactor: in-vessel H₂ production (TRACTEBEL work)

- FP retention in the Phebus FPT2 primary circuit: comparison between ASTEC calculation and measurements (JRC and UJV work)

SARNET2 general features

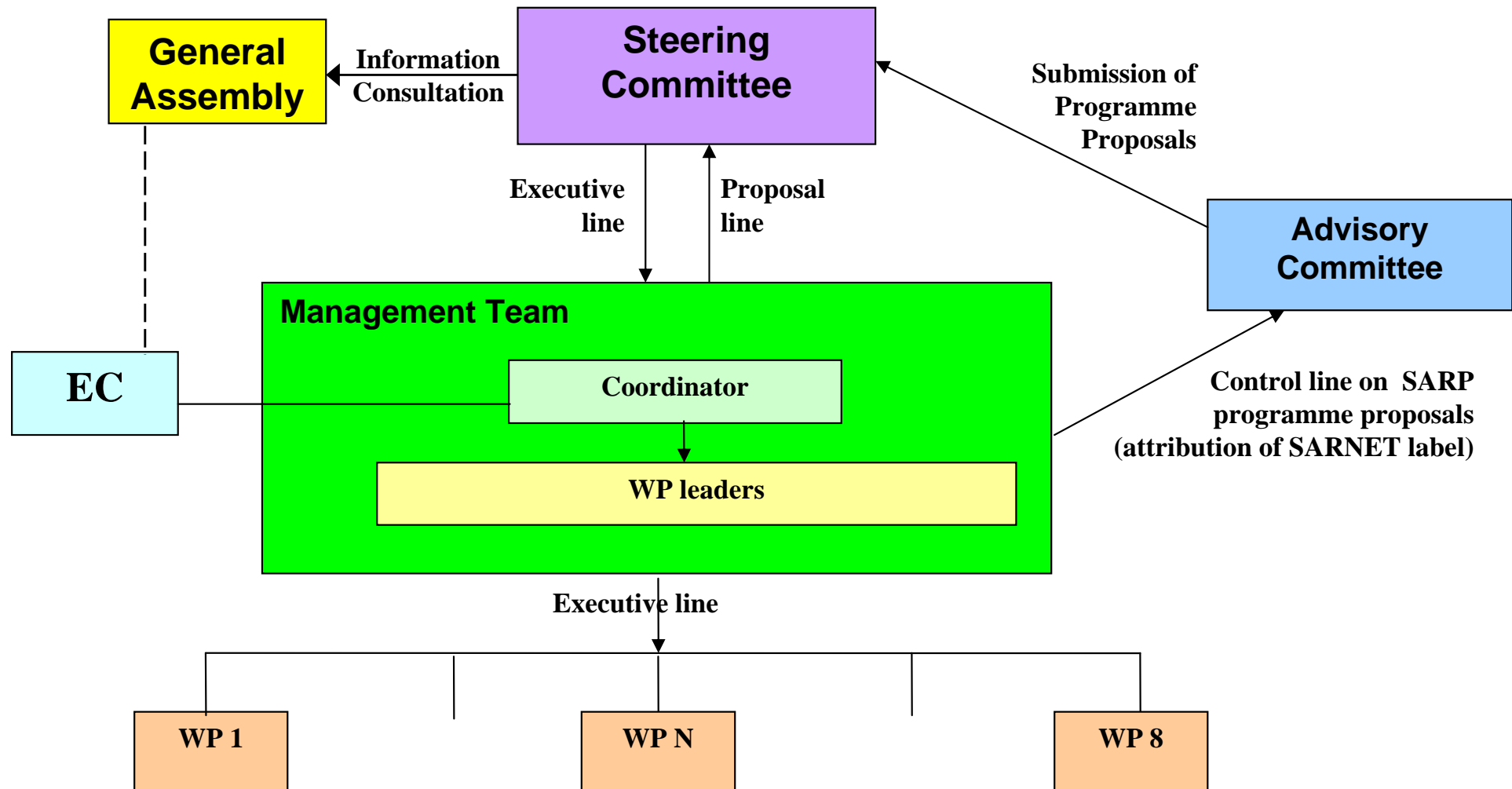
- 41 partners (most were already SARNET partners):
 - 8 universities
 - 23 research organisations
 - 5 industry / utilities
 - 5 TSO / safety authorities
- 21 countries (18 European countries, USA, Canada, Korea),
- Total planned effort by the partners: about 150 person.years,
- Total partners' budget about 36 M€ (including experiments),
- EC contribution: 5.75 M€

SARNET2 main objectives

Similar objectives than SARNET but with following specificities:

- Ultimate aim of **self-sustainability** in the SA research field through activities in networking, integration, knowledge management, exchange of information, dissemination of results and training to keep the SAM competences alive in Europe and worldwide.
 - Efforts focusing on the **6 high priority issues** as determined in SARNET / SARP WP.
 - In particular, special focus on the corium issues (coolability and MCCI), including **major experimental activities**.
- *The strong cooperation with international programmes (Phébus FP, ISTP, ISTC, OECD/CSNI GAMA, ...) achieved in SARNET will be enhanced.*

SARNET2 organisation scheme



SARNET2 Work-Packages

*Integration
&
Dissemination*

- WP1: NoE **Management**, incl. updates of the research priorities,
- WP2: **Spreading of Excellence** (courses, ERMSAR conferences, mobility of researchers)
- WP3: **Information Systems** (web, ACT, DATANET)
- WP4: **ASTECC** (capitalisation of knowledge, assessment, extension to BWR and CANDU)

R&D

- WP5: corium and debris **coolability** (core reflooding..)
- WP6: **MCCI**
- WP7: steam explosion and hydrogen combustion in **containment**
- WP8: oxidising impact on **source term** (Ru, HBU and MOX fuel), iodine chemistry in circuit and containment

General conclusions (1/2)

Most SARNET objectives have been reached...

- 1st step towards a sustainable integration of the European SA research capacities.
- ASTEC and DATANET → preservation of knowledge produced by thousands of person-years of R&D and dissemination to end-users.
- Collaborative work on PSA2 → 1st steps towards harmonization of methods within Europe (continuation through the ASAM-PSA2 EC FP7 project).
- Spreading of Excellence activities → efficient transfer of knowledge to younger generations.
- Collaborative work on Corium, Containment and Source Term → large progress to solve remaining outstanding issues, and to provide model recommendations for ASTEC.
- Research Priorities → direct impact on national programmes and associated budgets; optimisation of the European (and worldwide) Resources.

General conclusions (2/2)

- **ASTEC is now the reference European integral code for SA studies in present PWR-VVER:**
 - Models are at the State of the Art except for reflooding of degraded cores,
 - Applicability to all Gen.II reactors and to BWR and CANDU (for the latter: except for core degradation ⇒ extension in SARNET2),
 - New V2 series starting with **ASTEC V2.0** in March 09 with EPR and mechanistic core degradation models,
 - Beyond: repository of knowledge created in SARNET/SARNET2 and ISTP, ISTC, OECD projects.
- **SARNET2** now in final negotiation phase with EC: start in 1st quarter of 2009 for 4 years.
 - Besides the scientific objectives, the integration and dissemination aspects, one major objective is the **long term self-sustainability** of the network through the creation of a legal entity.

Acknowledgements

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