The Safety Research in the European Strategic Research Agenda (SRA) of the Sustainable Nuclear Energy Technology Platform (SNE-TP)
<table>
<thead>
<tr>
<th>Date</th>
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<tr>
<td>September 21, 2007</td>
<td>Launching of SNE-TP</td>
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<td>September 29-30, 2007</td>
<td>Executive Committee and « Governing Board »</td>
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<td>January 9, 2008</td>
<td>SRA organization meeting</td>
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<td>February 6, 2008</td>
<td>SNE-TP Executive Committee</td>
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<td>February 19, 2008</td>
<td>First SRA Technical Meeting</td>
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<td>May 26, 2008</td>
<td>Second SRA Technical Meeting</td>
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<td>July 10, 2008</td>
<td>SRA Draft validation meeting</td>
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<td>By end of July 2008</td>
<td>Latest release of the SRA under a Draft form</td>
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<td>During the summer</td>
<td>Validation by EC Experts,</td>
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<td>November 26</td>
<td>Presentation of the Converged SRA Draft at the General Assembly open for public consultation,</td>
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<td>Beginning 2009</td>
<td>Finalization of the SRA.</td>
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SRA: Matrix Structure

Cross-Cutting Activities

Reactor Concepts & Specific Research Issues
Main groups in the Reactor Systems 1/2

- **Current and Future Light Water Reactors (including SCLWR)**, coordinated by V. Prunier (EDF) and A Bredimas (EoN);
- **Advanced Fuel Cycle for waste minimization and resource optimization**, coordinated by D. Grenèche (AREVA);
- **GEN-IV Fast-Spectrum Reactors**, coordinated by F. Carré from CEA; the group is subdivided into four sub-groups:
  - SFR, coordinated by F. Carré from CEA,
  - LFR, coordinated by L. Cinotti from Del Fungo,
  - GCFR, coordinated by R. Stainsby from AMEC-NNC,
  - ADS, coordinated by P. Baeen from SCK-CEN.
Main groups in the Reactor Systems 2/2

- **HTR and other application of Nuclear Energy**, coordinated by D. Hittner from AREVA;

- **New Nuclear Large Research Infrastructures**; coordinated by A. Versteegh from NRG and B. Boulis from CEA; the group is subdivided into two sub-groups:
  - ◇ Critical and irradiation nuclear facilities,
  - ◇ Fuel cycle facilities.
SRA Organization and Working Group Leaders

- **Cross-cutting Activities**

- **Structural Material Research**, coordinated by C. Fazio, from FZK,

- **Pre-normative research, codes and standards** coordinated by Stéphane Marie, CEA

- **Modelling, Simulation & Methods** *(including physical data and tools and means for qualification and validation)*, coordinated by J.M. Cavedon, & M. Zimmermann, PSI,

- **Advanced Driver & Minor Actinide Fuel Science & Properties**, coordinated by J. Somers, JRC-ITU,

- **Safety**, coordinated by G.B. Bruna, IRSN, as a representative of the European TSO Organisation
Strategic Research Agenda
Cross-cutting Activity : Safety

- **Context**

- Very effective collaboration among Contributors (35 from 8 Countries and 20 Organizations),

- Many Contributors have participated in some selected parts only,

- In general, Contributors for **Current** and **Advanced and Innovative** Fission Reactors are different.
Summary of the SRA Safety Chapter

- Forewords
- Uncertainty analysis and “safety margins”: two cross-cutting topics for safety research
- Current Reactors
- Advanced and Innovative Fission Reactors
The connection between safety research and regulation is mandatory in the nuclear technology.

Even if the excellent performance record of existing installations might suggest that a high safety level can be achieved without new huge research efforts, consciousness of research needs should be maintained, focusing on new trends, supporting public information and training.

Anticipatory research should look ahead to safety questions that may arise in the future, due to changes in the design and operating-mode, and the appearance of new concepts.
The ultimate goal of nuclear safety is to prevent unacceptable radiological releases to the public and/or to the environment.

Protective and safety systems or features are intended to:

- Preserve the integrity of the different physical barriers,
- Mitigate the effects of their failures and should provide the necessary level of margins;

The regulatory acceptance of the limiting values of variables is set sufficiently high to assure conservatism with respect to the onset of damage;

“Safety Margins” are enforced on safety variables.
Strategic Research Agenda
Cross-cutting Activity: Safety

Safety variable distribution (Barrier or System integrity)

Likelihood of Barrier failure or System loss

“Safety Margins”
An extension of the concept of “Safety Margins” has been recently proposed.

- The set of the Design Basis Accidents was extended to the almost complete set of all credible scenarios, including out of design situations, which generates a “Risk Space”;

- The use of realistic dynamic models is encouraged and the end state of a sequence is no longer based on the use of success criteria for safety functions;

- Uncertainties of several types can be explicitly taken into account in the calculation of the conditional damage probabilities.
Strategic Research Agenda
Cross-cutting Activity: Safety

A : Relevant Sequence Space
B : Risk Space
C : Sequence Family

Increased Risk Scale
Priority topics for action (short-term within the FP7) [issues to be either implemented or reinforced]

- **Reactor Physics and Dynamics**
  - Generation of extended data libraries,
  - Improvements in the cross-sections generation processes,
  - Up-dating the reference transient core-dynamic codes,
  - Improvement of methodologies to reassess the reactivity limits vs. burn-up,
  - Development, validation and generalisation of coupled computation chains,
  - Extension of uncertainty analysis capabilities, (through sensitivity, variational and perturbation tools).

- **Thermal-Hydraulics**
  - Pressurized Thermal Shock (PTS),
  - Inherent boron dilution in case of LOCA,
  - Re-flooding following LB-LOCA (Large Break-LOCA),
  - Reactivity initiated accidents and related coupled computation tools,
  - Main Steam Line Break (MSLB),
  - Long term coolability of partly damaged core,
  - Development and assessment on thermal stratification.
Strategic Research Agenda
Cross-cutting Activity: Safety (Current Reactors)

Priority topics for action (short-term within the FP7) [issues to be either implemented or reinforced]

● Criticality
- Improving user-friendliness and robustness of the computation chains,
- Codifying and structuring knowledge and enlarging validation
- Creating and implementing rigorous and physically based methodologies to establish safe, but not redundant, sub-criticality limits,
- Extending the corium re-criticality studies,

● Nuclear Fuel
- Fuel response in case of LOCA and RIA both for reactor (operating and reloading) and spent fuel pool conditions,
- Implementation and assessment of a multi-scale approach,
- Development of the simulation-tool cascade,
- Interpretation, analysis and internalisation of the experimental results,
- Development of computation tools including advanced models on:
  - the plasticity and the loss of ductility,
  - the Fission Gas behaviour in the fuel matrix,
  - the sensitivity of the anisotropy to the burn-up,
  - the clad behaviour, the coupling to thermal-hydraulics,
  - the development of models for new materials.
## Strategic Research Agenda

### Cross-cutting Activity: Safety (Current Reactors)

### Priority topics for action (short-term within the FP7) [issues to be either implemented or reinforced]

- **Human and Organisational Factors**
  - Priorities established in agreement with the ETPIS (European Technology Platform for Industrial Safety):
    - Survey of the human and organizational practices in current reactor operation,
    - Evaluation of the impact of staff reduction on safety,
    - Extended research on the impact of subcontracting in sensitive industry,
    - Development and acquisition of knowledge on man-machine interface,
    - Formalization of practices and methods for evaluation of human and organizational factors, including an adequate link to risk and “Safety Margins”

- **I&C and Electrical Systems**
  - Development of test methods to predict ageing effects on I&C components,
  - Harmonisation of ageing knowledge of I&C components,
  - Understanding environmental parameters impacting I&C ageing,
  - Establishment of branch technical positions including architectural and technological aspects,
  - Anticipation of new challenges and the follow-up of technology changes such as the adoption of programmable digital automation components.
Strategic Research Agenda
Cross-cutting Activity: Safety (Current Reactors)

Priority topics for action (short-term within the FP7) [issues to be either implemented or reinforced]

- Aggression and Hazards

In recent years, new threats are coming up forcing to focus not only on internal hazards, but also on the destructive action of external agents including the time.

When assessing the safe behavior of a system, a component or an equipment, its robustness and resistance to the aging-related phenomena and to all kind of external aggressions is to be demonstrated, including

- Flooding,
- Extreme weather conditions,
- Seism,
- Fire.
Strategic Research Agenda
Cross-cutting Activity: Safety (Current Reactors)

Priority topics for action (short-term within the FP7) [issues to be either implemented or reinforced]

- **Plant Simulation**
  - Contribute to the design through the simulation of the transients and the actuation of the different safety and safeguard systems,
  - Simulate the transients adopted to prepare the responses to emergencies and external hazards, and the exercises to preclude any reactivity release to the environment,
  - Be used for teaching and personnel training.

- **Emergency Management**
  - Improvement of the modelling of the long term emergency management actions in agricultural and inhabited areas and develop a framework for the sustainable rehabilitation of contaminated areas.
  - Improvement of the decision support systems to deal with new threats.
  - Implementing the European platform for decision support and emergency management.
Priority topics for action (short-term within the FP7) [issues to be either implemented or reinforced]

- **Severe Accidents**

Priorities based on the six SARNET “high priority” issues:
- Molten Corium Concrete Interaction (MCCI): experimental activities and development of computation capabilities in the existing tools,
- Ex-vessel and in core corium cooling: experimental activities and development of computation capabilities also accounting for specific BWR needs,
- Melt relocation into water and ex-vessel Fuel-Coolant Interaction (OECD SERENA2)
- Hydrogen mixing and combustion in containment: - OECD SETH 2 -
- Completion of the current programme on Iodine chemistry in RCS and containment,
- Air ingress and Fission Product (FP) release: treatment of the oxidising impact on FP release from the fuel elements (effect of high burn-up and MOX).

Moreover:
- Extension of the modelling in the ASTEC code to include the loss of water and air ingress in spent fuel pool scenarios.
- Harmonization of the PSA level 2 practices.

A major concern in the field remains the loss of unique experimental facilities.
Advanced and innovative reactors encompass a variety of different designs and operating modes. They span a very large set of configurations, including small and large size cores, fast-neutron and moderated spectra, gas, water and liquid metal cooling, each one matching more or less completely and comprehensively the objectives of the GEN-IV roadmap.
Natural resource optimization and waste minimization are goals more likely affordable for systems with fast neutron flux, such as **SFR - Sodium Fast Reactor**, **GFR - Gas Fast Reactor**, and **LFR - Lead Fast Reactor**.

Graphite moderated, gas cooled high temperature reactors such as the **Very High Temperature Reactor (V/HTR)** are more likely to be inherently safe; they also have the best potential for a diversified energy production (electricity, but also industrial heat and hydrogen).
Operating experience can contribute to identify crucial needs for **Advanced and Innovative** system research,

All the modifications adopted for **Current** reactors and the associated safety assessments should entail research, including code-development and experimental activity.

Experiments contribute to the knowledge because they participate in the validation of the code physical models and, may provide unexpected results which allow disclosing hidden phenomena and ignored variables.
Nuclear actors are presently facing a very open landscape as regards the industrial maturity of concepts.

That is very challenging from the safety point of view, because the safety assessment is strictly tied to design features, the details of which remain widely unknown for the most concepts at the present stage of development.

The risk exists that the research effort outcomes will show-up either quite poor or straightforward or false.
Major Safety concerns for GEN-IV

- Minimizing the risks inherent to the coolant (sodium; lead, ...),
- Practically precluding any large energy release in case of severe accident,
- Minimizing the system vulnerability to external events and aggressions,
- Assessing the impact of MA -Minor Actinides- fuels,
- Diversifying the safety systems (e.g., decay heat removal),
- Developing an improved instrumentation for early detection of abnormal situations,
- Developing improved instrumentations and techniques for in service inspection and repair.
The relevant R&D activity can be grouped in several main fields of endeavour:

- Core Physics and Simulation,
- Residual Heat Removal,
- Fuel Integrity,
- Fission Product Release,
- Reduction of Major Risk of a Broad and Severe Damage of the Core,
- In Service Inspection and Repair.
Strategic Research Agenda Cross-cutting Activity
Safety

Concluding Remarks 1/2

• The need for new experimental and simulation tool, aimed at sustaining safety analyses, should be focussed on current reactors with GEN-IV development in perspective,

• The public acceptance plays a key role and may strongly affect the profitability of an investment in the nuclear field,

• The high cost of experimental activities calls for participation of partners at the international level.
Concluding Remarks 2/2

The results of the R&D should be presented in such a way as:

◊ Being really user friendly,

◊ Supporting the dissemination of a nuclear knowledge,

◊ Promoting confidence on the capability to manage nuclear technologies and plant behaviour both in the normal operation and in the transients,

◊ Attracting newcomers and young people to the field.