EU RESEARCH ON SEVERE ACCIDENT MANAGEMENT : RESULTS OF THE 4-th AND PROSPECTS FOR THE 5-th EURATOM FRAMEWORK PROGRAMME

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ABSTRACT

In this paper an overview is given of the most important aspects of the research activities organised by the European Union (EU) in the area of reactor safety under both the past 4th and the current 5th Euratom Framework Programmes (FP). This research consists of the following 4 areas: reactor safety; waste management; future systems; and radiation protection. Under FP-4 ('94-'98), the particular area of reactor safety was focusing on "Severe Accident Analysis" – the main subject of this paper -, whereas under FP-5 ('98-'02) it is focusing on "Operational Safety of Existing Installations".

To set the general frame, a short description is also given of the main stakeholders of nuclear fission research (i.e. regulatory authorities, utilities and vendors), faced with new targets (e.g. minimisation of operating and environmental costs in a deregulated market) and new feedbacks from the "customers" (e.g. public perception of reactor safety).

Also given is a brief description of the main facts of FP-4 and FP-5 with emphasis on the clustering approach of research projects in the same field. As far as the future is concerned (next framework programme 2002-2006), the challenge to Euratom research is to reorganize itself in line with the new European Research Area (ERA) concept, bringing together private and public resources. For the next framework programme in general, the following instruments will be proposed: networks of excellence; integrated projects; and the participation of the EU in programmes carried out jointly by several Member States. Finally conclusions are drawn on the main achievements of framework programme research in reactor safety and on the Commission's intentions to face the new challenges of the "changing world".

1. INTRODUCTION/CO-OPERATION OF MAIN STAKEHOLDERS OF NUCLEAR FISSION RESEARCH

Reactor safety is still perceived as a concern by the public at large: it remains directly linked to public confidence. As a consequence, in particular in the EU, it remains a key issue for international research - in line with general safety principles established on a world scale more than 10 years ago. Reactor safety, however, is not an objective per se: it should be optimised together with other requirements, such as health protection, plant economics (technical performance) and environmental protection. Improvement of nuclear power plant (NPP) performance means, amongst other things, increasing plant availability, controlling operation and maintenance costs, and improving the fuel cycle as well as optimising the whole plant organisation. This is the subject of the current Euratom research activities devoted to modernisation of materials and equipments in existing installations. Understanding the phenomenology of (highly unlikely) severe accidents and developing appropriate mitigation measures is another area of current Euratom research – of particular interest for this paper. Also of interest for Euratom research are advanced reactors of the evolutionary type: their prime objectives are to simplify plant operation and inspection, to extend the service life of systems and components, and to reduce capital cost in general, while further improving their safety.

The traditional stakeholders of research programmes in nuclear fission have not changed over the last decades. They are mainly the regulators, the utilities and the vendors as well as the research organisations themselves, whether governmental or industrial. Note that these traditional stakeholders are used to have many interactions, in particular through international research programmes, such as Euratom FP actions.

Roughly speaking, the following can be said about the research priorities of the three traditional groups of stakeholders:

- for the regulatory authorities: safety
- for the utilities and the services sector: safety and performance

- for the vendors and the designers: safety, performance and innovation.

The research organisations, on their side, are expected to offer their services to these three groups, thereby making the best out of all above-mentioned priorities (i.e. safety, performance and innovation).

In Europe, the "nuclear needs" of the main stakeholders have not changed over the last decades. They are the following: to ensure flexibility in energy supply by maintaining the nuclear option open; to contribute to health and safety as well as to non-proliferation by a better co-ordination of European research and training activities; to maintain industrial competitiveness by preparing the next generation of reactors; to maintain broad nuclear expertise for non-energetic applications; to develop sustainable solutions for fuel cycle management and waste disposal; to share the same nuclear safety culture amongst the EU and the applicant Central and Eastern European Countries (CEECs); and finally, to improve the impact of Euratom research actions by enhancing their public benefit and their added European value.

What have changed recently are the boundary conditions for the nuclear industry and for the relevant research programmes. For all stakeholders, the enlargement of the EU towards the CEECs, in particular, requires new co-operation modes to integrate a variety of scientific research traditions and safety cultures across the various countries concerned. In addition, for industry both in the EU and in the CEECs, return on investments becomes the main consideration in the broadly liberalized and competitive electricity market. How to optimise plant safety and economics, while gaining public acceptance, is one of the new challenges to Euratom research in the "changing world" (that is, currently within the EU: deregulated electricity market, mergers of large companies, low growth for electricity demand, general public mistrust with respect to nuclear energy, privatisation of research, and outside the EU: enlargement towards the CEECs and world-wide globalisation). Another characteristic of this "changing world" is the drastic reduction of both regulatory and industrial budgets for nuclear fission research.

2. EURATOM RESEARCH IN REACTOR SAFETY UNDER FP-4 AND FP-5

At EU level, a large part of the research in nuclear fission is carried out through multi-partner projects under multi-annual Euratom Framework Programmes, co-funded and co-ordinated by the European Commission / Directorate General (DG) Research (responsible for the "indirect actions") in co-operation with DG Joint Research Centre (responsible for the "direct actions").

The strategic goal of the previous specific 4th Euratom Framework Programme (FP-4, 1994-1998) was "to stimulate closer collaboration amongst all parties involved in nuclear energy, to reach a common understanding and to find solutions to open questions". Under the "indirect actions" of FP-4, the objectives of "Nuclear Fission Safety" were thus essentially knowledge-driven. Research consisted of 4 areas, namely: reactor safety (EU budget of EURO 42 Million); waste management (EU budget of EURO 42 Million); future systems (EU budget of EURO 5 Million); and radiation protection (EU budget of EURO 57 Million). Research in reactor safety addressed primarily severe accident analysis, focusing on the prediction of timing and mode of failure of the main barriers. The variety of projects in this area started from early accident progression in the primary coolant system and went up to severe damage to the containment integrity, under the very unlikely assumption that the safety systems are not working satisfactorily. A smaller part of research was devoted to other areas, such as: plant modernisation with emphasis on the prediction of safety margins for existing installations, and advanced safety concepts with emphasis on passive decay heat removal systems for evolutionary reactor designs.

The "indirect actions" in reactor safety under FP-4 consisted of a total of 67 multi-partner projects (shared-cost and concerted actions), focusing on severe accident phenomenology and structured in 7 clusters, each devoted to one key safety issue. These 7 key issues were : materials ageing (AGE), in- and ex-vessel corium behaviour (INV and EXV), radiological source term (ST), containment integrity (CONT), accident management measures (AMM) and innovative safety concepts (INNO). All 67 projects were presented, cluster by cluster, at the conclusion symposium FISA-99 (EC Luxembourg, 29 November – 1 December 1999 / proceedings in EUR 19532 - ISBN 92-828-9588-2 – published in April 2000). The total cost of these 67 projects in reactor safety research was EURO 62.8 million, out of which EURO 34.2 million was contributed by the EU budget. Another EURO 7.8 million was added for support to the PHEBUS-FP programme and for accompanying measures. The main objectives and achievements of the 5 clusters INV, EXV, ST, CONT and AMM are described in Section 3.

The strategic goal of the current specific 5th Euratom Framework Programme (FP-5, 1998-2002) is "to help exploit the full potential of nuclear energy in a sustainable manner, by making current technologies even safer and more economical and by exploring promising new concepts". Under the "indirect actions" of FP-5, the objectives of "Nuclear Fission" are thus more end-user-driven. Research consists of the same 4 areas of FP-4, but with different budgets, reflecting the new trends, namely: reactor safety (EU budget of EURO 38 Million); waste management (EU budget of

EURO 59 Million); future systems (EU budget of EURO 12 Million); and radiation protection (EU budget of EURO 49 Million). Research in reactor safety under FP-5 addresses primarily the optimisation of both plant safety and performance: almost equal financial weight is given to research in plant modernisation (with emphasis on plant life extension and management or PLEM) and to research in severe accident management (SAM), whereas the weight on evolutionary concepts (EVOL) is increased, as compared with FP-4.

Under FP-5, until now, the "indirect actions" in reactor safety consist of a total of 41 multi-partner projects, structured in 3 clusters (PLEM, SAM and EVOL) and worth a total amount of approximately EURO 50 million, out of which approximately EURO 27 million will be contributed by the EU budget. The summaries of all 41 projects are available on the Web site of the Community R&D Information Service (CORDIS – see homepage http://www.cordis.lu/fp5-euratom/src/projects.htm). From now on until 2002, another series of project proposals related to reactor safety research are expected for a total EU budget contribution of approximately EURO 9 million. Another EURO 2 million should be added for support to the PHEBUS-FP programme and for accompanying measures.

The clustering approach of the FP-5 projects in reactor safety is best described as follows. The PLEM cluster (16 projects) consists currently of 3 fields (namely: integrity of equipment and structure; on-line monitoring and maintenance; organisation and management of safety) and 6 items (namely: materials embrittlement; materials corrosion; fracture mechanics; NDT inspection of components; water hammer loads; safety culture). The SAM cluster (16 projects) consists currently of 2 fields (namely: assessment of severe accident risk; severe accident measures) and 6 items (namely: corium behaviour; reactor pressure vessel; source term – with PHEBUS playing a key role -; hydrogen; by-pass sequences; code development). The EVOL cluster (9 projects), finally, consists currently of 2 fields (namely: evolutionary safety concepts; high burn-up and MOX fuel) and 3 items (namely: analytical tools / codes; methodologies; operational practices and design improvement; databases).

The main implementation instruments of the "indirect actions" under FP-4 and FP-5 are the cost-shared and concerted actions, which represent more than 90 per cent of the total research budget. The rest consists of accompanying measures (useful, for example, to support specific training and education activities) and the Marie Curie individual fellowships (useful for the mobility of researchers across the Member States) - see web site of the COmmunity R&D Information Service CORDIS at http://www.cordis.lu/improving.

Besides the "indirect actions" described previously and co-ordinated by DG Research, it is worth recalling the "direct actions" in nuclear fission carried out by DG Joint Research Centre (5 establishments in 5 countries) under the common Euratom umbrella. The following web site provides useful information about JRC activities: http://www.jrc.cec.eu.int/. One of the main actions of JRC in reactor safety research consists in operating European networks in the field of structural integrity for nuclear components. The network on Ageing Materials Evaluation and Studies (AMES), the European Network for Inspection Qualification (ENIQ) and the Network for Evaluating Structural Components (NESC) each deal with a specific aspect of fitness for service of materials in structural components.

3. EU CO-SPONSORED RESEARCH IN SEVERE ACCIDENT MANAGEMENT UNDER FP-4 (1994-1998)

No single definition of the source term really exists. Two definitions, however, are encountered more than others. They identify the source term as the inventory of radionuclides, resulting from a severe accident:

- either available for dispersal from the containment – with important implications not only for licensing purposes but also for additional engineered safety features (which is the main purpose of Euratom research devoted to SAM)
- or dispersed over the area outside the containment - with important implications for evaluations of emergency plans (which is treated in other areas of Euratom research).

Severe accidents also are defined in various ways, with different, sometimes very challenging, implications for RTD activities of common (international) interest.

For example, according to OECD/NEA, a severe accident is defined as one, which exceeds the design basis of the nuclear power plant sufficiently to cause significant damage to the reactor core. A similar definition is given by the European Utility Requirements (EUR Document, 1995), namely: they are “unlikely event sequences beyond accident conditions involving significant core damage which have the potential to lead to significant releases”: they are a subset of the so-called “design extension conditions”. They are called also beyond-design-basis accidents (BDBA). Containment by-pass accidents can also be considered here, because of their potential to release large quantities of radioactivity into the environment.

Another definition is as follows: severe accidents are events of very low probability but high consequences, with trans-frontier and long-term effects. New RTD tools might be needed to study this type of event since the standard safety assessment tools are usually developed for high-probability low-consequence events, with validation domains often limited in space and time. As it is naturally difficult to calculate exactly the consequences of BDBA scenarios, it is usually agreed to concentrate on the evaluation of "trends" during severe accident progressions and to predict as realistically as possible their contributions to the overall risk.

Finally, a very practical definition consists in prescribing threshold values: this type of definition is very prescriptive in terms of doses. For example, a severe accident is one giving rise to an uncontrolled release of a size capable of giving (whole body) doses of 100 mSv at 3 km from the plant site. For reminder, the study of dose evaluations for the criticality accident at the Tokai Mura uranium conversion facility (September 1999) has shown that all doses were less than 50 mSv, except for 3 workers directly involved in the accident.).

The studies of (severe) beyond-design-basis accidents (BDBA) are very important to evaluate a level of "enhanced" plant safety, i.e. to envisage an additional 4th level to the traditional defence-in-depth. Ideally a majority of severe accident situations should be designed out. In practice reinforced prevention and mitigation measures are under development to reduce to a minimum the probability and the magnitude of severe accidents (and hence the associated radiological risk, i.e. the consequences on man and environment). More generally, the discussion around the source term definition is driving many of the innovations in the design of additional safety measures both in the operation of nuclear power plants and in the organisation of emergency preparedness, in the extremely unlikely case of a severe accident.

In line with the need to understand the most risk-relevant phenomena of severe accidents, a total of 36 research projects, put together in 4 clusters called INV, EXV, ST and CONT (described here-under in Sections 3.1, 3.2, 3.3 and 3.4, respectively) were conducted with the aim to improve the multibarrier approach, in particular, by contributing to the development of a 4th level of defence-in-depth (mitigation measures). The research was structured around the following key safety issues, relevant to operating installations as well as evolutionary LWRs:

(a) maintaining the pressure vessel integrity under severe accident conditions, that is: ensuring in-vessel melt retention, making use of either massive in-vessel water injection on the degraded core or/and of ex-vessel cooling by flooding the reactor pit, whenever possible

(b) maintaining the containment integrity under severe accident conditions, that is: preventing containment leakage due to cracking or perforation as a result, for example, of hydrogen explosions or/and corium attack on the basemat, using either hydrogen recombiners or/and core catchers, respectively.

In line with the need to develop severe accident management measures and to evaluate their effectiveness, a total of 9 projects, put together in another cluster called AMM (described here-under in Section 3.5), have been conducted, focusing on accident management methods (including operator assistance, as well as instrumentation and signal validation under harsh conditions) and on improvement of PSA-level 2 techniques.

3.1 In-vessel core degradation

In the cluster INV, the emphasis was on the corium risk in the vessel: e.g. energetic fuel-coolant interactions (possible steam explosions) and hydrogen generation as a consequence of quenching of an overheated/degraded core. The safety issues treated in this cluster were related principally to the integrity of the first and second barriers, that is: ensure integrity of fuel pins and reactor coolant system (RCS), i.e. arrest or slow accident progression after major fuel pin ruptures and core disassembly, by managing melt cooling and in-vessel melt retention (IVR).

The accident management measures (AMM) proposed, for existing as well as for future reactors, are as follows: 2 strategies, separately or simultaneously, consisting of (i) internal and/or (ii) external reactor vessel cooling (IRVC and/or ERVC), i.e. molten core quenching and/or full reactor cavity flooding strategy, respectively, making use of existing and alternative resources, systems and actions.

3.2 Ex-vessel accident progression

In the cluster EXV, the emphasis was on the corium risk outside the vessel, in the very unlikely case of vessel failure, e.g. generation of burnable and non-condensable gases as a consequence of core debris ejection on the containment floor and interaction with the concrete basemat. The safety issues treated in this cluster were related principally to the integrity of the third barrier: ensure containment basemat integrity, i.e. arrest or slow accident progression after RPV failure by managing corium and RPV materials retention and cooling on the basemat.

The accident management measures proposed, for future reactors of the "evolutionary" type, are summarized in one strategy based on a ex-vessel core catcher for corium spreading, using either homogeneous spreading to a shallow melt layer or distribution of the melt in a multi-crucible device.

3.3 Accident progression in the containment building

In the cluster CONT, the emphasis was on the hydrogen risk : e.g. explosions (deflagrations and possibly detonations) as a consequence of critical hydrogen concentrations, including the effects of air, steam and radioactive aerosols. The safety issues treated in this cluster were related principally to the integrity of the third barrier: ensure integrity of containment building, i.e. arrest or slow accident progression after RPV failure, by managing in-containment radioactivity retention and containment atmosphere cooling.

The accident management measures proposed (for existing as well as future reactors) were as follows: 2 strategies, separately or simultaneously, in the cases of early and late containment failure, respectively, consisting of :

- strategy n° 1 = use passive autocatalytic recombiners (PARs) and/or igniters for the "practical elimination" of early containment failures due to hydrogen explosions
- strategy n° 2 = use for example spray systems and filtered containment venting for the "control" of late containment failure due to gradual pressurisation.

3.4 Radiological source term

In the cluster ST, the emphasis was on the radiological source term risk from releases of radioactive materials out of the different barriers: e.g., in the worst case, leaks to the atmosphere and to the aquatic environment. The safety issues treated in this cluster were related principally to the containment of the severe accident radioactivity within the various barriers, i.e. not only the traditional bounding volatile radionuclide Iodine but also other risk relevant radionuclides such as Caesium and Strontium, and others (e.g. Te, Ru, La, Y, Ce, Zr, Pu, Np and Cm).

The accident management measures proposed, for existing as well as future reactors, consist of several strategies, comprising severe accident source term mitigation methods able to operate also for long periods, taking into account the possible time variation of the source term.

3.5 Accident management measures

The scope of the research activities foreseen in the cluster AMM was the improvement of diagnostic means with respect to severe accidents, and the assessment and use of accident proved information technology. These are key activities necessary for the development and implementation of severe accident management measures for both existing and future NPPs. Here is a list of some of the most remarkable achievements:

- development of integrated SAM models (e.g. coupled event tree/fault tree techniques, Accident Mitigation Event Tree or "AMET", Risk Oriented Accident Analysis Methodology or "ROAAM") for the assessment of severe accident management measures, and proposals for Severe Accident Management Guidance (SAMG)
- development of algorithms for signal validation and accident identification, and assessment and improvement of the survival potential of plant process instrumentation under accident conditions,
- establishment of a pilot PSA level 2 database and improvements in the use of expert judgement approaches in PSA
- strategies to prevent/mitigate specific scenarios, like Boron dilution
- assessment of human and organisational factors.

4. IMPACT OF EURATOM RESEARCH ON THE DECISION-MAKING PROCESS OF THE MAIN STAKEHOLDERS (I.E. REGULATORY BODIES, UTILITIES AND VENDORS)

4.1 Regulatory-driven research priorities / Emphasis on safety

Safety authorities in OECD countries have warned that cutbacks in nuclear safety research can have an adverse impact on the ability to fulfil safety responsibilities. Speaking collectively through the Committee on the Safety of Nuclear Installations (CSNI) of the Nuclear Energy Agency (NEA), they are particularly concerned by the shutdown of large research facilities and the break-up of experienced research teams, as funding for government programmes is continuously reduced. As a result of discussions started in the early 1990's, a CSNI report identified in 1996 a total of 13 priority areas for further research, namely: (1) Steam generator and pressure vessel integrity ; (2) Component ageing ; (3) Human factors ; (4) Computer-based control and safety systems ; (5) Validation of fire simulation codes and active fire protection measures ; (6) Extended applications of thermal-hydraulic codes ; (7) Fuel damage limits at high burn-up ; (8) Further development of probabilistic safety analysis tools ; (9) Fission product release in relation to containment leak-tightness ; (10) Better understanding of steam explosions ; (11) Development of models and a data base on core debris coolability ; (12) Hydrogen combustion and mitigation techniques ; and finally (13) the Effects of ageing on containment integrity.

Since the Euratom programme committees are working in close co-operation with CSNI and other international bodies, it is no wonder that some of the above research areas became priorities in the strategy of the Euratom Framework Programmes. For example, 6 out of the 13 priorities of the above CSNI report were selected for Euratom research under FP-4 and FP-5 (namely : numbers 2, 8, 9, 10, 11 and 12). Component ageing (priority 2), in particular, is the main subject of the PLEM cluster. Due to their own priorities (based on a mixture of European regulatory and industry interests), the Euratom committees decided to introduce the 2 following new topics in FP-4 and FP-5 : « severe accident management measures» (e.g. advanced decision support tools - see SAM cluster) and « innovative safety concepts » (e.g. passive decay heat removal systems - see EVOL cluster).

In the particular area of severe accident management, it is well known that designs and operating procedures need to satisfy increasingly stringent rules which, in many countries, are enforced by national regulatory bodies. Research in nuclear safety, thus, has often a strong regulatory component. Worth mentioning here is the central role of the EC co-sponsored programme PHEBUS-FP, managed by IPSN and run at CEA Cadarache, which brings essential contributions to the issues of severe core degradation and source term and thereby enables technical safety organisations to validate numerical prediction tools needed for the development of severe accident management guidance (SAMG) strategies. The link with the relevant Framework Programme activities is ensured through a series of supportive shared-cost and concerted actions. Finally worth mentioning is the research conducted in the area of organisational factors, which is playing an increasing role in the global plant safety assessment.

Talking about real impact of Euratom research, it is worth mentioning a study made by an international group of regulatory experts with the aim to assess the regulatory decisions – essentially of mitigative type - taken on the basis of international research (including Euratom research) in the particular area of SAM. For operating plants, for example, there is a general consensus – based amongst others on results of projects in the INV cluster - that no backfits are needed to ensure containment integrity against the alpha (steam explosion) failure mode and that for low power reactors (for example, Loviisa/Finland) core coolability through in-vessel melt retention is possible in case of severe accident. Passive autocatalytic recombiners for hydrogen risk management have been installed in many European NPPs: their installation on the industrial side and their assessment on the regulatory side have benefited from many research projects - amongst others in the cluster CONT. Revision of radiological source term specifications is underway in many countries: this is based amongst others on results of the international programme PHEBUS-FP in connection with the cluster ST. Probabilistic safety assessment techniques were improved – amongst others in the cluster AMM – especially for beyond design basis events and human factors. For advanced evolutionary plants, containment coolability through melt spreading was investigated and assessed from a regulatory point of view – based amongst others on results of the projects in the EXV cluster.

4.2 Utilities-driven research priorities / Emphasis on safety and performance

Utilities have their own experts' circles, such as WANO (World Association of Nuclear Operators) for reactors in operation worldwide. More specifically within Europe, as far as the next generation of reactors is concerned, a very interesting harmonisation effort is underway in the European Utility Requirements (EUR) group. In addition to legitimate commercial interests depending on plant performance, the utilities and the associated services naturally share the same safety concerns as the above-mentioned regulatory bodies. Their research programmes usually contain the following two separate functions : (1) safety and reliability and (2) operability and availability.

Safety and reliability. Safety and health requirements are to be satisfied both on an individual and collective level, through on-going improvements in radiological protection (e.g. dose reduction or ALARA programmes). Also needed are a better knowledge of the mechanisms that cause the materials to deteriorate and of the properties of new materials that may be used to replace them, as well as the development of new testing and analysis techniques. The safety and reliability are further increased through advanced interactive information and communication systems, with a rapid response when confronted with an emergency situation.

Operability and availability. Robotics and automation help improve the operability, for example, by introducing mobile robots into the processes and monitoring process variables in a local and remote real-time manner. In addition, nuclear fuel management should be optimized in terms of burn-up, technical/economic analysis of multi-cycle management of reload batches, back-end of the cycle, storage, sample taking and sample preparation and quality assurance programmes.

Talking about real impact of Euratom research, it is worth mentioning here a study made by an international group of industry experts (representing both the utilities and the vendors) with the aim to assess the technical decisions –

essentially of preventive type - taken by the industry on the basis of international research (including Euratom research). For operating plants, for example, improved in-service inspection and repair techniques have been developed using non-destructive testing techniques – based amongst others on results of projects in the AGE cluster. Similarly, improvements of industrial significance were brought to dosimetry and reconstitution techniques qualification to monitor reactor pressure vessel degradation – also investigated in the AGE cluster.

For obvious reasons, Euratom research in reactor safety is inclined to privilege actions related to function (1) of the above list, namely: "safety and reliability", as this topics fits best the two key criteria of "public benefit" and "European added value".

4.3 Vendors-driven research priorities / Emphasis on safety, performance and innovation

In order to optimize plant safety and performance, the vendors and designers naturally are interested in innovations in view of the next generation of reactors. In addition to the above-mentioned functions "safety and reliability" and "operability and availability", their research programmes usually contain the following two separate functions; (1) maintainability and constructability and (2) new materials and economics.

Maintainability and constructability. For maintenance purposes, the state of the existing installations and their components should be permanently monitored, with a view to being able to make technical and economic decisions at any time. Advanced maintenance strategies should be developed such as integrated maintenance management systems. Constructability of any new design feature (be it hard- or software) is another important requirement in plant management practice.

New materials and economics. New materials with improved features and characteristics should be developed and used, with the aim of saving raw materials and power, thereby making the company become more competitive. In addition, new opportunities and products should be acquired, with a view to improving technological diversification and to optimize the entire fuel cycle.

Talking about real impact of Euratom research, it is worth recalling the above study, aimed at assessing the technical decisions taken by the industry on the basis of international research (including Euratom research). For advanced evolutionary plants, for example, steam injectors and passive cooling systems (for both the pressure vessel and the containment) were developed – on the basis amongst others of projects in the cluster INNO. For advanced innovative plants, such as high temperature reactors, preliminary conclusions were drawn – in the same cluster INNO - for new materials with high resistance to radiation damage and high temperature conditions and with reduced activation.

For obvious reasons, Euratom research in reactor safety is inclined to privilege actions related to function (2) of the above list, namely: "new materials and economics", as it is long term oriented, with a view to contribute ultimately to the competitiveness of European industry in general.

5. CONCLUSIONS / MAIN ACHIEVEMENTS OF FRAMEWORK PROGRAMME RESEARCH

In this overview paper, it has been shown how Euratom research has been able hitherto to respond in part to the EU research needs in the area of nuclear fission energy. In addition, the benefits of strong co-operation between private (e.g. industrial) and public (e.g. governmental) organisations in the nuclear area have been illustrated by describing some remarkable results obtained from Euratom research actions where all nuclear actors were involved. More information about the shared-cost and concerted actions of the current FP-5 Euratom programme in reactor safety will be given at the FISA-2001 symposium (12-14 November 2001, Luxembourg), free of charge and open to all persons interested: the co-ordinators of the current 41 projects of FP-5 will present the state of their project and discuss their views on further developments. In addition, a series of lectures of general technical interest will be delivered.

In the framework of the "changing world", it seems obvious that not only national technical experts and international organisations but also the public at large will have their say in the nuclear decision process. Therefore, also a better communication is needed amongst the various circles of (nuclear) experts and the public at large, both within Europe and outside. There is no doubt that the emphasis, currently put on public acceptance, will have an impact on both the contents and the organisation of future Community research, in particular, in the nuclear fission area.

As a consequence and in line with the concept of European Research Area (ERA), which lies at the heart of the next framework programme (next framework programme 2002-2006), Euratom research will be "decentralised" and will count a new group of stakeholders, namely: policy makers and opinion leaders. Their priorities are not necessarily of a purely technical nature, as it is the case of the traditional stakeholders discussed in this paper (i.e. mainly: the regulatory bodies, the utilities and the associated services, the vendors and the designers as well as the research organisations themselves). The new (additional) priorities are, for example: human and environmental protection, risk management and communication, etc. As a result, Community research will encompass new dimensions, e.g.: it should meet science and technology needs arising from the implementation of other Community policies (e.g. safety of citizens in its various aspects) and it should ensure the coherence of Europe's contribution to international efforts in support of the EU's foreign policies. In general, the following instruments will be proposed: networks of excellence; integrated projects; and the participation of the EU in programmes carried out jointly by several Member States. In addition, to help structuring the ERA, special emphasis will be put on the following activities: increased funding for human resources and researcher mobility; sharing of research infrastructures, including broadband communication infrastructures; efforts on science/society issues; and innovations of particular interest to the knowledge-driven society. More information about the ERA concept can be found in Communication COM(2000)612, entitled " Making a reality of the European Research Area : Guidelines for EU research activities (2002-2006)" (see http://europa.eu.int/comm/research/area.html).

There are no doubts that Community research in nuclear fission will continue to contribute to offer a response to some of the main concerns raised by all stakeholders and by the European citizens at large. The task of identifying the new research needs, arising from the present "changing world", and of programming international research to address the new challenges will require more than ever the clear engagement of all actors.

"Helping exploit the full potential of nuclear energy in a sustainable manner", which is the main aim of the current Euratom FP-5, is quite a challenge for now and will remain so in the future. To meet this challenge in the particular field of nuclear fission and radiation protection for future framework programme activities, the main actors sharing this aim are invited to build up networks of excellence and integrated projects, in co-operation with the Commission services, bringing together governmental and/or industrial resources with a view to solving problems of mutual interest, thereby making a reality of the European Research Area.