NUCLEAR SAFETY RESEARCH IN OECD COUNTRIES

Summary Report of Major Facilities and Programmes at Risk

Nuclear Energy Agency
Organisation for Economic Co-operation and Development

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

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NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consists of 27 OECD Member countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Republic of Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities also takes part in the work of the Agency.

The mission of the NEA is:

- to assist its Member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

FOREWORD

In 1996, the Senior Group of Experts on Nuclear Safety Research Capabilities and Facilities (SESAR/CAF), which was investigating the ability of OECD Member countries to sustain an adequate level of research, identified a number of facilities and programmes that were important for continuing research needed by the safety community during the coming decade. It also pointed out that many of these facilities and programmes were facing increasing budgetary constraints, and that some would cease to be supported at the national level in the near or medium-term future. Some of the facilities were of interest to more than one country. It therefore seemed logical to investigate the possibility of operating the facilities in an international context, in order to share the costs and the expertise, and to promote quicker and deeper international consensus on safety issues.

It was in this context that in 1997 the NEA Committee on the Safety of Nuclear Installations (CSNI) decided to set up a Senior Group of Experts on Nuclear Safety Research Facilities and Programmes (SESAR/FAP).The new Senior Group of Experts was asked to identify facilities of potential interest for present or future international collaboration, to make specific recommendations regarding facilities, research programmes, and joint projects, and to discuss other possible forms of international collaboration. For efficiency, the group was restricted to the countries running the widest and most advanced research programmes.

This work was a continuation of the work performed over the period 1992-1997 by the CSNI Senior Group of Experts on Safety Research (SESAR) which had issued three reports: the first one entitled *Nuclear Safety Research in OECD Countries* reviewing the research being carried out and setting down views on likely future requirements and priorities; the second one entitled *Nuclear Safety Research in OECD Countries: Areas of Agreement, Areas for Further Action, Increasing Need for Collaboration* addressing the future direction of nuclear safety research and international collaboration in the field; and the third one entitled *Nuclear Safety Research in OECD Countries: Capabilities and Facilities* discussing existing and planned capabilities and experimental facilities to fulfil the needs identified in the two previous publications.

This report summarises SESAR/FAP’s main findings and its recommendations to the CSNI. The full report has been published under the title *Nuclear Safety Research in OECD Countries: Major Facilities and Programmes at Risk.*

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SUMMARY

1. Background

The NEA Committee on the Safety of Nuclear Installations (CSNI) has a central role in providing OECD Member countries with authoritative advice on matters relating to nuclear safety. Because of this pivotal position and having available input from the most senior safety experts from the Member countries, it has been involved with and been concerned about the maintenance of essential research capabilities and facilities[1] for some years. In particular, it has noted the decline in available resources in many Member countries and the inevitable piecemeal loss of physical and human resources. In some Member countries this has been exacerbated by economic and structural changes. Since its aims include engendering international collaboration and the identification of areas of agreement and areas for future action, it undertook some time ago to gather information, analyse it and develop an international strategy for the efficient husbanding of essential nuclear safety research. The first work was commissioned in 1992, when a Senior Group of Experts on Safety Research (SESAR) was set up to review research being carried out and draw conclusions on likely future requirements and priorities. Its work was reported in the document "Nuclear Safety Research in OECD Countries".[2] A follow-on report was also commissioned which took the arguments further. It was published in the document "Nuclear Safety Research in OECD Countries: Areas of Agreement, Areas for Further Action, Increasing Need for Collaboration". The result of these studies was to raise a concern in the CSNI about the ability of Member countries to sustain an adequate level of safety research capability individually, and potentially collectively, even though there was an international consensus in the majority of technical areas on research needs and objectives. This concern extended from the loss of important experimental facilities and the failure to replace them, to the loss of critical competencies and hence threatened to undermine the ability to adequately regulate and support operating reactors and in the development of new designs. Therefore, in November 1995, the CSNI decided to set up another SESAR, this time to focus more specifically on research capabilities and facilities (SESAR/CAF). The results of this activity led to a wide-ranging review of available capabilities and facilities in the document "Nuclear Safety Research in OECD Countries: Capabilities and Facilities". This was presented to the CSNI in December 1997. The report contains a very large amount of information on capabilities and facilities in Member countries, although it is not claimed to be exhaustive. It provides an overview of the SESAR's projections for both the short and near term (less than 5 years) and long term (more than 5 years) time scales. It also contained specific recommendations to the CSNI for future action. In summary these were:

- That the CSNI take a proactive role in organising and implementing co-operative projects to provide key safety related facilities in the future.

1. The terms capability and facility are used in this report to cover, respectively, "the ability to perform a given task or to fulfil a given requirement; it implies a combination of expertise and access to specialised equipment" and "a semi-permanent installation, generally larger than bench scale; this may also include analytical equipment which has been made especially for a given type of study".

2. Nuclear Safety Research in OECD Countries, OECD, 1994.

- That the CSNI act as a forum at which facilities threatened by closure are identified and any possible international support programmes initiated.
- That the CSNI continue to monitor the situation with input from its Working Groups and receive advice from a small group of suitably qualified experts able to encourage co-operative actions in the light of evolving needs.
- That the CSNI seek a solution to the continuing problems arising out of commercial and other sensitivities and intellectual property rights.

As a direct result of this, the CSNI took the view that further and more specific action was justified in order to address this concern which is perceived as serious for the Industry and the Regulators, and which is getting worse. It decided, therefore, to continue the work of the SESAR, but with very significant changes to its mandate. The main tasks – terms of reference – assigned to the group may be summarised as:

- To identify key facilities potentially interesting for present or future international co-operation (whether this has been proposed or not by the host country).
- To make specific recommendations regarding facilities and research programmes, joint projects, etc., including, if necessary, recommendations regarding new facilities.
- To consider, where appropriate, other forms of international co-operation (e.g. data banks, exchange or sharing of experts, the establishment of "Centres of Excellence", joint development of computer codes, etc.).
- To utilise the information from the current position of Facilities and Programmes (FAPs) to give a view on future issues of strategic importance, and to make recommendations accordingly.
- To present an annual report to the CSNI.

In summary, the SESAR/FAP group was set up by the CSNI to address the immanent loss of Facilities and Programmes which may be considered to be at risk and are crucial to nuclear safety research, and to recommend actions required. The overall goal was "to ensure timely CSNI action is taken, as needed, so that an infrastructure of safety research facilities and programmes is maintained that assures the safe generation of electricity via nuclear power now and in the future."

In this, the setting up of the group could be seen as a response to the recommendations of the previous work, especially in the need for a much more proactive mode of operation; it moved the debate ahead by suggesting practical solutions. Also, the terms of reference recognised that there is an evolving situation and that "snapshots" of the current position (or at least the current position when the data was gathered) are inadequate in the dynamic situation pertaining today. This all reflects the view that the heightened importance of optimal international research programmes requires a more formal and focused approach on the part of the CSN.[3]

It is the dynamic nature of the situation that has brought into sharper focus the need for a more structured approach to achieving a strategy for international collaboration. The process which has been adopted in this work in order to achieve that which is discussed in Section 3 of this introduction. We begin by highlighting some of the key events and changes which are affecting

3. We note that the recently initiated CSNI Programme Review Group will carry this forward as part of its terms of reference.

current decision making in the nuclear context and hence directly impact on the issues driving the need to improve collaboration in the safety research area.

As mentioned above, the group's work is based on a number of previous activities which have been reported in SESAR documents.[4] This means that it benefits from this experience and its recommendations should be seen in the context of an analysis of the situation that is continually being refined. Because of the rapidly changing situation, **the report was "frozen" in December 1999**. Some few updates have been made, but none of the principal recommendations have been compromised. During 2000, the final draft of the report was issued, for comments, to a wide audience, including other CSNI and NEA expert groups, industry, laboratories, and government agencies.

In addition to these objectives one of the critical requirements for future planning is the establishment of minimum programme needs to help draw a benchmark of the necessary future activity and thereby give the CSNI a baseline against which to judge requirements. Such a set of minimum programme needs has been introduced and is discussed in detail in the individual chapters of the full report. We believe that this is a potentially important contribution from the group and that it should be used by others. Minimum programme needs do not in themselves identify Facilities and Programmes at risk, but rather would expose any which are and would still be needed to fulfil the minimum programme requirements.

1.1 Definition of "Centres of Excellence"

In this report we use the term "Centre of Excellence" rather loosely. Such centres have proved successful in the past, for example the Halden Reactor Project, PHEBUS-FP, and earlier the LOFT Project.

The basic constituents of a Centre of Excellence as defined for this work are as follows:

"Joint undertakings and international research programmes centred around internationally recognised expert teams operating a major facility which participating countries have agreed forms an international resource which they will jointly support for a reasonable period

or

internationally recognised research programmes focused on major topics which participating countries use as a means of maintaining their capability in that technical discipline,

or

a combination of these two".

We note that the usual model for a Centre of Excellence would be a team of internationally recognised experts centred upon a major experimental facility. However, we would also include focused analytical/theoretical teams and, increasingly on, "virtual" Centres of Excellence where members are not usually co-located, but communicate via modern telecommunications.

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4. Nuclear Safety Research in OECD Countries, OECD, 1994; Nuclear Safety Research in OECD Countries: Areas of Agreement, Areas for Further Action, Increasing Need for Collaboration; OECD, 1996; Nuclear Safety Research in OECD Countries: Capabilities and Facilities, OECD, 1997.

Under some conditions, networks of experts and facilities operating in a co-ordinated manner to investigate focused problems can be considered to form a Centre of Excellence. An example of such a Centre of Excellence network was the PISC (NEA Programme for the Inspection of Steel Components). Similarly, under appropriate conditions, data banks and the associated expertise required to maintain them can also be considered Centres of Excellence. These conditions include high quality advanced work as well as focused topics and an internationally supported strategic plan with well-defined long-term objectives.

We recognise the practical difficulties with funding (especially continuity of funding), mobility of research workers, international recognition of academic qualifications and, of course, the questions of security of national strategic needs.

It is worth noting that similar discussions are underway in other international organisations, in particular the European Commission in the framework of the Communication on European Research Area (ERA). This is proposing a number of objectives of common interest, such as mobility of researchers, opening up of national programmes and networking of Centres of Excellence in addition to measures more specific to the European Union countries.

2. Context

Since the establishment of the previous study in 1995, and certainly since the first work was initiated in 1992, there have been a number of key changes to the milieu in which the nuclear industry in general and nuclear safety research in particular finds itself. These affect the basic assumptions on which the "foresight" process for determining the future needs of capabilities and facilities depends. The assumptions used in the previous work were rather simple, i.e.:

- plants currently operating will seek life extension and some will seek uprating;
- new designs will continue to be developed; and
- operational problems will continue to occur.

In fact, it is now of course clear that the situation is more complex than this and that a number of sometimes conflicting pressures must be taken into consideration. Forecasting under these conditions is notoriously difficult, especially for the longer term. Nevertheless, difficult or not, it is essential to use the best information available and the judgement of experts since the alternative of no strategic planning is not acceptable. All decision making is done under uncertainty and it is our aim to reduce the associated risks by bringing together information and expert judgement to give the best possible advice. Clearly, focussing on shorter, rather than longer-term developments will give a better chance of success. Nevertheless, one of the key challenges facing the group is to rationalise the short-term requirements against the current best estimates of the medium and long-term trends.

There are many pressures on the Nuclear Industry today. In principle they are well known, i.e. economic, environmental and socio-political. However, the balance between positive and negative influences changes, as do the time scales over which the changes occur. In addition to long-term factors such as the need for action over global warming, there are more immediate factors that have an important bearing on the present context of nuclear power. Not all of them apply to all Member countries, but they are certainly having very significant effects in some. Many of these are discussed at some length in the introduction to a 1998 CNRA (Committee on Nuclear Regulatory Activities) report on "New Future Nuclear Regulatory Challenges"[5] and are not repeated here.

In the field of nuclear power safety, OECD Member countries' government agencies have broadly similar responsibilities. In several Member countries, the funding levels of national Government safety research programmes have been reduced over recent years, and increased reliance placed on private companies to maintain an adequate level of safety research. Care is needed to ensure that this does not have an adverse impact on the ability of government agencies to fulfil their safety responsibilities, especially since the reduction in Government direct or imposed funding in this area may not have been offset by concomitant increases from the Industry. The CSNI has expressed concern that dwindling budgets and support as well as stagnant programmes may lead to the untimely shut down of large facilities and the breaking up of experienced research teams with the consequent loss of competence and the reduced capability to deal quickly and efficiently with future safety problems. In addition, research and educational programmes play a key role in attracting, training and retaining new talent and expertise in nuclear safety.

It is understandable that the Industry's response to the situation outlined above has been to reform and regroup to give itself the best chance of survival. The supply side, i.e. plant constructors and the infrastructure of supporting companies has had to switch from new projects to services and upgrading. Their requirements for innovative research have, therefore changed considerably. The nuclear generating utilities likewise have had to reconsider all aspects of their operations in response to commercial pressures and increased competition.

This indicates how volatile the "context" of the Nuclear Industry is today. Of course not all of the most difficult situations apply to all Member countries and they are by no means homogeneous in their own "national context". However, in attempting to derive international actions, the overall situation has to be taken into account. Planning in this environment is clearly complex and difficult. However, it is possible to extract the key technical issues facing the industry in the light of these conditions. These reflect the basic driving forces now acting on the nuclear industry i.e.:

- very few new plants will be built soon;
- asset protection and life management;
- end of life and waste disposal; and
- general economic pressures, including deregulation, ownership consolidation and particularly in the USA the move towards risk informed regulation.

From these concerns, we believe that the following are the key technical issues that underpin the needs of both Industry and regulators in the current context:

1. Plant life management, including:

- ageing of components, systems and structures;
- ageing of analytical tools and documentation;
- application of modern standards to old plant (and the ageing of the standards themselves in the light of new developments);

5. New Future Nuclear Regulatory Challenges, OECD 1998.

- life extension; and
- backfitting and upgrading.

2. Reduction in operating margins, including:

- fine tuning plant for greater efficiency, for example by power upgrading as has been done in Finland and Sweden;
- extending fuel burn up;
- responding to the economic pressures of deregulation; and
- using risk-informed regulation through expanded and improved applications of PSA.

3. Severe Accidents, including:

- the continuing need to develop practical and robust severe accident management schemes;
- the optimisation of design solutions for next generation plant; and
- the improvement of the capability to quantify accident progression and radioactive source terms.

Therefore, our working assumptions are that the key issues summarised above will provide the main driving forces for the research which is required, and that the dynamic period of change will continue, making it necessary to focus planning primarily on long (up to 10 years) and short-term (up to five years) issues.

In conclusion, we believe that the dynamic change currently being experienced by all parts of the Industry world-wide and the potentially conflicting demands for securing the necessary safety research demands a proactive, “managed” approach to the future provision of nuclear safety research capabilities and facilities. It is in this “context” that this work has been done and which has led to the definition of the objectives discussed below.

3. Objectives

The above descriptions of the tasks provide the outline of the objectives of this work. We note in particular that the overriding objective is to identify areas for collaboration that would give a higher efficiency at the international level. We might add that this collaboration is seen as providing a bridge to cover the expected complex period of evolution and change currently being experienced. More specifically we can identify a number of areas where co-operation would be beneficial. These are:

- to resolve specific current safety issues;
- to safeguard key facilities through collaborative experimental programmes;
- to sustain key expertise through combined research and applications programmes;

- to provide training and education in relevant nuclear engineering and other physical sciences for the refreshment of the nuclear safety research community;
- to develop and maintain databases of relevant information both from previous research output and in underlying materials properties; and
- to determine the need, justification and scope of new facilities which would lend themselves to collaboration from the outset.

A crucial element in all of these is to provide recommendations on the practicality of the suggestions, including an estimate of costs, both capital and ongoing.

4. Method of working, scope and organisation of the full report

The method of working follows that utilised in previous SESAR reports. Senior experts from Member Countries took responsibility for specific technical areas[6] and have written the individual chapters of the full report. Once the chapters were completed, a consensus on recommendations was then obtained from the whole group. In addition a peer review was also undertaken. In this particular activity there were no areas where consensus recommendations could not be reached and so there is no need for any minority reports. The detailed recommendations are given in the chapters of the full report whilst for this summary they have been paraphrased as necessary.

4.1 Criteria

Because this work intends to provide practical, and as far as possible quantitative advice, it is important that its recommendations are transparent and that the criteria underpinning them are well established. Whilst this will always have a strong element of expert judgement, the group has used the following overriding criteria in its work:

- Is there a major short-term safety issue and is it relevant in the overall context of future needs?

  and

- Is the capability or facility currently under threat?

These reflect the overall objectives of the group, but are not specific enough to define practical projects based on combinations of quantitative data and expert judgement. We have therefore agreed the following set of more detailed criteria against which we have judged the suitability of projects for international collaboration and “screened” our recommendations:

- *Risk importance*: this may be quantitative, being derived from either PSAs or on system based assessments, or it may be judgement, based on the identification of key issues in uncertainty reduction.
- *Closure*: it is essential that the international community agree that the technical issue addressed by the facility is still open.

6. The technical areas follow the same definition as in previous SESAR documents: see Section 4.2 of this report.

- *Uniqueness to the nuclear industry*: resources should be focussed on capabilities and facilities where there are no other front line industrial or research interests. Examples of uniqueness are: core melt progression experiments, specific thermal-hydraulic test rigs, test reactors and critical facilities and hot cells. Examples on non-uniqueness are: instrumentation, heat transfer, basic Computational Fluid Dynamics (CFD) developments and some aspects of human factors.
- *Applicability to a broad range of conditions*: capabilities and facilities need to be flexible and able to accommodate different users needs. It should also be relevant to scaling criteria, if the technical demands of the subject area require it.
- *Responsibility*: the ownership of the capability (either Government or Industry) must be clearly established and there should ideally be clear commitment from the owner to support any future international programme in their facility. However, for specific and important FAPs, the group will raise the possibility of an international action even if the host country is not initially supportive.
- *Credibility*: the management provisions must be acceptable against modern standards, e.g. including proper financial, quality and technical control.
- *Size*: in order to limit the number of possible projects, an initial cut off point will be US$1 million or more.

The criteria have been applied using the so-called “essential requirement templates” (abbreviated to “templates”), which have been incorporated into each chapter of the full report. The “questions” in this mechanism are summarised in the following generic template. The aim here has been to be as transparent as possible in exposing how the group reached its recommendations. We should note again that the minimum programme needs act as a baseline against which to judge requirements. They do not in themselves identify facilities and capabilities at risk.

The generic template in the following figure summarises the questions to which each technical area has been subjected in the evaluation processes and, according to the different positions in the template, the conditions that must be fulfilled to support a recommendation for further action. Those issues which satisfy the criteria and secure a “yes” response in the “need for future CSNI action” column of the table are then expanded upon in the list of recommendations. This approach was applied to approximately 97 technical areas and issues.[7] It therefore represents a comprehensive coverage of a large number of relevant issues, but is, inevitably, not exhaustive.

The SESAR/FAP Group has considered what the meaning of “essential” is in this context and has used its judgement to form the basis for its recommendations by building upon its experience with respect to what type of information is necessary to resolve a safety issue. Accordingly, in the absence of existing national or international programmes, SESAR/FAP has developed a limited number of recommendations to maintain or enhance co-operative effort, or to launch new programmes where it has been judged that essential needs are in danger of being lost. We have tried, through our use of these criteria to be as transparent as possible in giving a rationale for our decision for these recommendations.

7. As defined in the templates in the individual chapters.

4.2 Scope

In terms of reactor types, the work continued to be limited primarily to Western LWRs (PWRs and BWRs), and to PHWRs. Where relevant, this was extended to VVER reactors.

The technical areas covered are as in previous SESAR documents, and for continuity we have retained the categories used before. These are:

- thermal-hydraulics;
- fuel and reactor physics;
- severe accidents;
- human factors;
- plant control and monitoring;
- integrity of plant and structures;
- seismic analysis;
- risk assessment; and
- fire risk assessment.

On the Risk Assessment topics we note that it is very much a “compendium subject” which draws on input from many other areas. Nevertheless, the basic methods and issues (e.g. the treatment of uncertainties, common cause failures, completeness and the inclusion of human factors) are separate, well defined technical issues in their own right. In the previous report this heading included both fires and seismic events. These are in fact distinct topics in their own right and so this time they are included as separate categories.

Table.1 **Generic template for determining essential facility and programme needs and need for CSNI action in specific technical areas**

Chapter	Future needs & challenges	Safety significance	Sufficient knowledge available?	FAP essential?	CSNI action needed?
Technical areas	List the technical area or phenomenon still unre-solved or of high uncer-tainty. Source of issue could be from: • SESAR reports; • operating experience; • industry initiative • other.	Rank the safety signifi-cance of the technical issue based upon deter-ministic analysis, PSA information and/or qual-itative judgement. This is expressed in the simple categorisation as being High, Medium or Low.	Is there already sufficient knowledge to resolve the issue? This is a simple yes or no based on expert judgement.	Is a facility or pro-gramme needed to resolve the issue?	Criteria for inclusion[8] as a recommendation. *Overriding Criteria:* • Is there a major short-term safety issue, and is it relevant in the overall context of future needs? and • Is the FAP currently under threat? *Additional Criteria:* • Is the project risk important? • Is the technical area still open? • Is the FAP unique to the nuclear industry? • Is the FAP flexible?

8. In order to emphasise that these criteria were used to filter our recommendations, they are repeated before the appropriate sections of each chapter.

The geographical coverage was, of course, extended to all the Member countries,[9] but in addition includes capabilities and facilities in the Russian Federation. The rationale for the latter is the availability of large scale, relevant facilities that are potentially able to make an economically attractive, technically sound and sometimes unique contribution to reactor safety research. It has the additional value of providing a means of safeguarding some of the key nuclear capabilities and facilities in that country, an action identified as necessary in the continuing support from Western countries to the improvement of nuclear safety in the New Independent States (NIS) of the Former Soviet Union. At present the coverage in the Russian Federation is not comprehensive and it is the hope of the group to see this expanded in the next phases of the work.

The time frames are also as in the previous report, with short term meaning less than five years and longer term more than five years. As we have said above, we would expect priority to be given to those activities pertaining to the short term, but with the added requirement that short-term priorities are set against longer-term considerations. Also, because this is now a rolling programme, issues may arise as they come into its planning horizon.

4.3 Summary of the method of working

The general approach adopted in this work may be summarised as follows:

- To build on the areas categorised and reviewed in the earlier SESAR/CAF report, as updated in the technical chapters here of the full report.
- To define a set of criteria for judging the suitability of projects for international collaboration.
- To highlight particular concerns in the short term established in the broader context of longer-term trends.
- To obtain technical reviews and advice from experts via specific questions generated out of the SESAR/FAP's considerations and from special *ad hoc* specialists' meetings concerning potential programme planning for capabilities and facilities.
- To develop a set of practical recommendations for the CSNI.

5. Principal recommendations

The SESAR/FAP Group has arranged its recommendations into two categories:

1) Strategic Recommendations (i.e. those that address broad crosscutting or policy matters), and
2) Specific Recommendations (i.e. those that cover specific activities). These are discussed in turn below.

9. We have included in this category those Central and Eastern European Countries (CEEC) currently enjoying membership of the NEA.

5.1 *Strategic recommendations*

- That immediate consideration is given to setting up Centres of Excellence, on an international basis, as the key focal points for the safeguarding of key Facilities and Capabilities in the future. Examples of these are given for specific technical areas in the following recommendations and in the chapters of the full report. However, there is now an urgent need for practical steps to be taken to begin to identify potential areas and to establish what must be done to create viable Centres.
- That the future role of the CSNI Working Groups in this context should be to provide points of focus for the specific technical areas which can give easy access to necessary up to date technical information. This should be set up so that such information can be made readily available, and not only be linked to annual meetings.
- It is vital to find ways of drawing the Industry into this future activity. The means for this may well be different in different technical areas, but a feeling of "ownership" by the Industry is necessary.
- With the closer ties between the OECD and New Independent States (NIS) of the Former Soviet Union and Central and Eastern European Countries CEEC), it is now timely and important to perform a full review of the facilities and capabilities potentially available in those countries.
- It is necessary to develop and factor into CSNI activities a strategic vision of the needs of the research community and Industry, based upon information available from, for example the CNRA work on new future nuclear regulatory challenges,[10] the recent NDC (NEA Committee for Technical and Economic Studies on Nuclear Energy Development and Fuel Cycle) study on nuclear education and training[11] and the recent CNRA Workshop on Assuring Nuclear Safety Competence into the 21st Century.[12]
- The CSNI should have a strategy to ensure that recommendations and actions remain current.

5.2 *Recommendations for immediate action on facilities and programmes*

The following recommendations have been taken from the individual chapters of the full report as being the Senior Group's view of the highest priority and those most deserving of action. Not every chapter is represented here, just those leading to the highest priority actions. The detailed justification for these recommendations (using the template already described) is given in the individual chapters of the full report. Near-term and longer-term actions are presented. Near term refers to the next one to five years and longer term, more than five years.

10. New Future Nuclear Regulatory Challenges, OECD, 1998.
11. Nuclear Education and Training: Cause for Concern?, OECD, 2000.
12. Assuring Nuclear Safety Competence into the 21st Century, OECD, 2000

(a) Near-term actions on facilities and programmes

We previously recommended action by CSNI to prevent the near-term loss of key thermal-hydraulic and severe accident facilities. These recommendations are in direct response to our first two terms of reference.

Thermal-hydraulic FAPs

Three major Thermal-hydraulic facilities, in danger of being closed in the near term (1-2 years), are recommended for international collaborative programmes. In priority order, they are PANDA, PKL and SPES.

We continue to believe that it should be the aim of the research/industry community to maintain LWR and PHWR thermal-hydraulic facilities, both because of the potential need for future confirmatory experiments, and to support code development and provide educational opportunities – that is to underpin the future of **capabilities** in this area. Therefore, SESAR/FAP also recommends that the CSNI monitor the status of other key thermal-hydraulic facilities, including APEX and PUMA (in the USA), RD-14M (Canada) and LSTF (Japan), to ensure that they (or successor facilities, as appropriate) remain available to Member organisations.

Severe accident FAPs

The situation on FAPs in the severe accident area is moving quickly. During the period when this report was being prepared, the FARO facility at the JRC Ispra has been announced for closure, and most recently the possible closure of the ALPHA facility in Japan, throwing the whole area of Fuel/Coolant Interactions (FCIs) and its supporting FAPs into a difficult position. Events have overtaken the Senior Group, clearly illustrating the need to continuously monitor and respond to events. The Group's recommendation is based on our understanding of the current position.

As a necessary response to the current situation, the Group recommended and the CSNI approved a meeting of technical experts[13] in the area of Fuel/Coolant Interaction *(*FCI) and Core Debris behaviour. The objectives of such a meeting would be:

- To consider the impact of the loss of the FARO facility and its associated expertise. The loss of FARO is serious as this was a unique facility in both in and ex-vessel FCI and its closure leaves key safety issues unresolved.[14] This now leaves the field with few facilities (principally ALPHA – but note the warning above – and MAGICO) and, if they are to be safeguarded, the meeting must recommend suitable actions.
- To consider the programmatic needs of the area and the availability of FAPs and other resources required to provide them.

13. We note that by the time of finalisation of this document, a meeting on Core Debris Behaviour had taken place. A meeting on FCI was under consideration.

14. By unresolved, we mean in this context that remaining uncertainties in the physics process make it impossible to either rule out the mechanism as a threat (albeit of very low probability), or be able to calculate with sufficient accuracy the implications if such an event were to occur.

- To address the case for a future strategy for an international Centre of Excellence in FCI, to consider its location and potential resource needs.
- To consider the programmatic needs and action necessary to obtain experimental results in debris coolability needed in order to be able to understand in-vessel and ex-vessel debris coolability and the viability of core catchers.

These considerations should include proposals for the RASPLAV continuation and, on the basis of a host country proposal, the MACE facility should be considered for a co-operative OECD project.

The SESAR/FAP group also recommends that a Data Bank for Fuel/Coolant Interaction and Debris Coolability be established.

In addition, many national programmes on iodine chemistry and fission product behaviour under accident conditions have been terminated or dramatically reduced over the past several years, with the prospect of further decreases in the near term. To ensure that adequate expertise and capabilities remain available to the international nuclear community in this area of reactor safety, and to facilitate international collaboration among Members.

SESAR/FAP recommends that a Centre of Excellence on Iodine Chemistry and Fission Product Behaviour be established immediately.

Integrity of equipment and structures FAPs

There exists a substantial quantity of data and information on ageing, but it resides in different organisations, different countries and in diverse formats. It is necessary to collect this data and to make it consistent and readily available. Most facilities for materials testing, including standard and medium scale testing machines, hot cells and EAC (Environmentally Assisted Cracking) rigs, exist in Member countries and there is no need to identify central facilities that might be operated co-operatively. For critical needs in the area of structural integrity assessment (ageing of nuclear power plant components with safety significance), information and knowledge should be available. The highest priority recommendations are given below:

- To co-ordinate and develop an overall international programme in materials ageing issues relevant to the nuclear industry, especially those with safety implications.
- To begin a study of the development of an international Data Bank and Centre of Excellence for materials ageing data and analytical tools with the aim of attracting Industry and Government Agency participation. The NEA Nuclear Data Bank may be seen as a model, but the Group would not wish to limit any future Centre of Excellence activities. This recommendation directly addressed our third term of reference as it is strategic in nature.

This is revisited below in our recommendations concerning actions for the CSNI Working Groups and the generation of future technical advice. Other near-term recommendations for action were also developed. These are summarised in the following table and discussed further in each chapter of the full report.

(b) Longer-term actions on facilities and programmes

Longer-term actions at this time involve monitoring facility status and ensuring certain key programmes are maintained. These are summarised along with the near-term actions in the following table and discussed in detail in the individual chapters of the full report. They also include specific requests to the CSNI Working Groups for action. We have also included in the table all of the immediate actions discussed above.

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The recommendations are summarised in Annex, in the form of extracts from the full report.

Table 2. **Summary of SESAR/FAP recommendations (for immediate, near-term and longer-term action)**

Area	Immediate	Near term	Longer term
Chapter 2: **Thermal-Hydraulics**	PANDA, PKL and SPES should be considered for a co-operative OECD project; needed to support code development and provide educational opportunity.	Experts to: • define experimental needs; • co-ordinate T/H research programmes; • collect, maintain and service key experimental data. Monitor the status of the APEX and PUMA facilities in the USA, RD-14M in Canada and LSTF in Japan.	Evaluate feasibility of reduction to one major facility for each reactor type world-wide.
Chapter 3: **Fuel and Reactor Physics** Chapter 3.1: Fuels		Experts to: • define experimental needs; • promote exchange of information about codes through user groups, and; • promote industry involvement, inclu-ding cost sharing.	Monitor hot cell and reactor availability for RIA and LOCA experiments for high burnup fuels.

Table 2 (cont'd) – **Summary of SESAR/FAP recommendations (for immediate, near-term and longer-term action)**

Area	Immediate	Near term	Longer term
Chapter 3: **Fuel and Reactor Physics** Chapter 3.2: Physics		CSNI Working Group to: • strengthen ties to NSC (NEA Nuclear Science Committee) work on physics for future systems.	Monitor facility availability for measurement of nuclear data and integral reactor physics parameters for modern fuel and core designs.
Chapter 4: **Severe Accidents** Chapter 4.1: In-vessel Chapter 4.2: Ex-vessel	• Conduct a meeting or meetings of experts to consider the situation concerning ex-vessel FCI in the absence of FARO and the needs for experimental data in debris coolability. • On basis of a host country proposal, MACE should be considered by a group of specialists for a co-operative OECD project. • Include proposals for the RASPLAV continuation project.	Experts to: • develop database; • assess impact of upcoming losses of expertise; and • consider the needs for further data on core catchers.	• SOAR on Severe Accident issue resolution and research needs. • Generation of a database on debris coolability. • Consider the needs for further data on core catchers.

Table 2 (cont'd) – **Summary of SESAR/FAP recommendations (for immediate, near-term and longer-term action)**

Area	Immediate	Near term	Longer term
Chapter 4: **Severe Accidents** Chapter 4.3: Fission Products	Establish a Centre of Excellence in Iodine Chemistry and Fission Product Behaviour.	Monitor status of iodine and fission product behaviour facilities (associated with FP release, transport and containment phenomena)	• Monitor status of facilities capable of performing fission product release experiments with active, irradiated materials. • Establish benchmark exercise on iodine and fission product behaviour.
Chapter 5: **Human Factors**		CSNI Working Group to: • define research needs for human performance data collection and modelling; • pursue the participation of industry, including non-nuclear industry; and • monitor and update human factor research strategy.	• Maintain the Halden Reactor Project as a Centre of Excellence. • Promote availability of HF expertise. • Monitor the effects of Utility restructuring on management and organisational performance research needs.

Table 2 (cont'd) – **Summary of SESAR/FAP recommendations (for immediate, near-term and longer-term action)**

Area	Immediate	Near term	Longer term
Chapter 6: **Plant Monitoring & Control**		CSNI Working Group to: • monitor and communicate to Members I&C developments in non-nuclear industries on safety, control and monitoring systems; • monitor developments on qualification of non-nuclear software for possible nuclear application; encourage Member collaboration on software qualification for safety systems; • monitor developments on introducing software-based monitoring and decision-aid tools into control rooms; and • define research needs to ensure safety of replacements of ageing I&C.	• Maintain I&C initiatives with Halden Reactor Project. • Strengthen ties with NSC work on software.

Table 2 (cont'd) – **Summary of SESAR/FAP recommendations (for immediate, near-term and longer-term action)**

Area	Immediate	Near term	Longer term
Chapter 7: **Integrity of Equipment and Structures**	Establish a Centre of Excellence in materials ageing (data, methods, and conditions for life management.)		Monitor hot cells for mechanical testing and material testing reactor availability.
Chapter 8: **Seismic**		CSNI Working Group to: • promote data exchange, including earthquake observation data.	Monitor status and identify opportunities for co-operative programmes using large shaking tables. Establish a "virtual" Centre of Excellence for test data and analysis results.
Chapter 9: **Risk Assessment**		CSNI Working Group to: • promote the sharing of methods, criteria and experience and strengths and limitations.	To pursue co-operative efforts to develop methods, standards, criteria, data and analyses.
Chapter 10: **Fire Risk Assessment**		CSNI Working Group to: • define experimental programme needs based upon fire PSA needs.	Experimental work should be done co-operatively.

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1998-2000

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Annex

SUMMARY OF RECOMMENDATIONS

Extracts from full report

THERMAL-HYDRAULICS

(*Extracts from Chapter 2 of the full report*)

2.3 Summary and recommendations

There is a real danger that Member countries will discontinue operation of existing large-scale facilities or code development efforts needed for the resolution of present safety issues and for maintaining competence in the future. In view of this situation, the following is recommended.

2.3.1 Facilities potentially interesting for international collaboration

Experimental programmes are needed to reduce uncertainties regarding phenomena, processes and system behaviour and extend the database for code validation of the currently used system codes and for possible future codes. Table 2.1 of the full report shows the most important of these facilities in relation to the research needs. Some of these facilities are potentially interesting for international collaboration. A variety of experimental facilities have to be kept in operation, because:

- each of these facilities has at least one important unique feature; loss of that feature cannot be compensated by other existing facilities;
- code validation strategy is based on a matrix covering a variety of phenomena, parameter ranges and scales that cannot be covered by a single facility; and
- large experimental facilities with their research environment are centres of competence; maintaining this competence at several locations is necessary.

While this report was written, important facilities came to the end of their programme (BETHSY, MARVIKEN). Most of the remaining programmes will be completed in the next two to five years, and the facilities are threatened by lack of financial support in the future. To maintain an adequate level of experimental research requires to keeping the majority of these facilities operating. A common OECD co-operative experimental programme could substantially support this goal.

2.3.3 Specific recommendations

Experimental research capabilities should be maintained almost at the present level. Member countries cannot rely on the survival of certain key facilities elsewhere.

Member countries operating major facilities should be encouraged to offer specific tests as contributions to the common programme. In return, they would have access to results obtained abroad. Being part of a consistent international programme should strengthen the facilities position in obtaining national or EC support.

Recommendation 2.1
Three major facilities have been identified that are threatened by closure in the next two years and that should be of primary concern to OECD Member countries. In priority order these facilities are:

- PANDA: flexible large-scale facility for 3D effects, multi-compartment containment behaviour and passive heat removal. Integral system behaviour investigations.
- PKL: 4 loop facility in 1:145 scale, hot and cold leg ECC with eight accumulators, for boron dilution accidents, accidents under shut-down conditions, and preventive accident management (AM) procedures.
- SPES: 3 loop full pressure integral facility for flow regimes and system behaviour of new design reactors, optimisation of EOP and AM procedures.

(BETHSY was deleted from the original list because it will no longer be available and the LSTF was not considered to be at risk when the list was drawn up)

It is recommended to establish an OECD co-operative experimental programme in thermal-hydraulics that addresses common research needs and makes use of these unique facilities.

The US experimental facilities APEX and PUMA are major contributors to the design certification of the advanced light water reactors. Similarly, Canada's RD-14M thermal hydraulics facility supports both current and advanced CANDU designs. Although not under immediate threat of closure, the availability of these facilities in the future should be of concern and monitored.

Recommendation 2.2
Monitor the status of APEX, PUMA and RD-14M to ensure their future availability (or timely replacement, as may be required to support future advanced reactor designs). This should apply equally to all facilities mentioned in Table 2.1.

2.3.4 Other needs for international collaboration

Best-estimate analyses are increasingly used in licensing. This entails the need for quantification of uncertainties. Several methodologies exist for this purpose but practical applications are few.

Recommendation 2.3
Harmonisation of the various methods for quantifying the uncertainties should be promoted by OECD/NEA. Because TH codes are validated using data from different scale facilities, extrapolation to full reactor scale requires a consistent approach.

Recognising the needs for improving calculational capabilities for present reactors and for modelling of phenomena in advanced reactors, USA, France and Germany are clarifying their positions towards a future code. NEA Member countries should develop a common position about needs for and desired features of a possible future code.

Recommendation 2.4
A co-ordinated approach to development and validation of future thermal-hydraulic codes should be promoted by OECD/NEA.

Data from past experimental programmes are being lost due to closure of the facility, retirement of specialists and the lack of funding for maintaining the data and the associated documentation in a form amenable to today's computer software. The necessary database for the validation of present and future computer codes is eroding. Once data from large-scale experiments is lost it will be impossible to recover it in the future.

Recommendation 2.5
Essential experimental data from previous programmes should be maintained for code validation. We recommend that the NEA Data Bank be made the focus for an international project to preserve this important data.

FUEL

(*Extracts from Chapter 3 of the full report*)

3.1.3 Summary and Recommendations

i) Facilities potentially interesting for international collaboration

The main area of concern identified as short-term needs is the establishment of a technical database on both UO_2 and MOX fuel behaviour at high burnup, particularly establishing the safety criteria for possible transients in current LWRs. In addition, specific requirements may emerge since the MOX fuel behaviour is dependent on fabrication procedure and Pu content.

As for long-term needs, design and utilisation of fuels will keep evolving for better economy, different fuel cycles or responding to different core design and operation of future reactors. In particular, the use of inert-matrix fuels, which may well be a workable technology, could require significant R&D effort.

The needs for fuel irradiation and in-pile testing for unusual events and for simulated accident conditions are not expected to decrease in the foreseeable future. Therefore, in order to meet these needs, research reactors such as CABRI, NSRR, HBWR and BR-2, and the hot cell facilities with the capabilities necessary for the maintenance and utilisation of the research reactors, should be maintained.

iii) Specific recommendations

Proprietary information on fuel design and utilisation often becomes a big obstacle to international co-operation. This often causes it to be restricted to bilateral and exclusive arrangements. More efforts need to be focused towards realising a clear definition of the common tasks, disclosure and easy access to the information, and active and general exchange of the output from the contributing organisations.

iv) Other possible forms of international collaboration

Some Member countries have been using MOX fuel in their reactors for a significant operational time period and have subsequently generated operational data. The NEA should try to develop international co-operative activities with vendors, utilities and research organisations to allow access to relevant information.

REACTOR PHYSICS

(*Extracts from Chapter 3 of the full report*)

3.2.3 Summary and recommendations

Several facilities have been dismantled during the last decade. Current facilities appear however to be adequate world-wide which should be able to respond to the needs of existing systems or for proposed advanced systems. However, phasing out additional facilities would lead to a shortage of expertise and lack of independent measurement and review capabilities. The NEA Nuclear Science Committee (NSC) promotes international collaboration through its different working parties to preserve in particular facilities designed to measure differential nuclear data (such as the GELINA Facility, IRMM, Geel, Belgium and the ORELA Facility, ORNL, Oak Ridge, US) as well as those used for measuring integral data of significance for various reactor types and those for obtaining data relevant to criticality studies.

Template 3.2.2 (in the full report) summarises the recommendation for the reactor physics issues. It is felt that no immediate action is needed assuming that the existing FAPs are maintained. In the longer term the status of the facilities should be monitored and, if there is a danger of loosing the capability to measure operational or basic nuclear data, action should be recommended.

The efforts of the NSC and its different working parties to promote and establish international collaborations in the general field of reactor physics should be pursued. Support from the CSNI is important in that respect.

SEVERE ACCIDENTS – IN-VESSEL

(*Extracts from Chapter 4 of the full report*)

4.1.3 Summary and recommendations

The attached table (in the full report) summarises the safety significance and sufficiency of knowledge discussed in Section 4.1.2. This table serves as a template that defines the baseline from which to judge whether or not a facility and/or programme is needed to resolve the issue and, based upon current facility and programme status, whether or not action by the CSNI is recommended. Given the current state of knowledge and facility and programme status, the following recommendations are made:

Core degradation and melt progression – the state of knowledge for LWRs is sufficient to address all the phenomena associated with high priority issues. In addition, work at the QUENCH facility and PHEBUS will provide experimental data for the foreseeable future to assess analytical tools. For PHWRs, additional information on CANDU core disassembly and degradation is required, but new programmes and facilities have been established by AECL to address CANDU-specific issues. Therefore, no action by the CSNI is recommended at this time.

Fuel/coolant interaction – additional model development and experimental data are needed to predict the occurrence and energy from FCI under low-pressure conditions. Although some facilities and programmes remain in progress, and a new large-scale programme in support of molten fuel-moderator interactions in PHWRs is being established in Canada, the loss of FARO nevertheless eliminates large-scale experimental data using LWR prototypic materials.

Recommendation 4.1.1

The CSNI should consider having a specialist meeting to review the specific modelling and experimental needs to complete development and validation of FCI analytical tools and recommend a programme, in the absence of FARO and KROTOS, to meet the needs. This programme should acknowledge and build upon ongoing work and make recommendations for CSNI action to fill in any gaps. Recommendations should be provided in time for consideration by the CSNI at their annual meeting in 2000. In addition, some consideration should be given to maintaining FCI data.

Debris interaction with lower RV head – additional work to understand corium stratification in the lower RV head and the cooling effects of in-vessel and ex-vessel water are needed for the assessment of new and existing designs. This information is important for assessing the success of accident management strategies. For PHWRs, additional information on CANDU core disassembly and degradation is required, but new programmes and facilities have been established by AECL to address CANDU-specific issues.

Recommendation 4.1.2

The CSNI should consider having a specialist meeting to review specific modelling and experimental needs and recommend a programme to meet these needs. This programme should acknowledge and build upon ongoing work, including the RASPLAV follow-on work, and make additional recommendations for CSNI action to fill in any gaps. Recommendations should be provided in time for consideration by the CSNI at their annual meeting in 2000.

SEVERE ACCIDENTS – EX-VESSEL

(*Extracts from Chapter 4 of the full report*)

4.2.6 Summary and recommendations

In the area of ex-vessel severe accidents, where the resolution process of safety issues as corium coolability, hydrogen control and containment integrity is still in progress, research remains particularly active and characterised by a high level of co-operation and association. This clearly depends not only on the fact that experiments are technologically complex and expensive and national budgets are facing progressive reductions, but also on the possibility of having access to facilities with unique characteristics, and, more generally, on the interest of extending the consensus on the validation approach to safety arguments.

The European Community, supporting through the Nuclear Safety Programmes many projects in this area, provided further opportunities for integrating research capabilities and for taking benefit of complementarities of experimental facilities. The situation is slightly changing in the Fifth Framework Programme, where severe accident research has been de-emphasised among the objectives of the area "Operational Safety of Existing Reactors". In this perspective, because of the lack of financial support, there is risk to lose, in the short term, other capabilities and facilities in this area.

The template for determining essential facility and programme needs and need for action by the CSNI illustrates this situation. In a large number of safety significant areas, research needs are adequately satisfied by existing facilities and programmes. Only in two cases the risk of losing unique facilities, putting in danger the resolution of safety significant issues, convinced the SESAR/FAP group to express the following recommendations requiring an action to be taken by the CSNI:

Recommendation 4.2.1 – Corium Debris Coolability
On the basis of a host country proposal, the MACE facility should be considered for a co-operative OECD project.

Recommendation 4.2.2 – FCI *(see also Recommendation 4.1.1)*
The CSNI should approve a Specialist Meeting with the objective of evaluating the impact of the loss of a unique facility like FARO on the resolution of key safety issues in the ex-vessel area (as well as in in-vessel). Actions should be recommended to safeguard other remaining facilities and to preserve experimental and analytical capabilities on FCI for the future needs including the feasibility of setting up a Centre of Excellence in this field.

Recommendation 4.2.3

Consideration should also be given to a proposal for the RASPLAV continuation programme, including ex-vessel core catcher studies.

For the facilities going to a final closure, it is finally recommended that a complete database of (at least) the most qualified experiments is maintained for further code validation processes, and that the most relevant technological solutions adopted for achieving the required simulation for facility instrumentation and for facility operation, remain documented.

SEVERE ACCIDENTS – FISSION PRODUCTS

(*Extracts from Chapter 4 of the full report*)

4.3.3 Summary and recommendations

The following Table 4.3 (in the full report) summarises the safety significance of the information discussed in Section 4.3.

It can be seen from the table that, in general, facilities and capabilities are available to meet the research needs identified in Section 4.3.1. Clearly the PHEBUS-FP facility and programme represents the major activity in the area, with significant contributions being provided by other programmes and facilities world-wide. Available results have already led to the shifting of iodine research priorities. While there are no major programmes addressing low volatility fission product release from core-concrete interactions, there is a good database from the ACE tests and this area is not considered a priority when compared with other issues (e.g. late-phase release). Similarly, the impact of hydrogen burns on fission product chemistry is considered of secondary importance compared with their effect on containment performance. Continuing efforts are being made to understand and model fission product behaviour in shutdown accidents, the impact of high fuel burnup on FP release and transport, and the short-term and long-term removal paths for aerosols in the containment. Attention should nevertheless be given to the risks associated with the closure of several important Canadian facilities: both the Blowdown Test Facility (BTF) and the Radioiodine Test Facility (RTF) have recently been closed, and the NRU reactor will likely be shutdown by 2005.

For future power plants, there is a clear trend towards a reduction in the possible releases in the case of accidents. The demonstration of this, even if it is made easier by special design features, requires an improved knowledge of all the significant phenomena involved in the source term determination, and the continuation of the research and expertise.

Many of the capabilities and facilities described above are unique to the nuclear industry. In the long term, PHEBUS-FP will be the only remaining in-pile facility and would be extremely expensive and time consuming to replace. Some of the other facilities e.g. for out of pile release studies, are smaller and less expensive. However, they provide an ability to meet emerging safety issues such as air ingress and the impact of using higher burn-up and MOX fuel and for low power and shut down conditions. Furthermore, the technological environment of specialised skills and equipment within which the smaller facilities exist can provide considerable flexibility allowing a rapid response to changes in research requirements.

To examine some important release phenomena such as the second and third items of the table more deeply than possible with present programmes, some specific installations or modifications of existing facilities will be needed, the VERCORS and VEGA facility are of special importance in order to answer to this need.

Perhaps even more important than the facilities themselves is the expertise residing in this area. Such expertise involves a variety of disciplines (e.g. reactor physics, materials science, mathematical modelling, chemistry and aerosol science) which has been built up over many years and is unique to the nuclear industry.

The fission product domain has benefited greatly in the past from international collaboration. This has been especially true of the experimental programmes. Some examples of this are:

- Marviken V aerosols test;
- LOFT programme;
- LWR Aerosol Containment Experiments (LACE); and
- Advanced Containment Experiments (ACE).

This tradition of collaboration continues with such international work associated with the PHEBUS-FP experiments and the associated analytical projects. As may be seen from Section 4.3.2, other smaller facilities which address different aspects of the problem are in operation or are being built in many countries. This gives some optimism that there is no **global** danger of losing competence or expertise in this area over the next few (i.e. two) years. However, some national programmes and facilities in the areas of iodine chemistry and fission product behaviour have been closed and there are clear indications that others are under threat of closure; capabilities and facilities have already been lost in, for example, Canada, the USA and the UK, and further erosion of capabilities is expected over the next few years. It is important that further loss of expertise in this important area of reactor safety be averted. Efforts should be made to establish opportunities for technical specialists from those countries where programmes are declining to continue to contribute via active programmes established elsewhere. Furthermore, to ensure that key expertise is retained for the industry as a whole, Centres of Excellence should be established in the areas of fission product behaviour and iodine chemistry, based on the facilities and expertise currently resident in national programmes.

Specific recommendations

Considerable expertise in fuel and fission product release and transport have been developed world-wide over the past many years in support of individual national programmes. However, as these programmes are being wound down, facilities are being shut down and expertise is being lost from these important components of reactor safety. Particularly noteworthy examples are, the termination or significant reduction of national research programmes in iodine chemistry and fission product release and transport, and the prospect that, left unaddressed, these programmes will decline even further. These are very complicated areas of reactor safety, which will require many years of hands-on experience before any level of expertise can be demonstrated. Although programmes such as PHEBUS play an important role in helping to retain expertise in these areas, additional initiatives are required to ensure that expertise residing in many national programmes is available to assist industry in the future. The SESAR/FAP group thus recommends the following:

Recommendation 4.3.1
The CSNI should encourage the establishment of a Centre(s) of Excellence in Iodine Chemistry and Fission Product Behaviour. This Centre of Excellence should be structured so as to facilitate maximum participation of OECD countries interested in maintaining core expertise in these fields. The Centre should thus be linked to existing major programmes on

iodine chemistry and fission product behaviour, but be closely linked via modern methods of telecommunication with experts from participating countries and organisations with the aim of executing a collaborative programme of research, development and modelling. As a starting point to this initiative, the CSNI should request proposals from members interested in hosting this Centre of Excellence.

Overall, it is important to consolidate the whole area by establishing a Centre of Excellence in fission product behaviour and iodine chemistry.

Other possible forms of international collaborations

In this area of long-term expertise, it is important that a benchmark activity be established in order to interpret the extensive database already acquired and to assess its applicability to reactor safety cases. Such an activity is also considered essential to maintain the knowledge of the teams, in countries where facilities are threatened with decommissioning. In addition, this would contribute to the longer term aim of achieving rationalisation and harmonisation of codes for use in PSA Level 2. Possible themes for such benchmarks are iodine behaviour, aerosol removal phenomena, or the estimation of the source term under realistic accident conditions. Coupling with core degradation mechanisms should also be studied, namely for fission product releases and their interaction with control rod and structural material emission from the core.

HUMAN FACTORS

(*Extracts from Chapter 5 of the full report*)

5.3 Summary and recommendations

Table 5.1 (in the full report) gives a summary of human factor research needs and examples of relevant current programmes.

The facility situation for collecting basic data on human performance is currently improving. In particular, the Halden Project can continue to provide a focus for international research and technical networking in this area and also its role as a centre for education could be extended. The Halden Board of Management recently provided views on the long-term direction of the project. In particular, the new multifunction-multipurpose HAMMLAB 2000 man-machine laboratory in Halden, to be commissioned by the year 2000, will extend the scope of potential studies to all operational and abnormal states and emergency conditions and provide a near-real-life testing environment. It has been estimated that the initial investment cost of the HAMMLAB 2000 laboratory (with a flexible control room, three different plant simulators and buildings) is close to three million USD. The expected annual operating cost is some two million USD, of which the salaries of the research staff (human factors specialists) is more than half.

Through close co-operation with the Halden Project even small national programmes may be viable. Project members can also use the software and know-how from HAMMLAB to build their own facilities for specific applications. Indeed, due to cultural differences, man-machine research laboratories are needed in several places. Good networking and benchmarking activities between the laboratories are highly useful.

The simulator facilities of utilities and their support organisations, and those of plant and simulator vendors, are essential resources. Such facilities include EPRI Simulator & Training Centres in Kansas City and Houston, EdF facilities in Paris and Lyon, CRIEPI facilities in Japan and the KSG simulator training centre at Essen in Germany.

On the basis of the attached systematic decision-making table, the template, Table 5.2 (in the full report), specific recommendations are given.

Recommendation 5.1
Collection of basic data and development of human performance models:

- Promote efficient international use of the new unique research facilities, such as Halden’s HAMMLAB.
- Facilitate availability of operating experience and simulator data from the utilities. Develop a Common Human Reliability Database.

- Use the data for the development of human performance models and for definition of criteria for personnel selection and training.

It is essential that there is strong international participation in the planning and execution of the experiments at the unique facilities as well as in the analysis of the results. Much of the data analysis of experiments on the major facilities can be carried out by expert teams from several organisations – periodically attached to the facility teams as necessary.

There is a need for a stronger role of the utility industry. Operational experience and simulator data, mostly available only to utilities, is the most relevant source of information for in-depth studies by human factor experts. In the future, much more basic data on human performance in better-defined format should be collected and exchanged. Real operational experience data is vital to validate data from training simulators and research facilities. Credible work with operating organisations requires that the research team combines behavioural science and technical expertise and people that are skilled in working closely with plant operational, maintenance, engineering and management staff. In certain experiments at research facilities, operating staff from commercial plants must be made available. It would be an obvious benefit if industry representatives could participate more in the relevant Working Groups of the NEA.

Data from high fidelity, well equipped simulator facilities are needed to provide qualitative and quantitative data for the development of human performance models, for both individuals and groups, particularly for use in PSA.

Human performance data is also necessary for setting criteria for personnel selection and for defining training programmes. Educational background, experience and personal characteristics are all important.

Recommendation 5.2
Specific actions by and co-operation between CSNI Working Groups to enhance research planning and networking:

- Monitor and update human performance research strategy.
- Reinforce systematic networking and benchmarking activities, in particular in the area of management and organisational performance.
- Watch the potential effects of utility restructuring due to deregulation and privatisation.
- Encourage joint activities with other industries.

It has to be understood that progress in many human factors research projects takes time. Interaction of small groups at various institutes is essential. Transfer of the results to the end users requires in most cases close interaction between the research and user groups.

Reinforced systematic networking activities are needed particularly in management and organisational performance research to initiate and manage comparison and benchmarking activities. As much of the information needed and also results of the research are confidential, these networks should serve as fora for confidential in-depth discussions between researchers as well as between researchers and the users of the results.

It is important to identify the potential negative effects of the extensive restructuring of nuclear utilities in many countries. Outsourcing may result in losing company memory, overview and core competencies. Increasing competition may threaten the sharing of good practices. Seeking efficiency easily overloads key people. Also, positive impacts are possible and should be utilised to the maximum extent.

Since most human factor issues have a common generic basis, joint projects and sharing of facilities and experts with other industries having similar problems is of high value.

Longer-term considerations

The experimental facilities being completed or planned will provide many new opportunities and there are a large number of training simulators, which will continue in operation and can deliver data for information and research in this field. However, to ensure expertise applicable to the nuclear industry, Halden should be maintained as a Centre of Excellence.

In some countries, the availability of human factor experts is very limited. It would help these countries to support relevant groups at universities and to provide the universities with access to problems of true practical interest for nuclear industry and regulation. Some human factor training should be offered to a larger number of technical specialists, e.g. in the context of experience feedback. The European Commission and The IAEA could organise relevant courses.

PLANT CONTROL AND MONITORING

(Extracts *from Chapter 6 of the full report*)

6.3 Summary and recommendations

The I&C requirements of the nuclear industry can be divided into three areas: safety systems, control systems and monitoring systems. Based on the discussion in the previous section, the future needs and challenges for these areas, along with the assessments leading to any required actions, can be summarised as in Table 6.1 (in the full report).

For safety systems, there are four key basic needs. First, the effects of ageing phenomena on I&C equipment need to be addressed. While this need has a high safety significance and a programme is required to address our knowledge deficit, no action is required of the CSNI. Member countries should, however, maintain ongoing monitoring programmes for trends in ageing related failures and problems. Secondly, adequate performance of safety-critical I&C systems should be ensured under accident conditions. This need also has a high safety significance, but there is sufficient knowledge available, and therefore, no programme is required. Thirdly, the overall reliability of safety-critical I&C systems should be enhanced. While our knowledge is not entirely sufficient to secure this enhancement, it has only medium safety significance, so again no formal international programme is required. Lastly, support is required for jurisdictions pursuing new reactor designs. This too is has a high safety significance, and there should be additional R&D, but no specific action is required of the CSNI, as developments for improved designs should be pursued by the jurisdictions and corporations involved.

For control systems, there are three basic needs or challenges. Similar to safety systems, adequate performance of control systems should be ensured under accident conditions, the overall reliability of control systems should be enhanced, and support is required for jurisdictions pursuing new designs. For all three, the safety significance is not as high because the existing systems should perform adequately. Nevertheless, Member countries should maintain ongoing monitoring programmes for trends in ageing related failures and problems, and jurisdictions pursuing improved reactor designs will require an active R&D programme.

For monitoring systems, there are also three basic needs. First, monitoring systems should be developed for severe accident parameters to support accident-management procedures. Such systems would have a high safety significance, and our current knowledge is insufficient, making a programme essential. No action is required of the CSNI, however, because a large integrated programme is not required to develop monitoring systems for severe accident parameters. The last two needs, to support life extension of components and to provide for future designs, are of low safety significance and therefore do not require specific OECD-sponsored programmes.

Having concluded that there are no specific programmes needed to address future needs and challenges for nuclear I&C, and there are no significant facility requirements, there are nonetheless opportunities for co-operative programmes that should be pursued in the short term. In particular, the nuclear industry can take good advantage of the active research and development on I&C technology for many non-nuclear industries, particularly those that require high safety integrity and reliability (e.g. aircraft avionics and telecommunications). It is therefore recommended that the CSNI Working Groups monitor developments in non-nuclear industries on behalf of Member countries, and encourage collaboration between research groups in Member countries.

6.3.1 Specific Recommendations

In the near term, the following recommendations are proposed:

Recommendation 6.1

CSNI Working Groups should monitor developments in non-nuclear industries (e.g. aerospace, telecommunications, advanced software methods) in the area of instrumentation and control, co-ordinate collaboration between nuclear and non-nuclear industries in this area, and communicate advances in associated technology to Member countries. They should also encourage increased collaboration between research groups in Member countries working on nuclear plant safety, control and monitoring systems. This collaboration should be widely based, but with a focus on advancing reliability, ensuring performance in hostile environments, and addressing ageing phenomena and the issue of digital obsolescence. Collaboration is also encouraged in evaluating the safety assessment methods used in other industries; these methodologies which have probable application to the nuclear industry.

Recommendation 6.2

CSNI Working Groups should monitor developments in Member countries for the qualification of non-nuclear software-related products for nuclear applications. They should also encourage increased collaboration between research groups in Member countries working on software qualification and related safety-system requirements.

Recommendation 6.3

The CSNI Working Groups should monitor developments in Member countries on the processes used to introduce software-based monitoring and decision-aid tools into control rooms, including approaches to failure modes and effects on human operators.

Recommendation 6.4

The I&C activities of the Halden Project should be continued as a means of fostering collaboration on research related to nuclear I&C systems, and as a means of ensuring the continued development of nuclear I&C experts to address future issues.

In the longer term, the nuclear industry requires an assured supply of qualified personnel capable of understanding and addressing I&C issues that are unique to nuclear reactors. This can be achieved in part by assuring the continuation of the I&C activities of the Halden Project.

INTEGRITY OF PLANT AND STRUCTURES

(*Extracts from Chapter 7 of the full report)*

7.3 Summary and recommendations

The optimal ageing management of reactor materials requires an important knowledge on degradation phenomena and evaluation techniques. There exists a substantial quantity of data and information on ageing, but the information is on different organisations, different countries and diverse formats. It is necessary to collect the data and to homogenise it.

7.3.1 Facilities potentially interesting for international collaboration

Most facilities for materials testing, including standard and medium-scale testing machines, hot cells and EAC rigs, exist in the Member countries and there is no need to identify a central facility that might be operated co-operatively. However there are very few facilities for testing very large specimens and the issue of predicting failure of large structures from small size specimens is not yet fully resolved. If maintenance of such large testing facilities is too great a burden for any one country then interested parties should consider ways of operating one facility for the benefit of all countries through international partnerships. The CSNI Working Groups have been a focus for such activities in the past. Table 7.1 (in the full report) shows large facilities available for international co-operation.

7.3.3 Specific Recommendations

For critical needs in the area of structural integrity assessment (ageing of NPP components with safety significance) information and knowledge should be available. It is proposed to better co-ordinate the activities and experiences in qualified data banks; prevention based systems, international co-operating groups. Therefore, the CSNI Working Groups should define possibilities of such integrating structures and propose a plan of actions.

> ***Recommendation 7.1***
> Define a plan of action (CSNI Working Groups) for the development of an international data bank and Centre of Excellence for materials ageing data and analytical tool, for example to better define safety margins, with the aim of attracting industry and government agency participation.

In the past, single ageing processes have been investigated predominantly with regard to safety, e.g. neutron and thermal embrittlement, environmentally assisted cracking and fatigue phenomena. The measures taken to cope with all the ageing mechanisms regarding continuous monitoring, inspection, surveillance and maintenance were mainly related to collect information using empirical approaches. From today’s point of view, structural integrity must be optimised by implementation of advanced tools and methods like qualified methods for ISI and monitoring of degradation, predictive micro-mechanical models, more-dimensional phase diagrams (temperature, pressure, concentration, time), and prevention based systems and risk-informed methods.

Recommendation 7.2
Focus the activities of the CSNI and the CNRA on the synergistic interaction between all the ageing mechanisms and its influence on continuous monitoring, inspection, surveillance and maintenance, initiate a strategic debate over the need to co-ordinate and develop an overall international research and training programme in materials ageing issues relevant to the nuclear industry, especially those with safety implications.

Recommendation 7.3
Continue and start benchmarks (CSNI Working Groups) to investigate the impact of boundary conditions, like thermal-hydraulics, temperature variations, radiation, chemistry, for different operational and accident situations on the integrity of aged components.

SEISMIC ANALYSIS

(*Extracts from Chapter 8 of the full report*)

8.3 Summary and recommendations

8.3.1 Facilities potentially interesting for international collaboration

The main area of concern is the shaking test facilities. These are normally general-purpose facilities and are used for various types of industrial equipment and structures. There are very few facilities exclusively used for nuclear testing.

Shaking tables with less than one hundred tons capacity are widely available in the world as shown in the attached table. From the name of the organisations owning those tables it is apparent that they are used for general purposes. Because of this there seems to be no need to worry about keeping up these test facilities in future. On the other hand, regarding the shaking table class with a capacity of a thousand tons, only one table, the Tadotsu Shaking Table, exists in the world, and it is used exclusively for nuclear equipment and structures.

With respect to shaking test needs in future, full size tests are still necessary for seismic margin tests, degraded structure tests for testing structures and components to failure. It is imperative to keep this kind of capability to test full-scale and large size specimens.

8.3.3 Specific recommendations

For seismic design, there are differences among countries according to their earthquake environments. Existence or not of new plant projects also affects countries' attitudes on the needs for seismic research. According to local circumstances, each country has different interests and this is reflected in the priorities given to such topics as: re-evaluation of existing power plants, research into methods for economic improvements, fragility evaluation for seismic PSA, and so on.

In order to identify common interests, it is necessary to encourage international information exchange and collaboration, and to improve international capability of seismic design through workshops, ISPs and sharing of earthquake observation data. It is also important to promote seismic test programmes requiring large-scale tests by selecting from these common issues projects which would be attractive as international collaborative research exercises. Public Acceptance is also an important factor.

8.3.4 Other possible forms of international collaboration

Because the seismic capability of equipment differs according to their design conditions, seismic evaluation results are not always adaptable directly for use in other countries. By clarifying these differences, it is recommended that efforts be made to utilise test data and test information from different countries as a common database. It is important that this type of collaboration is given a try. In this case, a "virtual" Centre of Excellence would seem to be the most appropriate form of collaboration.

RISK ASSESSMENT

(*Extracts from Chapter 9 of the full report*)

9.3 Summary and recommendations

Risk assessment is an important subject for both regulators and utilities and they will need to maintain the necessary expertise. The template (in the full report) outlines the challenges which it classifies as of either high or medium safety significance. Further knowledge is necessary and in all areas facilities and/or expertise is essential. With one exception, which is in the area of data collection and analysis, no proactive action is required. Each Member country should maintain technical capability in this area.

Co-operative efforts to develop methods, standards, and criteria and share experience should be pursued. Of particular note here are the CSNI Working Group activities (e.g. on fire PSA) and the recent COOPRA collaborations. Pooling and sharing of data and the analysis of data are also encouraged. In this regard the ICDE programme for common cause failure is valuable, as is continuation of the reliability data workshops. There are no facility needs associated with this area.

It is recommended that the CSNI Working Group on Risk Assessment is charged with developing methods and standards criteria, and to ensure that the sharing of experience is encouraged, including strengths and limitations of using PSA.

FIRE RISK ASSESSMENT

(*Extracts from Chapter 10 of the full report*)

10.3 Summary and recommendations

A summary of the fire assessment activity described in the template (in the full report) indicates that the research challenges in this area are quite significant but need better co-ordinating and are all of high or medium safety significance. Further knowledge is required for all topics and in some a research facility will continue to be essential. However, additional requirements in other industrial sectors should ensure that facilities and expertise continue to be maintained.

It is recommended that the CSNI Working Groups are given the task of defining the experimental research needs based on fire PSA and in particular consider the possible uses of the RUT facility.

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