Russian Minatom
Nuclear Safety Research
Strategic Plan

An International Review

March 1999

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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- *encouraging harmonization of national regulatory policies and practices, with particular reference to the safety of nuclear installations, protection of man against ionising radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;*
- *assessing the contribution of nuclear power to the overall energy supply by keeping under review the technical and economic aspects of nuclear power growth and forecasting demand and supply for the different phases of the nuclear fuel cycle;*
- *developing exchanges of scientific and technical information particularly through participation in common services;*
- *setting up international research and development programmes and joint undertakings.*

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BACKGROUND

The “Safety Research Strategic Plan for Russian Nuclear Power Plants” was published in draft form in late 1998. It was developed at the Russian International Nuclear Safety Centre (RINSC) of the Russian Ministry of Atomic Energy, by a working group of fifteen senior Russian experts representing twelve Russian organisations, chaired by Professor Armen A. Abagyan. These experts were assisted by a Project Team of other technical experts from key organisations throughout Russia, and by the US International Nuclear Safety Centre (USINSC) whose role was principally that of facilitator and reviewer. The Plan consists of 12 chapters, each addressing a specific technical area and containing a number of proposed research programmes and projects to advance the state-of-knowledge in that area.

In part because a strong Recommendation to undertake such a Plan was made by the 1998 OECD/NEA study, “Safety Research Needs for Russian-Designed Reactors”, the OECD Nuclear Energy Agency was asked by the Director of RINSC (Professor S. Bugaenko) and the Director of USINSC (Dr. D.J. Hill) to organise an international review of the Plan when the English-language version became available in October, 1998. This report represents the results of that review.

OBJECTIVES OF THE REVIEW

The NEA undertook the review with the objective of providing an independent verification on the scope, priority, and content of the research described in the Plan based upon the experience of the NEA group of experts. Another objective was to identify areas where similar work is being done in other countries, possibly forming the basis for co-operative research and beneficial exchanges of information, and specifically to identify possible NEA activities from which Russia could benefit.

Some of the specific questions that the NEA review activity addressed included:

- the extent to which the Plan is complete, coherent, and comprehensive;

- whether the Plan is well-rounded and contains all of the various types of research activities (theory; analysis; experiments; methodology development; data bases; etc.);

- whether the assignment of priorities within the Plan is coherent and consistent;

- the degree to which the Plan is likely to be effective in improving safety, by identifying specific activities that will put into practice the knowledge gained in other parts of the Plan;

- whether the resources and time scales specified in the individual Plan elements are reasonable and realistic;

- whether the Plan takes appropriate account of knowledge and ongoing research elsewhere in the world; and

- how the individual elements of the Plan might take advantage of international co-operative arrangements, both within the OECD/NEA programme and more generally around the world.

REVIEW PROCESS

The NEA appointed an international "Group of Senior Experts" to carry out the review and a rapporteur to work with the Group to develop this report. This "NEA Review Group" met in Paris on December 4-5, 1998 and in Moscow on January 26-27, 1999. The Group had the benefit not only of the Plan, but also of important background information presented in Moscow by the various Russian experts who were responsible for the individual technical chapters. Also, the Group took account of the earlier OECD/NEA study, "Safety Research Needs for Russian-Designed Reactors", published in 1998, which had made a strong recommendation that Russia develop a Plan like the one which is being reviewed here.

At its first meeting in Paris, the Review Group developed a list of tentative issues and questions, which were the focus of the second meeting in Moscow, where the Group interacted with the full Russian team. The Russian participants in the Moscow meeting are listed in "Annex II." Dr. David J. Hill and Dr. Joseph C. Braun of the USINSC and Dr. Lev V. Tocheny of the International Science and Technology Centre also attended and participated.

In the introduction, the Russian Plan claims that its scope covers reactor-safety research on all of the various types of power reactors now deployed in Russia: VVERs (pressurised water reactors); RBMKs (graphite-moderated pressure-tube reactors); and BNs (liquid-metal fast reactors). However, the NEA Review Group observed that the Plan gives very little attention to fast-reactor safety, and it has concentrated its review effort on topics directed toward the VVERs and RBMKs, with more emphasis on VVER topics than on RBMK topics because the Plan itself has more emphasis on VVERs than on RBMKs. This review report does not cover those few elements of the Plan touching on fast-reactor safety research.

ORGANISATION OF THE REPORT

This report is organised into a set of general review comments below in the body of this report, and an extensive set of specific comments on the 12 individual chapters of the Plan, which can be found in "Annex I".

GENERAL COMMENTS FROM THE NEA REVIEW GROUP

The NEA Review Group wishes to congratulate the Russian team for having done an excellent job of assembling the Research Plan that is being reviewed here. The Plan is designed to address high-priority safety-research needs, through a combination of domestic research, the application of appropriate foreign knowledge, and the use of foreign collaborations. It represents major progress toward developing a comprehensive and coherent safety-research programme for the Russian NPPs, and the Review Group recognises the large amount of effort that has gone into it.

Furthermore, the NEA Review Group believes that the various elements of this Plan, when completed, will clearly represent an improvement in safety understanding, which will then lead to an improvement in the safety levels of the affected reactors themselves.

However, both the Review Group and the Russian experts themselves recognise that this draft Plan is only a first step toward the development of an overall up-to-date Russian programme for NPP safety research. It will need to be improved in order that it can optimise the available resources, address all of the principal safety issues in a balanced way, and thereby improve NPP safety most effectively. The goal of these comments from the NEA Review Group is to provide input to the Russian experts as they undertake the needed revisions to this first draft of the Plan.

A well-rounded safety research programme should contain the following elements: database and data gathering activities to ensure that plant and material property information is available to support analyses; computer programme development and validation to provide qualified tools to analyse plant performance; improved surveillance methodology; improvements to plant operation through operator training and support, and accident management procedures; improved components that can be retrofitted to existing plants and designs; and experiments to support computer programme development and validation.

A strategic plan for reactor safety research should identify the safety-research needs, provide a strategic approach for setting priorities for research and define the programme that addresses the research needs and is consistent with that strategy. The safety-research needs come from consideration of safety issues for operating plants and potential improvements for future plants. The strategy must balance the available resources with the requirements of the groups that will act on the R&D results – regulatory authorities, designer organisations for upgrades and for new plants, and utilities that operate the existing plants. The resulting programme should be well-rounded as previously discussed, while focused on providing the information required by the groups that will act on the R&D results. For example, a utility may require information for specifying a piece of hardware, whereas a regulatory authority may need information and analysis tools to develop a regulation or an inspection procedure.

The Russian Plan, as reviewed, provides for a programme containing most of the expected elements, but does not appear to have a clear strategy for setting overall direction and priorities, nor does it show how the proposed R&D would be implemented to meet specific safety-research needs. This lack of clear strategy and implementation details is reflected in the following set of ten principal conclusions. These ten conclusions summarise the NEA Review Group's **general comments**.

- The Plan is not yet a **strategic** plan: it needs an explicit overall strategy identifying objectives and priorities to which the individual research elements are tied.

- The Plan's scope should be expanded to include some important NPP-safety research areas that are omitted or are given only minor weight.

- The Plan contains priority assignments (higher vs. lower priority) within each research area, but in general the method used is not clear and the priorities that are assigned do not provide enough discrimination. Also, the overall priorities that are assigned across the entire Plan, based on the proposed manpower numbers, seem to the NEA Review Group not to reflect a comprehensive strategy for improving NPP safety. In many technical areas these priorities do not provide enough detail to guide the appropriate allocation of actual resources, or to support effective planning and implementation.

- The Plan does not explicitly deal with how it will be executed, in terms of management strategies, funding principles, identification of institutional users, collaborations between lead Russian organisations and other supporting organisations, and manpower/time scale aspects.

- The Plan is not explicit in identifying which activities are mainly directed toward improving the safety of the existing NPPs, and which are primarily motivated by developing new designs and evaluating their safety.

- The Plan contains many important methodology-development activities to provide tools for understanding and improving NPP safety, but in many cases these development activities are not well linked to actual applications that will directly improve NPP safety.

- The Plan is not well balanced between analysis and experiments: the current emphasis should be either clearly linked to strategic objectives or modified.

- The Plan does not give as much emphasis to RBMK safety issues compared to issues affecting VVERs.

- The Plan does not identify adequately the large number of opportunities to advance its aims by applying or adapting knowledge and tools already available in other countries. It also only identifies a few of the large number of potential opportunities for international collaborations in NPP safety research.

- As to particular priorities, **the NEA Review Group believes that the most important objective of this Plan ought to be to achieve as many short-term improvements in the safety of the existing operating power reactors as feasible**. For many of these areas, the issue is not simply one of doing the needed research, but of effective and rapid implementation of the new knowledge at the operating plants. Specific areas where we recommend greater emphasis are discussed below.

In the next section, we will provide more detail to support our conclusions on each of these ten major general points. However, the NEA Review Group wishes to emphasise again here, that we believe this Plan to be an **excellent starting point** which can, with the needed enhancements, provide what Russian NPP safety truly requires: a comprehensive, strategic, effective safety-research Plan that can take full advantage of the strong and broad technical capabilities available in Russia.

IN-DEPTH DISCUSSIONS OF THE GENERAL COMMENTS

A. The Plan is not yet strategic

The Plan does not **yet** seem to be a "strategic" Plan, in the sense that it seems at this stage to be a collection of a large number of different research ideas, but without an integrating theme (a "strategy") providing an overall framework.

The Plan would be substantially improved if an overall "strategy" could be developed and used to guide the whole endeavour, and then this could be applied to the individual elements in the Plan. Specifically, the NEA Review Group recommends that some specific overall **objectives** be cited, and for each individual programme or project the Plan ought to identify which of these objectives is the primary motivation for that programme or project, and also ought to identify the associated time scales.

The legitimate objectives of a specific safety research programme or project can include: to improve the safety level of an existing operating NPP; to improve the prevention of potential severe accidents; to mitigate their consequences; to extend the operating efficiency of an operating NPP; to reduce costs; to improve the effectiveness of operations or maintenance; to understand a safety issue better; to clarify the amount of a specific safety margin; to improve the ability of the operating entity to understand its plant safety level, or of the regulatory body to regulate; to develop or enhance an in-country analysis or other capability; and to improve the safety level of a new design. (Often, a specific research project will address more than one of these objectives).

Of course, sometimes a strict demarcation of the objective(s) is not possible, but where multiple objectives are contemplated these should **all** be identified.

B. Expand the scope

There are some important NPP-safety areas that the Plan does not cover, or only mentions in a minor way. These include (i) safety issues arising when reactors are shut down or operating at low power; (ii) safety issues arising from natural hazards (earthquakes, high winds, floods, etc.) or man-made external hazards (airplane crash, nearby industrial facilities or nearby transportation corridors, etc.); and (iii) equipment qualification, where there is a need for more comprehensive coverage, covering the topics of seismicity, fire, smoke, electrical equipment performance. (Parts of this topic are in Chapter 8, but the coverage is far from comprehensive.) In our comments on Chapter 8 in Annex I, we recommend that a separate chapter should be devoted to the entire area of equipment-qualification issues, and that substantial resources be assigned to these issues.

The NEA Review Group recommends that serious consideration be given to expanding the scope to include these areas, with priority to improving the safety of existing NPPs. In any event, if any important safety areas are not to be covered, the introduction to the Plan should clearly state a rationale for why these are not within its scope.

The Plan does not cover decontamination and decommissioning issues, but the NEA Review Group does not believe that these topics necessarily need to be part of this Plan.

Concerning the needs of GAN (Gosatomnadzor), a small part of the Plan (in Chapter 12) attempts to address a few of GAN's technical needs, but the coverage is not thorough. The fact is, of course, that every regulatory body needs certain tools (analytical, inspection, data-gathering, etc.) whose development requires research. The NEA Review Group recommends that the introduction to the Plan should clarify what research relevant to GAN's needs is included, and should explain the rationale for the decision to include or exclude certain categories of GAN-related research. Further, we believe that the Plan would be strengthened if input from GAN could be obtained at the strategic level, in terms of priorities, schedules, and implementation of the expected R&D results.

C. Improve prioritisation methodology

The way priorities are assigned in the Plan within each research area is not specific enough, and the priority assignments do not discriminate: each entry is assigned either "high priority" (in bold print) or "low". However, sometimes a research element is neither high nor low priority, but simply "to be done later", after some other elements are completed, when it then becomes high priority. It is recommended that the priority assignments in the Plan should be modified to designate some elements as "later", rather than simply as "high" or "low" priority.

More importantly, the overall priorities that are assigned across the entire Plan, based on the proposed manpower numbers, seem to the NEA Review Group not to reflect a comprehensive strategy for improving NPP safety. In many technical areas these priorities do not provide enough detail to guide the appropriate allocation of actual resources, or to support effective planning and implementation. [Section J will discuss some specific comments and recommendations by the NEA Review Group about priorities among the broad research areas.]

D. Need for a management strategy

The Plan does not demonstrate that an overall management strategy has been used to guide its structure or content. For example, for each specific research element, the Plan should identify a specific **lead Russian organisation** and the roles and responsibilities of all other supporting organisations that are expected to undertake the research. The funding principles to be used in resource allocation are also not described.

The specific **institutional user(s)** and each user's **safety needs** for each research result should be identified. The ultimate user may be the NPPs, or the design organisations, the equipment vendors, the power-station constructors, the research institutes, the regulatory body, and so on. Often, multiple users can be identified. Once identified, the ultimate user(s) should be brought into the planning process at the initial stage to assure that each research project is executed to optimise the user's ability to apply the new knowledge.

In some areas, the Plan also does not contain a realistic time scale. Specifically, for many of the Plan's elements, our Review Group concludes that the work almost surely cannot be completed in the short time period allocated in the Plan (within three years). We therefore recommend a careful and realistic evaluation of this timing issue, after which the Plan needs to be revised accordingly.

Many of the elements in the Plan should be carried out in a time sequence, with one element preceding another. The Plan does not explicitly recognise this except in a few places.

The lack of an overall strategic approach to managing the Plan's proposed work is related to the fact that the Plan does not provide much information about linkages among the different elements in order to demonstrate that the Plan represents an **integrated approach**. Rather, the Plan seems to be a collection of individual parts without an effort having been made to specify the overall linkages among the elements. We strongly recommend that the Plan should specify the **linkages** among different elements wherever they are important. For example, the Plan should specify the linkages between experiments and code development, or between data bases and their uses, and more broadly between research results and their application at the operating NPPs or at the design organisations.

There are, of course, many positive interactions among elements of the Plan that span across different chapters. Only a few of these are clearly identified, and many of the potential positive interactions are not identified. When planning the actual research work, positive synergistic benefits can result by taking advantage of these interactions. The Plan should attempt to identify these positive interactions.

E. Differentiate between existing NPPs and new designs

Some of the Plan's programme is directed mainly toward improving the safety of the existing NPPs, and some will mainly affect new designs and the ability to evaluate their safety. The Plan is not explicit in identifying which activities are in each category. It is recommended that the Plan make this identification for every programme and project: this is important because the relative priorities and timing are different, and the specific technical issues also.

F. Lack of application linkages

In many technical areas, the Plan's scope is not comprehensive enough. Often, an area of research is identified, but how the new knowledge will be applied is not, and the Plan does not contain any project to assure that the application occurs. The following questions are often left unanswered: "What will be done with the new knowledge?" "How will this knowledge be applied, and by whom, to improve safety?" More importantly, the Plan is missing specific research projects that address **how to apply** the new information.

The NEA Review Group recommends that the Plan address the above questions for each specific technical area. Equally important, new research projects need to be developed and included within the Plan that address how to apply the new information developed in other elements in the Plan.

G. Balance between analysis and experiments

There is a clear imbalance between the small amount of experimental research and the major amount of analytical work in the Plan compared to the expectations of the NEA experts. Many important questions that require experimental studies for their resolution are missing and should include fuel performance, equipment qualification testing, assessment of accident procedures, and certain severe-accident phenomena.

The NEA Review Group recommends that the introduction to the Plan explain the rationale for the decisions that have been made concerning the balance between experimental and analytical research projects. This needs to be done for each specific research topic area.

Many opportunities exist for Russian participation in international experimental safety-research programmes (see our detailed comments below), which can be both more effective and much less costly than embarking on major in-country experimental programmes.

H. RBMK vs. VVER emphasis

The Plan's coverage gives much more emphasis to VVERs than to RBMKs. The NEA Review Group recommends that the safety issues with existing RBMKs should be addressed more fully, with the appropriate level of detail in each broad technical area, so that RBMK safety receives adequate attention by the Russian safety research community in the immediate future.

I. International opportunities

It is strongly recommended that the Plan include Russian participation in several major international projects, now underway or now being established, in order to supplement the current and future research work carried out in Russian institutes. The Plan should consider incorporating international projects such as the Halden work, RASPLAV, the international bubbler-condenser studies, and the PSB experiments, among others.

The NEA Review Group was surprised to note that the Plan does not prominently feature research work now under way in Russia that is of high interest to the OECD countries. Besides the projects mentioned, this includes work on hydrogen combustion in severe accidents and reactivity-insertion-accident behaviour of high-burnup LWR fuel.

Russia has recently gained observer status in the safety-related committees of the OECD Nuclear Energy Agency, and should take advantage of the many activities within the NEA that could be of major benefit. The NEA Review Group recommends active Russian participation including most of the Principal Working Group activities. Specifically:

a) PWG 1 on Operating Experience and Human Factors has linkages to the work planned in Chapters 6 and 7.

b) PWG 2 on Coolant System Behaviour has linkages to the work planned in Chapters 3, 4, and 10.

c) PWG 3 on Integrity of Components and Structures has linkages to the work planned in Chapters 1 and 2.

d) PWG 4 on Confinement of Accidental Radioactive Releases has linkages to the work planned in Chapters 4 and 10.

e) PWG 5 on Risk Assessment has linkages to the work planned in Chapters 7 and 11.

f) The OECD Halden Project has numerous linkages throughout the Plan.

J. Priority assignments

The NEA Review Group believes that **the most important objective of this Plan ought to be to achieve as many short-term improvements in the safety of the existing operating power reactors as feasible**, while at the same time performing the multi-year research that can lead to major improvements in long term understanding. We have concluded, based on experience in our own countries, that a few of the broad areas within the Plan offer many more opportunities for near-term safety improvements than the other areas covered in the Plan. Based on our experience, the areas that the NEA Review Group would assign to the highest priority include human factors, accident management, fire safety, equipment qualification, and PSA applications. For many of these areas, the issue is not simply one of doing the needed research, but rather effectively and rapidly implementing the new knowledge in operating plants.

Specifically operational issues, accident management, and PSA, addressing the Plan do not include as much emphasis as the NEA Review Group expected to find. We recommend that the Plan ought to be modified to include more emphasis on research to develop operational and accident-management capabilities. Many of the research topics already included in the Plan will provide information that is of use in accident management, but the linkage to actual accident-management capabilities is not included in the Plan except in a few areas.

Data bases

There is an appropriate emphasis, which the Review Group believes is excellent, on developing data bases (such as metallurgical data bases, reliability data bases, etc.) specifically tailored to the Russian reactors needs.

Code development

The approach to code-development merits special consideration. First, it represents a very large fraction of the effort in the Plan, and second, experience in our countries with developing large code packages is relevant.

We observe that for many research elements the objective is to develop domestically a capability to perform certain analyses, to develop certain codes, or to understand certain technical areas better. Specifically in the code-development area, there is less emphasis on adapting western capabilities to the Russian reactor-safety situation than the NEA Review Group expected.

Because of the large expense and long time required to develop complex reactor-safety codes, we recommend that the Plan should give more consideration to the adaptation of existing western codes to Russian specific needs, instead of the almost exclusive emphasis in the Plan on developing new codes within Russia. The Plan should also clearly identify innovative features in code development that go beyond an adaptation of western codes to Russian needs. In the entire code-development area, the OECD countries are able and in fact eager to facilitate the process of code adaptation and sharing.

Near-term Safety Benefits

The NEA Review Group offers the following as examples of the types of activities that could lead to near term safety benefits:

- **Human Factors:** It is important to ensure that working conditions do not contribute to human error. For example, areas where operator actions or maintenance take place should be well lit; instruments, handwheels, gauges, etc., properly labelled, accessible, and working; temperature and humidity should not be excessive, etc. Also, much work has been done in OECD Member countries with respect to control room design, procedure development, staffing, and technical specifications that could be transferable to the Russian plants.

- **Accident Management:** Strategies and guidelines for the prevention and management of severe accidents in western LWRs are well developed and available from the NEA and its Member countries. Many aspects are applicable to VVERs and it should be fairly straightforward to adapt these to develop accident-management guidelines for VVERs without extensive research. The basic strategies could be the same (for example, depressurise, add water, cavity flooding if possible, containment sprays, sump pH control, hydrogen control, etc.), with the emphasis of the new research work on how to adapt them to VVER instrumentation, design features and timing. Guidelines and training applicable to VVERs could then be implemented.

- **Fire Safety:** Standard good practices could be instituted without much research. This would remove possible fire sources, install smoke detectors, barriers, and install fire-suppression equipment. This can then be supplemented by using advanced fire codes as they become available.

- **Equipment Qualification**: Key equipment that must function following an accident should be identified and tested under the environmental conditions resulting from the accident (temperature, humidity, etc.) so as to confirm its operability or, if it fails, why. Protective counter-measures could then be implemented.

- **PSA Applications:** Several PSAs have been done or are underway on Russian-designed reactors. These can provide insights as to important equipment, initiating events and human actions. These insights can be used in the near term to identify areas for design fixes, training, inspection, surveillance testing, etc. Collecting these PSAs and extracting and disseminating the important information to all similar plants, including suggestions on how to use the information, could improve safety in the near term without extensive methodology or data-base research.

ANNEX I

Chapter 1: Integrity of Piping and Equipment

The scope of this Chapter covers the integrity of the primary system, including the vessel, the piping, and the equipment; and for RBMKs it also includes the integrity of the channel tubes. The scope covers analysis methods for integrity; non-destructive-testing methods; leak detection; seismic issues; equipment ageing; and data base development. Priority is assigned to developing a variety of analysis methods using sophisticated computer-based approaches, and to developing and testing of various field methods for measurement and diagnosis. (The proposed work here complements the scope in Chapter 2).

1. Parts of the work in this Chapter seem to have significant duplication with work already accomplished either in Russia or elsewhere.

> *Recommendation*: **The Plan is to identify what is really new in each of the elements of this Chapter, based on a thorough review of work both in Russia and in the rest of the world. Then the specific work in the Plan needs to be targeted to the specific safety areas where it is most needed.**

2. The integrity of RBMK pressure tubes and issues related to RBMK in-service inspection of the primary system are mentioned in the introductory text of this Chapter, but not covered in detail in the research plans.

> *Recommendation*: **The integrity of RBMK pressure tubes and issues related to RBMK in-service inspection of the primary system is to be a major part of the work scope of this chapter. [Recent concerns with intergranular stress-corrosion cracking in primary-system RBMK piping illustrate the need for a comprehensive research effort in this area.]**

3. Steam-generator tube-integrity issues for VVERs are mentioned briefly in the Plan but assigned low priority.

> *Recommendation:* **The Plan is to give higher priority to research on steam-generator tube-integrity issues for VVERs, such as methods for detecting tube problems, and analysis of the consequences of tube-rupture events**.

> *Recommendation*: **The Russian Plan is to attempt to build upon advanced work elsewhere in the world on probabilistic methods for analysing piping and vessel integrity**.

> *Recommendation*: **Russian organisations are to explore co-operative programmes with western institutes in the areas of (i) code development, verification, validation, and certification, for studying strength, seismic stability, and residual lifetime of structures and equipment; and (ii) data base development for physical and mechanical properties of structural materials and weld joints.**

> *Recommendation*: **OECD Member countries are interested in work on the development of non-specimen methods of full-scale monitoring of mechanical properties of metals. Collaboration is to be cultivated.**

4. The NEA Review Group is pleased that NDT (non destructive testing) methods are recognised in the Plan as being high priority.

Chapter 2: Integrity of Building Structures

The scope of this Chapter covers the integrity of the important structures, including not only the buildings themselves but also the leak-tightness of containments and confinements. Other topics within the scope include VVER-440-213 bubbler-condenser structural integrity, ageing issues, seismic issues, and RBMK reactor well and reactor vault evaluations. Priority is assigned to seismic assessment and ageing analysis, database development to support structural assessments, and the provision of structural analysis tools. (The proposed work here complements the scope in Chapter 1 of the Plan).

1. The area of seismic-structural research is mentioned in this Chapter but not given major emphasis, even though seismic-structural issues remain a concern for Russian-designed reactors.

> *Recommendation*: **The response of containment and confinement buildings and of other major structures under seismic conditions is to be given higher priority. Also, the response under accident conditions from various external hazards (external explosions, floods, aircraft crash, etc.) is to receive priority. (Some aspects of this perhaps could be covered in Chapter 4: Identifying Severe Accidents and Mitigating their Consequences.)**

> *Recommendation:* **The structural investigations here have a significant link to PSA studies that can help identify the important containment loads under accident conditions. This linkage is to be developed.**

2. There is no mention of research on monitoring, inspection, and repair of concrete buildings.

3. The area of research into ageing phenomena is given priority (included in Appendix 2.2), but the specific proposed investigations are not presented in enough detail to enable the proposed work to be reviewed.

> *Recommendation:* **The Plan is to clarify that the scope here, using the words "building structures", also applies to "buried structures", and that underground structures are included within the scope of the Plan. Specific research projects on buried structures are to be considered as part of the Plan**.

Chapter 3: Reactor Dynamics and Safety

The scope of this Chapter covers code development and verification work in the areas of thermalhydraulics and core kinetics, and includes major multi-year efforts to develop a suite of separate and coupled advanced codes. No experimental work is included although comparisons of codes with existing experiments is implied.

1. All programmes in this area are assigned high priority, which does not provide enough differentiation.

> *Recommendation:* **It is necessary to develop both a strategy and a set of priorities for this work so that relative priorities can be established, and so that the timing of the individual elements can be established.**

2. The Plan does not provide separate discussions of work on VVERs and work on RBMKs; and it does not give separate discussions to thermalhydraulic studies and reactor-neutron kinetics studies.

> *Recommendation:* **When the Plan is modified to provide more detail, the presentation could be clarified significantly by presenting and discussing proposed research on VVERs and RBMKs separately, and on thermalhydraulics and kinetics separately.**

> *Recommendation:* **The very large code-development programme described in this section is to be sub-divided into several smaller pieces, each with its own specific objectives and plans.**

> *Recommendation*: **For each sub-element in this larger code-development programme, the Plan is to clearly specify which innovative features are expected to result from the work**.

3. The time allotted for this large effort is only about two years. The NEA Review Group believes that the development of such a suite in a few years,

and with the participation of many research organisations, presents an insurmountable challenge.

> *Recommendation:* **A more staged development plan might improve the use of resources and the chances for success. This staged development could proceed by first tackling developments that address the largest uncertainties, after which subsequent development cycles could address diminishing uncertainties in turn.**

4. The proposed work is almost entirely code development and validation; no experimental work is contained in this part of the Plan.

> *Recommendation:* **The Plan seems to cover comparisons between existing experimental data and the various codes to be developed, but the specific comparisons are not explained. It is important that the Plan describe the specific details of the work here, including experimental information both from within Russia and from international sources. The Plan is to make specific reference to the PSB facility.**

5. The allocation of resources is very high (about 800 man-years), almost one-third of the allocation in the entire Plan. While the absolute amount of man-years may not be excessive, the relative amount seems relatively high compared to the other areas in the Plan.

6. Many of the codes that this Plan seeks to develop are similar to codes that have already been developed in OECD Member countries.

> *Recommendation:* **Careful consideration is to be given to adapting foreign codes or models in areas where there is a high degree of similarity.**

7. In the area of spatial neutron kinetics, it is not clear why research work is needed for improving and verifying calculation methodologies and codes, and for developing improved models. Much is already known in these areas, especially for LWRs.

> *Recommendation*: **If additional work on neutron kinetics is necessary, the emphasis is to be on understanding design-basis events and on preventing the initiation of accidents**.

> *Recommendation*: **OECD Member countries are interested in work to better develop three-dimensional analytical capabilities for examining processes in the core. However, the NEA Review Group believes that the current schedule is unrealistic, in particular because experimental research would be needed.**

> *Recommendation:* **An urgent need exists for both experimental and analytical investigations of high-burnup VVER fuel. The Plan is to consider benefits that could be gained from participating in the planned OECD CABRI programme on this topic**.

Chapter 4: Identifying Severe Accidents and Mitigating their Consequences

The scope of this Chapter mainly covers code development and verification work in the areas of severe accident initiation and progression. The scope emphasises VVER reactor issues, and includes a large multi-year effort to develop a suite of separate and coupled advanced codes. No experimental work is included although comparisons of codes with existing experiments is implied.

> *Recommendation:* **Chapter 4 is to be considered in co-ordination with Chapter 10, Severe Accident Management**.

1. Chapter 4 has been mostly written with the safety of VVER reactors in mind.

2. RBMK issues probably deserve another (separate) chapter similar in scope to Chapter 4. However, whether or not the issues related to RBMKs receive a separate chapter, there is generally not enough consideration of work on RBMK severe accidents. For example, the Ignalina SAR project found that there was no way to do a proper Level-2 PSA because there was

no answer to basic key phenomenological questions (identified in the OECD Study); as a consequence, accident management plans could not be developed fully.

3. The Chapter is essentially devoted to code development, with very little emphasis on experimental work; this does not seem balanced, because there is an obvious need to learn more about severe accident phenomena before starting model and code development. This is especially true in the area of RBMK severe accidents.

4. The research elements in this Chapter do not seem to account adequately for the vast body of experimental information that has been developed. There needs to be **explicit** recognition of this throughout.

> *Recommendation*: **Careful consideration is to be given to adapting foreign codes or models in areas where there is a high degree of similarity in key features of the respective nuclear reactors.**

5. The work schedule described in Chapter 4 seems to be very ambitious: much more is described than can be accomplished in the time that is allocated (three years), even with the recognition that a major manpower effort is planned (115 man-years.) Clearly, the Plan is intended only as a first step, even though the text itself does not recognise this first-step character very well.

> *Recommendation*: **The Plan is to indicate tasks that must be performed first and which ones can be postponed, for each major project in this section.**

> *Recommendation*: **For each sub-element in this larger code-development programme, the Plan is to specify clearly which innovative features are expected to result from the work.**

6. The elements in this Chapter do not seem to have been planned with specific applications in mind, such as applications for changing the design or operations of NPPs, or accident-management applications. This linkage is crucial to the overall usefulness of the work in this Chapter.

7. Item 4.5, “Interaction of Core Melt Material with Concrete and Possibility to Cool Debris Phase”, promises more than the corresponding description of work given in the appendix.

8. The area of understanding the entire bubbler-condenser system for VVER-440-213 designs is covered in this Chapter, but assigned lower priority than the NEA Review Group would have expected.

9. There is no mention of direct containment heating issues for VVERs. (Whether work on this topic belongs here, or in Chapter 2, or both, is for the Plan's organisers to determine, but it is to to be covered somewhere in the Plan.)

Chapter 5: Radiation Thermal Mechanics of Core Components

This Chapter is not yet available. The scope of this Chapter is intended to cover all issues related to radiation thermal mechanics of fuel assemblies, fuel behaviour, core components, reactor internals (but not the reactor pressure vessel), graphite, etc. Research on fuel integrity, in particular fuel cladding, is also intended to be part of this Chapter. The reason given for the absence of this Chapter in the draft version of the Plan is that proprietary and commercial information on these topics needs to be separated from information that can be made public, which requires complex decisions.

The NEA Review Group emphasises that research on the broad topic of fuel behaviour is central to an overall understanding of reactor safety, and that such research has important links to most of the other Chapters in the Plan. The Plan is not complete, in a strategic sense, without such research.

Chapter 6: Simulators, Operator Training, and Support Systems

The scope of this Chapter covers the development of computer-aided training systems, symptom-oriented procedures for operators, and improved information-display methods, all of which are aimed at improving how operators are trained. Other topics within the scope include developing a training course and a database. Priority is assigned to the simulator-based training projects and to developing symptom-based procedures. The proposed work has close ties to work in Chapters 3, 4, 7, and 10, and could benefit from the PSA work in Chapter 11.

1. Most of the proposed work is related to the improvement of the interface between operators and simulators, to provide better tools for operator training. This is considered a very valuable contribution to the overall Plan.

2. There are clear linkages to the code-development work in Chapters 3 and 4, to the operational-safety issues in Chapter 7, and to the accident-management issues in Chapter 10. This work could also benefit from the insights derived from the PSA work in Chapter 11. However, those linkages are not recognised explicitly in this Chapter.

> *Recommendation:* **In each individual element in this Chapter, the Plan needs to identify who is the specific "user" of the results of the work.**

3. Considerable manpower resources (650 man-years) are devoted to the work within Chapter 6. The NEA Review Group considers this large allocation appropriate, because of the importance of the safety issues covered.

4. The NEA Review Group observes that the Plan does not seem to acknowledge the benefits of learning from research results already obtained in other countries.

> *Recommendation:* **In the Plan, advantage is to be taken of high-quality simulator work performed in the Czech Republic, the Slovak Republic, Hungary, and Finland, all of which have carried out projects specifically directed toward VVER-230 and VVER-213 operational safety and training. Also, work is now underway in Russia with collaboration and support from western countries on symptom-oriented procedures; this is to be acknowledged in the Plan, and the existing accomplishments is to be the foundation for the further work described here and is to be explicitly recognised as such.**

> *Recommendation:* **Generally, many of the proposed investigations in this Chapter could probably benefit from work already done at the Halden Reactor Project; Russia is a member of that Project.**

5. Training is organised quite differently in different countries because of cultural differences. This needs to be recognised in the work described here.

> *Recommendation*: **Programme 6.2, "Analysis of presentation system of safety parameters SPDS on full-scale simulators", is close to the OECD/NEA SCORPIO Project. Advantage is to be taken of this similarity even though the SCORPIO work may not be directly applicable.**

> *Recommendation*: **Programme 6.3, "Development of expert system for development support of symptom-oriented emergency instructions", is similar to the OECD/NEA PLASMA (PLAnt Safety Monitoring & Assessment) Project**. **These similarities should be exploited**.

6. Control-room simulators are now a commercially available item throughout the world. This needs to be recognised in this Chapter.

> *Recommendation*: **The word "internet" in Programme 6.6 is to probably be replaced, for clarity, by "internet technology". This is a detail but an important point of clarification**.

Chapter 7: Operational Safety and Human Factors

The scope of this Chapter covers advances in accumulating and assessing operational experience, accident-precursor analysis, human-factors studies, and database development. Priority is assigned to the precursor and human-factors aspects. The proposed work has close ties to work in Chapters 6 and 10, and could benefit from the PSA work in Chapter 11.

1. The Plan devotes substantial manpower resources (144 man-years) to this area. The NEA Review Group considers this allocation to be appropriate, although the distribution of effort needs careful evaluation.

2. Different countries need different research work in this area, because of the varying cultures, employment conditions, and hierarchical relationships within the workplace. This needs to be recognised explicitly in the work to be undertaken.

> *Recommendation*: **Russian working conditions and organisational structures, which are different from conditions and structures prevailing in OECD member countries, could in themselves be a useful topic for research.**

> *Recommendation:* **The proposed work potentially has close ties to work in Chapters 6 and 10, and could benefit from the PSA work in Chapter 11. These ties are to be developed explicitly.**

> R*ecommendation*: **In this Chapter as in the area of Chapter 6, advantage is to be taken of high-quality work performed in the Czech Republic, the Slovak Republic, Hungary, and Finland, which has been specifically directed toward VVER-230 and VVER-213 safety.**

> *Recommendation:* **In area 7.2.2 (accident precursors), the analysis models would need to be plant-specific. Advanced work in this area is underway in Germany, Finland, France and especially in the US, which for many years has had a very large "Accident Sequence Precursor Programme" sponsored by the US NRC. It might be useful to organise an international training seminar in this area to take advantage of existing experience in several western countries.**

> *Recommendation:* **In area 7.2.2 (accident precursors), emphasis is to also be placed on developing methodologies for collecting the operational data. Experience in many other countries could be useful here as a starting point.**

> *Recommendation*: **Item 6 on page 124 (Development of recommendations to create conditions for faultless actions of personnel) could include work on: design issues, instrumentation, lighting, accessibility, etc. as well as human aspects (too much overtime, fatigue, etc.). The work to be planned in this area is to be described in more detail.**

3. In Programme 7.3 on training and support of personnel, there is much good material. The effort planned for this area seems too difficult to accomplish, however, in the short time allocated (44 man-years in only 10 months.)

4. In Programme 7.4, where the formation of an operational data base is discussed, the concept is excellent and very much needed, but it is not adequately linked to other elements of the Plan in other Chapters, nor is there enough time (two years) to do all that is ambitiously described.

Chapter 8: Electrical Equipment

The scope of this Chapter covers studies of a variety of safety issues related to electrical equipment. Priority is assigned to developing inspection methods, automation approaches, man-machine interfaces with electrical equipment, and information-collection systems. The proposed work has ties to work described in Chapters 6, 7, and 10.

1. In general, the reviewers believe that Chapter 8 covers topics which actually fall into several different categories: development, human factors, maintenance in operation, etc.

> *Recommendation:* **It may be beneficial to reorganise this chapter's structure (perhaps distributing the topics over different chapters), and to review the emphasis put on the various parts of the chapter.**

2. The several topics in this Chapter are given uneven emphasis, considering their relative importance to NPP safety.

3. Qualification of electrical equipment has been for many years a major safety issue in the US and elsewhere. The Ignalina Safety Analysis Report has documented that some limited work has been done for some equipment

in Russia, but this was found to be insufficient for the needs of that SAR project. Work in this area is missing from the Plan.

> *Recommendation:* **The Plan is to include research projects to understand how equipment behaves in harsh accident conditions. This would include identifying the hazardous environment (including electromagnetic interference issues for digital equipment), identifying which equipment must work in that environment, and how to qualify the equipment for service in such an environment**.

> *Recommendation:* **The NEA Review Group recommends that important emphasis be given to this broad area, perhaps by assigning it a separate full chapter.**

4. No generic database is available, and data are almost always vendor-specific, or manufacturer-specific, or proprietary, or all of the above. This makes this area particularly difficult and expensive to pursue.

> *Recommendation:* **Relevant work has been performed in the Slovak Republic in connection with the safety upgrading of the Mochovce plant. In planning work in this area in Russia, advantage is to be taken of this**.

5. Programme 8.2 is a topic related to fires, but an adequate linkage is not provided to the fire work described in Chapter 9.

6. Programme 8.3 discusses digital systems but it needs a linkage to other parts of the Plan.

7. Perhaps programme 8.4 (Development of methodologies and Recommendations to reduce failures due to personnel errors during the maintenance of electrical equipment) would fit better in Chapter 7.

8. The reasons for including programme 8.5 (Development of 6 kV cells of a new generation with improved technical and cost-efficient characteristics for NPP of a new generation) are not clear; this item seems to the NEA Review Group to be basically industrial development.

Chapter 9: Fire Safety

The scope of this Chapter covers several safety-research topics in fire safety. Priority is assigned to developing methods for assessing fire hazards and fire impacts on safety, including adaptation of foreign computer codes. Development of a fire database and of fireproofing methods are also contemplated. The proposed work has ties to work described in Chapters 8 and 11.

1. All programmes in this area are assigned high priority, which does not provide enough differentiation.

2. Overall, the work on fires described in this Chapter does not have enough linkage forward from the research results to actual changes in plant configurations or plant operations that would improve NPP safety.

3. The NEA Review Group notes that electrical cabinets are found in western fire-safety studies to be a major source of potentially safety-significant fires, but are not given special priority in this Plan.

> *Recommendation:* **There is a need for specific VVER and RBMK fire databases. The development of these could usefully profit from experience and information associated with similar databases existing in the US at Sandia National Laboratories and at the Electric Power Research Institute**.

4. Programme 9.4 covers the important need for the Russian institutes to have advanced codes that model fire-phenomena. This is high-priority.

5. Programme 9.6, “Development of techniques to assess fire protection stability of process equipment to dangerous fire factors”, is considered of interest but is not sufficiently defined.

> *Recommendation:* **Likewise, proposed work associated with challenges such as smoke, ventilation, environment, temperature, pressure, and steam is to be described in more detail**.

6. Fire safety is an area offering several opportunities for co-operative research, including joint international projects.

Chapter 10: Severe Accident Management

This Chapter covers the initial effort to scope out how accident-management procedures can be implemented in Russian VVERs and RBMKs. Priority is assigned to summarising experience and developing guidelines, with implementation left for the future. The proposed work has ties to work described in Chapters 4, 6, 7, and 11.

1. This Chapter is written for VVER severe accident management, not for RBMK severe accident management.

> *Recommendation:* **RBMK accident management deserves a Chapter of its own.**

2. The work described in Chapter 10 is clearly only a first step, to be implemented during the first twelve to twenty-four months. One of the expected results of this work is the development of the basis for further work on accident management concepts for Russian NPPs, and for improving the guidance for accident management.

> *Recommendation:* **Even recognising that the nature of the work in Chapter 10 is mostly a one-year scoping task, the level of manpower devoted to the Chapter 10 work seems too low, considering the large number of different topics requiring evaluation. It is to be increased**.

> *Recommendation:* **There is a missing link between this Chapter and Chapter 4; possible design solutions to the problems identified in Chapter 4 are to be investigated (for example, hydrogen management, spray systems, depressurisation, vessel cooling, instrumentation, sump water pH control, fission product control, etc.)**

3. The proposed work is focused on methodology, not on the practical development of severe accident management programmes, so the work

therefore is not practical enough. The Plan does not discuss any linkages to experiments that could confirm the effectiveness of various accident-management measures. These are missing aspects of this part of the Plan.

4. The NEA Review Group believes that one of the reasons that the Plan stresses work on **prevention** aspects rather than **mitigation** aspects, contrary to current orientations of programmes in OECD countries, is that much of the prevention work has already been done in the OECD countries, but prevention issues still need further research in Russia.

5. Human elements is a very important factor in severe accident management.

> *Recommendation*: **Operator aids are discussed in Chapter 6, and operational safety more generally in Chapter 7. There is to be more co-ordination between Chapters 6 and 7 and this Chapter**.

6. Efforts are underway to develop symptom-based procedures for Ignalina, an RBMK in Lithuania. The project has tentatively found that while such procedures are well-developed for LWRs, additional research is needed in this area before they can be implemented for RBMKs.

Chapter 11: Probabilistic Safety Analysis

The scope of this Chapter covers developing or adapting PSA methodologies, including computer codes and databases.

1. The relative priorities in this Chapter seem to be excellent: 11.2 (PSA methods) and 11.7 (data for PSA) are clearly the most important areas in which Russian PSA capabilities and information need to be further developed.

2. The level of effort planned for this area (20 man-years) seems much too small considering the importance of PSA in so many different areas of NPP safety today.

Recommendation: **The NEA Review Group recommends that the amount of resources in the Plan devoted to PSA ought to be increased substantially, because this area represents a major opportunity to enhance safety**.

Recommendation: **The involvement of staff from the NPPs themselves is very important in plant-specific PSAs. This is to be reflected in the Plan.**

3. Many western countries are supporting a lot of PSA work in Russia today at specific NPPs, with the objective of bringing Russian organisations up-to-speed in this area.

4. In the US, a PSA Methodology Standard is in development and has just been issued for public comment (February 1999); the standard will probably respond to many of the Russian needs in this area.

5. PSA for shutdown and low-power conditions are an important area of PSA that needs to be given adequate support.

6. The Plan does not contain explicit work to translate the PSA results into safety improvements.

Recommendation: **The Plan is to be modified to include projects that will translate the PSA results into safety improvements at the operating NPPs.**

Chapter 12: Improvement of the Concept of Safety Assurance of Nuclear Power Plants – Development of the System of Regulations and Standards on Safety

The scope of this Chapter covers activities comparing the Russian safety-regulatory regime with regimes in other countries, so as to help improve the Russian regulatory approach.

1. It is not clear to the NEA Review Group why this chapter (which is really related to work to be performed by regulatory organisations) is included in the Safety Research Plan.

2. The objective of this work (see page 185 of the Plan) is to compare Russian safety norms and regulations with their analogues in OECD Member countries. This is identified in the Plan as a high-priority need.

3. The European Bank for Reconstruction and Development (EBRD) has performed a line-by-line comparison of Russian regulations with those of major OECD Member countries, at the request of the Lithuanian regulator. This work is available in both Russian and English languages. It is to partially answer the questions raised in programme 12.2.

> *Recommendation:* **Broad comparisons of Russian and western regulations are probably not very useful, although comparisons of specific norms and standards can be. In any event, a comparison of the written regulations is to be accompanied by an evaluation of how they are implemented and enforced, which is the area in which real safety benefits can occur**.

ANNEX II

RUSSIAN PARTICIPANTS
Moscow Meeting, 26-27 January 1999

Professor Armen A. ABAGYAN (Co-Chairman)
VNIIAES

Professor Sergey E. BUGAENKO (Co-Chairman)
Director, RINSC
(International Nuclear Safety Centre of Russian MINATOM)

Professor Rafael V. ARUTUNYAN
NSI RAS (IBRAE)

Dr. Alexander M. BAKHMETYEV
OKBM

Dr. Sergey L. BOUTORIN
VNIPIET

Dr. Alexander D. EFANOV
IPPE, Obninsk

Professor Leonid P. KABANOV
RINSC

Dr. Alexander G. KRAEV
RINSC

Professor Nicolay E. KUHARKIN
RRC “Kurchatov Institute”
(invited but unable to attend)

Mr. Yuri A. KURAKOV
MINATOM RF

Professor Semen D. MALKIN
RRC "Kurchatov Institute"

Dr. Maxim V. MEDVEDEV
RINSC

Dr. Lev N. PODLAZOV
RDIPE

Professor Alexander A. POPOV
ENES MAE, RDIPE

Mr. Victor G. SAMOVICHEV
REA

Mr. Valeri SLOUTSKER
STC GAN

Dr. Herman E. SOLDATOV
VNIIAES

Mr. Vladimir VITKOV
VNIIAES

Dr. Alexander ZHUKARIN
VNIIAES

OECD PUBLICATIONS, 2, rue André-Pascal, 75775 PARIS CEDEX 16
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