Unclassified **NEA/CNRA/R(97)5**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development

OLIS : 16-Feb-1998
Dist. : 06-Mar-1998

English text only

OECD OCDE PARIS

NEA/CNRA/R(97)5
Unclassified

NUCLEAR ENERGY AGENCY
COMMITTEE ON NUCLEAR REGULATORY ACTIVITIES

Cancels & replaces the same document:
distributed 13-Feb-1998

1997 CNRA SPECIAL ISSUE REPORT

REVIEW PROCEDURES AND CRITERIA FOR DIFFERENT REGULATORY APPLICATIONS OF PSA

English text only

61999

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article I of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- 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.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996) and the Republic of Korea (12th December 1996). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

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 all OECD Member countries except New Zealant and Poland. The Commission of the European Communities takes part in the work of the Agency.

The primary objective of the NEA is to promote co-operation among the governments of its participating countries in furthering the development of nuclear power as a safe, environmentally acceptable and economic energy source.

This is achieved by:

- *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.*

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

COMMITTEE ON NUCLEAR REGULATORY ACTIVITIES

The Committee on Nuclear Regulatory Activities (CNRA) of the OECD Nuclear Energy Agency (NEA) is an international committee made up primarily of senior nuclear regulators. It was set up in 1989 as a forum for the exchange of information and experience among regulatory organisations and for the review of developments which could affect regulatory requirements.

The Committee is responsible for the programme of the NEA, concerning the regulation, licensing and inspection of nuclear installations. The Committee reviews developments which could affect regulatory requirements with the objective of providing members with an understanding of the motivation for new regulatory requirements under consideration and an opportunity to offer suggestions that might improve them or avoid disparities among Member Countries. In particular, the Committee reviews current practices and operating experience.

The Committee focuses primarily on power reactors and other nuclear installations currently being built and operated. It also may consider the regulatory implications of new designs of power reactors and other types of nuclear installations.

In implementing its programme, CNRA establishes co-operative mechanisms with NEA's Committee on the Safety of Nuclear Installations (CSNI), responsible for coordinating the activities of the Agency concerning the technical aspects of design, construction and operation of nuclear installations insofar as they affect the safety of such installations. It also co-operates with NEA's Committee on Radiation Protection and Public Health (CRPPH) and NEA's Radioactive Waste Management Committee (RWMC) on matters of common interest.

ABSTRACT

As a follow-up to the 1995 Special Issues meeting on Regulatory Approaches to PSA, CNRA agreed to discuss Review Procedures and Criteria for Different Regulatory Applications of PSA in 1997. This report summarises Member countries responses to the questionnaire and the subsequent CNRA discussions on this issue. Three main topics are looked at: integration of PSA into the regulatory decision process; technical requirements of PSA with respect to using PSAs to support regulatory decision making; and methods of review for PSAs that will be used to support regulatory decisions. The report summarises experiences of respondents and provides general conclusions that have emerged as well as significant differences in approaches.

FOREWORD

In 1995 the Committee on Nuclear Regulatory Activities (CNRA) held a Special Issues Meeting on Regulatory Approaches to PSA. This meeting and the subsequently issued report, OCDE/GD(96)7, reported on a Survey of National Practices in Member countries. As a follow-up to this meeting, the CNRA selected Review Procedures and Criteria for Different Regulatory Applications of PSA as topic for the 1997 Special Issues meeting. A working group was organised to plan and structure the meeting and put together this report.

In offering thanks to working group members and other contributors (listed below), special acknowledgement is provided to several key persons who provided valuable time and considerable technical knowledge towards the production of the report and at the Special Issues meeting. These include Mr. Philip Webster (AECB) who prepared the presentation on Applications of PSA; Dr. Charles Shepherd (NII) on PSA Requirements; Dr. Pieter de Gelder (AVN) on PSA Review Procedures; and Mr. Mark Caruso (US NRC) on Integration of PSA into the Decision Process and the final Summary and Conclusions. Mr. R. Isasia also made significant contributions in compiling the questionnaire responses.

Additional thanks is offered to the US Nuclear Regulatory Commission who led this task and especially to Mr. Caruso who served as Chairman of the working group and provided overall co-ordination for organising the structure of the Special Issues meeting and towards completion of this report.

Working Group Members and Contributors (in addition to those already mentioned):

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1. EXECUTIVE SUMMARY

1.1 Introduction

At its annual meeting in November of 1995, the Committee on Nuclear Regulatory Activities (CNRA) agreed to hold a special issue meeting in June 1997 concerning, 'Review Procedures and Criteria for Different Regulatory Applications of Probabilistic Safety Assessment (PSA)'. A working group made up of staff from the member countries was established to undertake the necessary work in support of the special issue meeting. The working group developed and issued a questionnaire which was used to gather information from each member country used in preparing this report. The report serves as the basis for discussion by CNRA members at the special issue meeting. The discussion at the meeting, including any recommendations for follow-up activity, will be documented in this report when it is issued in final form.

Following a brief summary of how countries responding to the questionnaire are using their PSAs, the report focuses on three main topics: integration of PSA into the regulatory decision process, technical requirements of PSAs with respect to using those PSAs to support regulatory decisions and methods of review for PSAs that will be used to support regulatory decisions. In the sections of the report devoted to these topics, experiences of respondents are summarised and any general conclusions that have emerged are stated; also, any significant differences in approach are noted. The working group's summary and conclusions are provided in chapter 6 of the report.

1.2 Use of PSA in the Regulatory Decision Process

In regards to the use of PSA in the regulatory decision process, the working group found that many countries are using information from plant specific PSAs in support of regulatory decisions in an apparent ad hoc manner. The working group also observed that while technical methods or guidance for some applications (e.g., TS) have been published, neither the use of formal written guidance for applying PSA in specific licensing decisions (e.g., in-service inspection programme) nor specific plans for developing such guidance were reported in the responses to the questionnaire, with the exception of a few countries. Nevertheless, further development of guidance seems likely since (1) several countries are currently developing such guidance; (2) many countries indicated that insights from risk assessments were being used to some extent in making regulatory decisions in their country; (3) overall the response to this CNRA initiative has been strong (19 countries responded).

Several countries that are experienced in applying both deterministic and probabilistic assessment principles in the decision making process described experiences that are summarised in chapter 3. Also described are a number of good examples which illustrate how probabilistic safety assessment has supported the concept of Defense in depth-in-depth.

The working group observed that PSAs are now commonly used to support licensing reviews of new reactor designs and that in some countries the existence of such a PSA is a requirement.

1.3 PSA Requirements

Regarding technical requirements for the PSA that is used to support regulatory decisions, the working group found that there was general agreement that current general requirements for conducting a comprehensive PSA, with some modification, would be satisfactory for most applications. Some countries indicated that while some applications can be developed fairly simply from the base PSA results, (e.g., ranking of modelled components using their importance measures) other applications will require a significant amount of additional work, (e.g., comparison of risks of shutting down the plant versus continued operation at power).

There was general agreement among respondents that the PSA should be as realistic as possible, that data should be plant-specific and that the PSA should be updated after any substantial changes are made to (1) the design or operation of the plant, (2) the success criteria assumed in the PSA or (3) the data used for initiating fault frequencies, component failure rates or other important parameters.

In regards to PSA requirements for specific applications, the working group noted the following:

- A number of countries indicated that having a “living” PSA and the ability to do risk calculations in real-time are important for supporting plant configuration control during operation and maintenance;
- Countries which use the PSA in support of formal periodic safety reviews stressed the importance of keeping the PSA up-to-date, and to the extent possible, treating the effects of plant ageing;
- The USNRC indicated that it was currently developing guidelines for using the PSA in a number of applications, including several that involve categorising structures, systems and components with respect to safety importance. Guidelines for these latter applications will address the use of importance measures which are standard outputs of state-of-the-art PSA software packages and were reported to be in use by many countries.

1.4 Procedures for Review of PSAs

In regards to procedures for reviewing PSAs, the working group observed the following from the responses to the questionnaire:

- Most countries responding to the CNRA questionnaire indicated that they are currently using their own internal PSA review guidelines derived from experience;
- A country whose regulatory authority does not yet have the technical capability and resources for conducting a comprehensive review of a PSA application, requests assistance from the IAEA’s International Peer Review Service;
- Two formal, published review procedures (one from Switzerland and one from IAEA) were described in the responses to the questionnaire and provided to the CNRA working group.

1.5 Future Activities

The working group concluded the following in regard to continuing activities reported in response to the questionnaire:

- most countries are expanding their use of PSA in regulatory matters;
- several countries are developing general and application specific guidelines, including acceptance criteria, for using PSA in regulatory matters;
- several countries are developing procedures for review of PSA and PSA applications;
- two countries are integrating their living PSA programme with their operational safety programme.

2. INTRODUCTION

The Committee on Nuclear Regulatory Activities (CNRA) of the OECD Nuclear Energy Agency (NEA) (hereafter referred to as the Committee) is an international committee made up primarily of senior nuclear regulators that is responsible for the programme of the NEA concerning the regulation, licensing and inspection of nuclear installations. It was set up in 1989 as a forum for the exchange of information and experience among regulatory organisations and for the review of developments which could affect regulatory requirements. The Committee reviews developments which could affect regulatory requirements with the objective of providing members with an understanding of the motivation for new regulatory requirements under consideration and an opportunity to offer suggestions that might improve them or avoid disparities among countries who are members of the NEA. The Committee focuses primarily on power reactors and other nuclear installations currently being built and operated. It also may consider the regulatory implications of new designs of power reactors and other types of nuclear installations.

2.1 Background

Frequently, the Committee holds a “Special Issue” meeting focusing on the regulatory aspects of a current issue that are of interest to member nations. At its annual meeting in November of 1995, the Committee agreed to hold a special issue meeting in June 1997 concerning, 'Review Procedures and Criteria for Different Regulatory Applications of Probabilistic Safety Assessment (PSA)'. The US Nuclear Regulatory Commission (USNRC), which represents the United States of America (USA) on the Committee, agreed to take the lead in preparing for the special issue meeting, including co-ordinating the development of a special report describing the review procedures and criteria used or being planned for regulatory applications of PSA in member countries. A working group made up of staff from the member countries was established to undertake the necessary work in support of the special issue meeting. The working group developed and issued a questionnaire which was used to gather information from each member country. The nineteen members who responded to the questionnaire are listed in Table 2-1. Responses to the questionnaire were used by the working group to prepare this draft report. A copy of the questionnaire is provided in Appendix A. A summary of each response to the questionnaire is provided in Appendix B.

2.2 Objective

The objective of this report is to summarise various procedures and criteria being used or planned by member countries when applying PSA in the regulatory decision-making process. This report formed the basis for discussion by delegates to the Committee at the June 1997 special issue meeting. The results of the discussion at the special issue meeting are given in Chapter 6.

This report is a follow-up to the 1995 Special Issue report entitled, “Regulatory Approaches to PSA” [NEA, 1995]. The 1995 study examined the use of PSA by regulators based on a survey of practices, and only touched on the subject of review procedures and criteria necessary for overseeing the application of

PSA in the licensing arena. The current study for the '97 special issue meeting focuses in on the key issues that must be addressed in order to fully integrate PSA into licensing matters.

2.3 Overview of Report

Chapter 3 of this report reviews current applications of PSA and identifies areas where the use of PSA has been increased since the '95 Special Issue report was produced.. A brief description of current applications in each participating member country is provided in Table 3-1. The main sections of this report (Chapters 4 through 6 and Appendix B) are devoted to summarising the responses to the Questionnaire. Chapters 4 through 6 provide the Committee with a picture of the extent to which member countries are requesting, reviewing and applying PSA results when making decisions that come before them. Appendix B provides a summary of each member's response to the questionnaire. Chapter 4 describes how PSA is being used or may be used in the future for regulatory decision-making including, the integration of risk insights developed using the PSA and more traditional deterministic rule-based requirements. Chapter 5 covers technical requirements for generating PSA results to be used in regulatory decision-making (e.g., requirements on PSA scope, level of detail modelling and data). Chapter 6 discusses current approaches for review and approval of PSAs that support regulated activities, including the acceptance criteria or standards that are used to decide whether the analysis is acceptable. Chapter 7 summarises the observations and conclusions that have been drawn by the working group from the responses to the questionnaire. The working group briefed CNRA delegates on the report at the June 1997 Special Issues meeting. The results of the discussion at the meeting are summarised in Chapter 7.

Chapter 7 also summarises the observations and conclusions of the work which has been carried out on this topic and indicates the continuing activities and potential future activities by member countries that further enhance the use of PSA in the regulatory decision-making process.

Table 2-1. Respondees

Country	Organisation	Technical Contact
Australia	Nuclear Safety Bureau	Mr. D. MACNAB
Belgium	AIB-Vincotte Nuclear	Dr. P. DE GELDER
Canada	Atomic Energy Control Board	Mr. P. WEBSTER
Czech Republic	State Office for Nuclear Safety	Dr. J. DUSEK
Finland	STUK	Mr. R. VIROLAINEN
France	Direction de la Sûreté des Installations Nucléaires	M. M. LABATUT
Germany	Federal Office of Radiation Protection	Dr. R. GÖRTZ
Hungary	Hungarian Atomic Energy Commission	Dr. L. VÖRÖSS
Italy	ANPA	Dr. V. CAMMARATA
Japan	Nuclear Power Safety Policy Division, Agency of Natural Resources and Energy, MITI	Mr. H. SAKAYORI
Korea	Korea Institute of Nuclear Safety	Mr. J. HO SONG
Mexico	Secretary of Energy National Commission for Nuclear Safety	Dr. S. WALLER MEJA
The Netherlands	Ministry of Social Affairs and Employment Nuclear Safety Department	Mr. M.F. VERSTEEG
Slovak Republic	Nuclear Regulatory Authority of the Slovak Republic	Mr. A. DUCHAC
Spain	Nuclear Safety Council, CSN	Mr. R. ISASIA
Sweden	Swedish Nuclear Power Inspectorate	Dr. J. NIRMARK
Switzerland	Swiss Federal Nuclear Safety Inspectorate	Dr. U. SCHMOCKER
United Kingdom	HM Nuclear Installations Inspectorate	Dr. C. SHEPHERD
United States	Nuclear Regulatory Commission	Mr. M. CARUSO

3. APPLICATIONS OF PSA

The topic of the regulatory applications of PSA was the subject of the '95 Special Issue addressed by the Committee [see NEA, 1995]. In view of this, the questionnaire drawn up to gather information on the review procedures and criteria for these regulatory applications of PSA (see Appendix A) did not require the respondents to provide this information again.

Respondents were offered the option of referring to specific sections of the 1995 report or their response to its associated questionnaire. Some did this, but others provided new information, either a complete submission or a list of new or expanded applications. Some respondents listed only regulatory applications while others included also those of the plant designer or operator.

The '95 report identified five groups of applications as follows:

- identification of weaknesses in plant design and operation, and backfitting
- supporting plant operation
- supporting regulation
- off-site risk management.
- other, e.g., prioritisation of R&D.

Some countries who responded to the 1997 questionnaire had not responded to the 1995 questionnaire, and vice-versa. It has therefore not been possible to prepare a definitive summary of which PSA applications have expanded and how; but, it is clear that the advance of PSA continues.

In summary, it seems fair to say that all respondents have continued, or expanded, their level of use of PSA in all aspects of regulation including design evaluation, operation, maintenance, inspection and accident management. This is in part due to the improvements in the quality of the PSAs being produced and the computer and software facilities available. In general, Level 2 PSAs now seem to be becoming the standard in many countries, with more and more moving towards having a "living"[1] PSA for each plant.

The use of PSA is strongest in countries where both the regulator and utility see benefits. This requires of the regulator however, a willingness to accept that some traditional requirements placed on licensees may burden them without contributing significantly to safety. Allowing the licensees to re-direct their resources to areas with a bigger impact on safety can benefit both the public and the utility.

Besides design evaluation, which is an application in all countries, the most common application mentioned in the responses is that of optimisation of technical specifications, particularly in countries

1. A "Living" PSA is a study that is updated regularly to reflect the existing design of the plant and operational practices and procedures currently in use.

whose licensing approach has been influenced by that used in the USA. Of particular interest has been the application of PSA insights to technical specifications for low power or shutdown states.

Another growing area is application of risk assessment to configuration management, where combinations of specific component, train and system availabilities, and their associated risk levels are evaluated in (or close to) real time. This, however, requires the commitment of resources to develop and maintain a living PSA; such a PSA will provide the information to allow the plant to be operated in a way that will help to ensure that the risk is at a level which is acceptable and as low as reasonably practicable at all times.

A growing area seems to be that of event analysis. Several countries have been participating in a project to develop a state-of-the-art procedure for using a PSA to gain insights into the risk-significance of operational events. This will complement the traditional root-cause analysis and allow prioritisation of post-event investigations. It will also serve to verify and continuously improve the PSA models.

Also worthy of note is the use of PSA to prioritise inspection activity by the regulatory authority. This allows the regulatory authority to focus their efforts on those components, systems or topics which are the most risk-significant.

Applications reported by respondents are listed in Table 3-1.

Table 3-1. PSA Applications Reported in Response to the 1996 CNRA Questionnaire[2]

Country	Applications Reported in 1996	Comparison with 1995 Response
Australia	- used to confirm deterministic limits and conditions	did not participate in 1995 survey
Belgium	- design evaluation for periodic safety review - accident management (added H_2 recombiners) - event assessment (new methods development) - prioritisation of R&D	increased scope over 1995, where only design evaluation and accident management were discussed.
Canada	- no regulatory applications. - utilities using PSA to demonstrate compliance with their own safety goals and to monitor risk during outages.	outage risk monitoring is a change over 1995
Czech Republic	- evaluation of proposed plant modifications - prioritisation of plant safety improvements - periodic safety review (NPP & research reactors) - improvement of operational procedures, plant modifications and organisational measures - operational safety assessment - changes to technical specifications - on-line "risk monitor" developed - design review for new plants	
Finland	- evaluation of proposed plant modifications - temporary exemptions from technical specifications (TS) - re-evaluation of allowed outage times - new TS for shutdown states - changes to emergency operating procedures - event assessment	scope similar to 1995

2. Appendix A

Country	Applications Reported in 1996	Comparison with 1995 Response
France	- design evaluation - evaluation of potential plant modifications - periodic safety review - technical specifications - emergency operating procedures - events assessment - maintenance activities	scope similar to 1995
Germany	- event assessment - analysis of proposed backfits - accident management - periodic safety review - evaluation of new designs - in-service testing and inspection program	scope similar to 1995
Hungary	- design evaluation - prioritisation of plant safety improvements	did not participate in 1995 survey
Italy	- no current applications; nuclear programme is dormant	did not participate in 1995 survey
Japan	no regulatory applications; utilities are strongly encouraged by regulatory authority to apply PSA. - comparison of alternative reactor designs - improvement of operational procedures and operator training programme. - accident management planning - periodic safety review - prioritisation of research activities	scope similar to that reported in 1995
Korea	- identification and evaluation of alternative design and operational strategies	scope similar to that reported in 1995

Country	Applications Reported in 1996	Comparison with 1995 Response
Mexico	- risk based evaluation of licensee event reports - prioritise risk-based inspections - operator training and examination - optimisation of technical specifications - risk based configuration management scheme being developed - maintenance effectiveness.	did not participate in 1995 survey
The Netherlands	New applications not reported in 1995 include: - backfit analysis for 1997 mods to Borssele - accident management measures identified	The following key applications reported in 1995 still apply: - design evaluations - technical specification improvements - prioritising inspection activities - event evaluation - improvement of operator training program - accident management planning - prioritisation of research and development activities
Slovak Republic	- evaluation of proposed safety upgrades - technical specification optimisation - event assessment	did not participate in 1995 survey
Spain	- improvement of design - improvement of procedures (test, calibration, emergency, etc.) - improvement of technical specifications. - analysis of incidents and operating experience. - evaluation or improvement of operator training programmes. - maintenance programme applications (pilot studies) - analysis of compliance with deterministic regulations, especially using a fire PSA.	Some advances since 1995, especially in TS exemption and incident review

Country	Applications Reported in 1996	Comparison with 1995 Response
Sweden	Update to 1995 response includes improved PSA data collection, especially on common cause.	The following key applications reported in 1995 still apply: - design evaluation - evaluation of proposed safety improvements - optimisation of technical specifications - maintenance planning - operational safety management
Switzerland	- periodic safety reviews - decision-making tool for design optimisation or backfits; - improvements in emergency operating procedures - technical specification optimisation, especially based on the results of the shutdown and low power PSA - accident management planning	some advances since 1995, especially in emergency operating procedure improvement, TS optimisation and accident management
United Kingdom	- identification of weaknesses in design or operation due to better level 1 PSAs not available for the magnox reactors, the level 2 PSAs being produced for the AGRs and the more detailed PSAs being produced for other types of nuclear installations. - determining allowable outage times and configuration control during operation and maintenance, - emergency planning	expanded use since 1995, particularly in design evaluation.

Country	Applications Reported in 1996	Comparison with 1995 Response
United States	- analysis of new reactor designs, - incident analysis and precursor studies, - optimisation of technical specifications, - improvement of operator training programs, - analysis of probabilistic safety indicators, - prioritisation of inspection activities, - optimisation of quality assurance programmes - optimisation of in-service testing/inspection - cost/benefit analysis of new proposed requirements (e.g., shutdown operations).	expanded use since 1995 in many areas consistent with the USNRC Policy statement regarding uses of PSA in regulatory activities [USNRC, 1995] and PRA Implementation Plan [USNRC, 1997]

4. INTEGRATION OF PSA INTO THE REGULATORY[3] DECISION PROCESS

Nuclear power plants in member countries have for the most part been designed, constructed and are operated based largely on a deterministic safety philosophy. In this approach to safety, a specific set of challenges (e.g., rupture of a reactor cooling water pipe) to the plant is first postulated; then, using analysis of the potential consequences of these challenges, design and operational requirements are derived such that there is high confidence that these challenges will be mitigated in an acceptable way. Because of the approximate nature of the analysis and uncertainty in the scope of the analysis as well as the methods, assumptions and data used in the analysis, a substantial amount of safety margin is incorporated in the design and operational requirements. Safety margin is incorporated by requiring redundant and diverse systems to mitigate challenges and multiple independent barriers that limit the release of radioactive material. Additional margin is incorporated by applying the highest quality engineering codes, standards and practices and the concept of Defense-in-depth to safety related equipment and activities, by including conservative safety factors in the design of certain systems, structures and components and by using conservative assumptions and conservative acceptance criteria when analysing plant response to challenges.

Probabilistic safety assessment is based on an analysis technique that ultimately permits an explicit, detailed, quantitative assessment of all possible accident sequences and their impact on public health and safety. It also permits a systematic, quantitative assessment of the uncertainties in the analysis. The challenges addressed in the deterministic approach are a special subset of those treated explicitly in PSA. As the probabilistic approach has been improved and refined, it has offered the designer, operator and regulator a more detailed and realistic picture of the safety importance of plant design features, operating procedures and operational practices. This picture has provided considerable insights that were not visible with the less detailed first generation analysis methods used in the design and licensing of most plants.

Deterministic and probabilistic safety assessment techniques are engineering tools-- each with their own strengths and weaknesses--being used in all member countries to varying degrees. The deterministic approach has for the most part produced safe plants; while the probabilistic approach offers the potential for optimisation with respect to both safety and economics. Integration of these two approaches to support regulatory decisions is about using the strengths of these two tools and what they have already brought to bear together to help make the best possible regulatory decisions.

3. The meaning of the terms regulatory and regulatory authority vary to some degree among member countries. In context of this report these terms refer to those actions and organisations whose principal focus is protecting the public from the potential hazards of producing electricity with nuclear power plants.

4.1 Relative Roles of PSA and Deterministic Assessment in the Decision-making Process

Many countries responding to the CNRA questionnaire indicated that regulatory decision-making should be based on a mix of deterministic and probabilistic assessments; and that those assessments can and should complement one another. In all countries, deterministic requirements are applied in the design and operation of nuclear facilities. In some countries, these requirements are fixed in law, and must be used (until they are changed) in regulatory decision-making where the rules provide explicit requirements. However, in some countries, there are issues, especially those encountered during plant operation (e.g., approvals of maintenance, testing and inspection approaches) for which no explicit criteria for approval exist and the regulatory decisions are necessarily made using experience and judgement based on engineering analysis. For such cases, availability of a PSA was cited by some countries as being beneficial and improving the basis for decisions that otherwise would be made based solely on deterministic engineering analysis. In the same regard, some other countries noted that insights from PSA will be helpful in improving decision criteria in the future.

It was reported by the USA that the concept of a mix of deterministic and probabilistic assessments which complement one another is at the heart of policy of the regulatory authority. They reported in their response that the traditional deterministic approach to regulation contains elements of probability such as the selection of credible design basis events and application of the single failure criteria; and the probabilistic approach to regulation is an extension and enhancement of the traditional deterministic approach, (e.g., PSA addresses a broad spectrum of initiating events by assessing the event frequency, and mitigating system reliability, including the potential for multiple and common cause failures.)

The United Kingdom (UK) reported that their decision making process is informed by the insights gained from the assessment made against both the deterministic and probabilistic principles; and, experience has indicated that these insights are generally in agreement (e.g., a failure to meet the single failure criterion for most active failures would be likely to equate to a low reliability of a redundant safety system.) This was the case for the improvements they made to one class of reactors which were identified as being required from both the engineering/ deterministic assessment and the PSA. However, they also cited cases where the insights gained from the assessment against the engineering/ deterministic and probabilistic principles where not in agreement. For example, the UK response described a situation where questions were raised regarding the acceptability of a single water supply tank for the emergency core cooling system. It was proposed that a second tank be added to satisfy the deterministic requirement for redundancy in safety systems. However, the PSA supported the conclusion that the addition of a second tank would not reduce risk enough to make it a justifiable safety improvement.

The overall consensus is that the deterministic and probabilistic approaches each have particular strengths and weaknesses. There have been summarised in Table 4-1. It can be seen from this table that the strengths in one approach can compensate for the weakness in the other approach.

Table 4-1. Strengths and Weaknesses of Deterministic and Probabilistic Assessments

	Deterministic approach	**Probabilistic approach**
Strengths	All safety issues are addressed explicitly, e.g., redundancy, diversity, equipment qualification, segregation, separation, etc. Conservative approach adopted which ensures that there is a margin to safety in accident conditions. Addresses human performance as a separate issue which ensures that the requirements to aid reliable performance are identified.	Considers the complete range of accident sequences and multiple failures included within the scope of the analysis Safety issues are addressed together thus ensuring a balanced approach. Takes account of the interdependencies between safety systems/issues explicitly. Uses a best estimate approach which ensures that all safety issues are treated equally. Allows uncertainties to be quantified.
Weaknesses	Safety issues are addressed separately which could lead to excessive requirements for some of them compared to the others. May miss some issues - particularly those which arise due to interdependencies. Does not systematically examine uncertainties.	Scope of the analysis may be limited so that it does not model all structures, systems or components. Some safety issues may not be addressed - e.g., pipe breaks in particular locations. Making judgements based on the PSA may be difficult in some cases due to large uncertainty in the results.

4.1.1 Licensing New Plants

All of those countries responding to the questionnaire indicated that while their current regulatory requirements and many of their regulatory procedures are based on a deterministic approach to reactor safety, they are either now utilising or plan to utilise the insights from risk assessments and the analytical power of risk assessment tools in making regulatory decisions. Indeed, while many plants operating in CNRA member countries were designed, constructed and licensed without the benefit of a PSA, it is now a requirement in some of these countries that a PSA be completed and reviewed by the regulatory authority before a construction permit or operating license is granted. Risk studies for new power plants are usually performed to identify vulnerabilities to severe accidents in the design of the plant, assess environmental impact, assist in emergency planning and assess the overall balance of the design. In the USA, such studies were helpful in confirming the safety benefits of a rapid depressurisation capability in an advanced pressurised water reactor design. In the UK, they confirmed that a filtered venting system was not required to protect the containment in a PWR following a core melt sequence in which the pressure was increasing in the long term.

In France, PSA is used to supplement the deterministic review of the plant design. For the N4 Series reactor design, some “beyond design basis accident” sequences (ATWS, Station Blackout, total loss of heat sink and total loss of steam generator feedwater) were required to be taken into account in the design. For the EPR design, some general probabilistic objectives were established by the regulatory authority. They included reducing core damage frequency below that for earlier designs and eliminating , for all practical purposes, outlier sequences with the potential for a large early release.

4.1.2 Regulation of Operating Reactor

The role of PSA in the day to day oversight of operating reactors varies considerably among member countries. At one end of the spectrum are countries with small nuclear programmes that are in the process of developing level 1 PSAs for their plants with plans to use the PSAs in regulatory oversight in the future. At the other end of the spectrum are countries with level 1, 1+, 2 and in some cases level 3 PSAs completed and reviewed for their plants and rules which require that these PSAs be used to varying degrees in regulated activities. In the middle of the spectrum are countries which do not have legally binding, risk-based decision criteria, but are advanced in their use of insights from PSAs to make better informed decisions. Some examples of formal use of PSA in the regulatory decision-making process regarding operating reactors follow.

In Finland, both deterministic and probabilistic considerations are required from licensees and applied in parallel to make regulatory decisions concerning operational safety. Plant specific living PSA’s are available for all operating plants. The results of the PSA must be considered in support of decisions on operational safety issues. In numerous cases the PSA has prompted the utility and the regulator to undertake safety provisions which were not recognised with deterministic reviews. However, irrespective of the fact that PSA was the incentive for the safety improvement, the regulatory authority always uses the deterministic review to ensure the conclusions drawn from the PSA are accurate and to complement the PSA review.

In the UK, all the nuclear licensed sites are required to have a safety case which includes a PSA to evaluate the design and operation of the plant and demonstrate that the risk to workers and members of the public from the plant is both tolerable and as low as reasonably practicable (ALARP). It is a condition of the site license that the safety case/PSA is updated during the lifetime of the plant to take account of plant modifications, new data or information which changes the basis of the analysis. An assessment of the safety case/PSA is carried out by the regulatory authority. This is done against the Safety Assessment Principles for Nuclear Plants (SAPs) which gives guidance on the deterministic requirements and defines the numerical safety criteria which need to be used in judging the results of the PSA. The regulatory decision making process is informed by the insights gained from the assessment made against both the deterministic and probabilistic principles.

Several countries indicated that in cases where they have considered information from the PSA in formal regulatory decision-making, the PSA has been tailored specifically for the application and coupled with other pertinent deterministic information to support the decision-making process. In these cases, the PSA is built from a baseline plant model and includes improvements in scope, level of detail, modelling assumptions, data, etc. deemed necessary by the user and the regulatory authority for the specific application in question. Examples of this process include review and approval of changes to technical specifications and system design reviews. When this approach is used it is especially important that changes to the model deemed necessary be justified and documented explicitly.

4.2 Integration of PSA Results with Deterministic Assessments in the Decision Process

Although many countries are considering information from plant specific PSAs regularly in the decision process and some are doing this per their requirements, formal regulatory guidelines and review procedures for specific applications (e.g., in-service inspection programme) are not in widespread use. Some countries indicated that formal written guidance is desirable; others took a contrary view based on their laws and policies and the nature of the relationship between the licensee and the regulatory authority (e.g., the relationship is sometimes less formal in countries with a small number of plants, such as Switzerland.)

In Spain, the regulatory process is basically deterministic; nevertheless, PSA insights are increasingly being taken into account. PSA arguments are developed and provide an additional input to the decision analysis; but, no formal criteria have been established to define the relative weight of such arguments in the decision process. Decisions are made on a case by case basis. The relative weight of probabilistic arguments is case specific, and there have been cases where PSA arguments were used to reject utility proposals that otherwise would be acceptable from the deterministic point of view. On the other hand, only negligible risk increases are accepted by the regulatory authority, or compensating alternate measures are required. In the case of compliance with fire protection regulations, PSA insights have played an important role in determining what plant modifications were really necessary.

Finland reported that use of PSA is required in parallel with use of deterministic rules in certain situations. This requirement was established after a number of experiences in which it was found that deterministic considerations alone would not provide all the necessary information needed to determine the appropriate regulatory action in response to events at operating reactors. The principal guidance for implementing this requirement is contained in a regulatory guide.

In the Czech Republic, the PSA has been used in conjunction with traditional engineering assessments to improve the quality of the technical specifications (TS) at the Dukovany nuclear power station. A risk-based assessment by a contractor was conducted first which lead to a recommendation for twenty-seven changes to TS, including two new TS, six reductions in allowed outage times (AOT) and nineteen increases in AOTs. These proposed changes were then evaluated by the utility and the regulatory authority with consideration given, but not limited, to issues not covered in the PSA and the uncertainty in the PSA. Based on these evaluations it was decided jointly by the utility and regulatory authority to accept the two newly proposed TS, five of the six proposed AOT reductions and three of the nineteen proposed AOT extensions.

In the Netherlands, amendments to the licences of operating reactors will require the licensees to have an operational living PSA. However, the exact content of the living PSA has not yet been defined. Both the licensees and the regulatory authorities are in a process of defining the boundary conditions for the possible applications. The use of PSA for configuration control, optimisation of technical specifications, or event analysis might be objectives to be pursued. It is expected that there will be some reluctance in accepting the final numerical outcomes because of uncertainties, incompleteness, too simplistic models, etc., of PSAs. However, final numerical outcomes will unavoidably play a role in the decision-making process.

Several European countries reported that, PSA and deterministic assessments are integrated within the context of a formal periodic safety review (PSR), which is conducted about every ten years. The deterministic part of the review includes a comparison of the design and the operational state of the plant with safety requirements in-place at the time of the assessment. In German periodic safety reviews, the PSA is used to examine the frequency of significant event sequences and the sum of all event frequencies. Additionally, the need for remedial action, (i.e., backfit) is considered if a significant event sequence, 1) shows higher as compared to reference values; 2) includes a short period of time between the initiating event and occurrence of damage, or if estimates show substantial radiological consequences for this event sequence.

The UK reported that the decision making process is informed by the insights gained from an assessment made against both the deterministic and probabilistic principles. Where these insights are different, there are no formal procedures to resolve this and it has been done on a case-by-case basis. The usual approach has been that: if either of the approaches has identified that improvements could be made to reduce this risk, this would be required unless the licensee could demonstrate to the satisfaction of the regulatory authority that there was an overwhelming case for not doing so. A similar approach is taken in Switzerland.

In the USA, regulatory guides (RG) and standard review plans (SRP) are normally used to articulate NRC staff positions and guide licensees and applicants in meeting the Commission’s requirements. The USNRC is currently developing new regulatory guides and inspection guidance, and updating their SRPs to address the application of PSA in developing programmes for in-service testing, in-service inspection, graded quality assurance, and in modifying technical specifications.

4.3 Use of PSA Insights for Consideration of Defense-in-Depth

Defense-in-depth is an approach to safety according to which accidents are prevented through redundancy and diversity and plants are designed and operated in such a manner that accidents that threaten public health can occur only if multiple (redundant) and diverse pieces of equipment (or human actions) fail. Release of radioactive materials from the reactor to the environment is prevented by successive and mutually independent passive barriers: fuel cladding, reactor coolant pressure boundary, and containment structure. These barriers, together with an imposed exclusion area and emergency preparedness, are the essential elements of Defense-in-depth at most nuclear power plants throughout the world. Given these multiple barriers, assurance of safety is provided by application of deterministic safety criteria for the performance of each barrier, and design and operation of systems (lines of Defense) to support the functional performance of each barrier. Maintenance of Defense-in-depth dictates that risk-informed decision-making not be made on the basis of public risk alone. The potential for core damage and containment failure must be considered along with deterministic information that bears on the reliability of key safety functions.

Most countries responding to the questionnaire indicated support for the notion that the PSA can and should be used to support and enhance the Defense-in-depth philosophy of reactor safety. And where some countries described ways in which the PSA has been used to identify excess conservatism in design or operation, no country suggested that the PSA should replace the existing deterministic approach to safety. A number of countries described applications of PSA that have strengthened Defense-in-depth; these applications are summarised below.

4.3.1 Balanced Design

The PSA can be used to demonstrate that the plant design is well balanced and not vulnerable to single failures or common mode failures. This is a well known application of PSA and one that carries a relatively low amount of uncertainty among PSA applications. Many countries mentioned that they employed this application of PSA. In the UK, the considerations of whether the design is balanced include the following: no single group of fault sequences dominates the total risk; excessive reliance is not placed on a particular system or provision to protect against accidents; the design of the engineered safety provisions is fault tolerant; and that there is no “cliff-edge” effect resulting in an unacceptable increase in risk from accidents beyond the design bases.

4.3.2 Safety During Non-power Operating Modes

Several countries pointed out in their responses that one of the major risk insights learned from the level 1 part of their PSAs is the non-negligible contribution to risk in non-power states, (e.g., on the order of 25 to 35 % of the total core melt frequency for plants in Belgium and the UK). Taking into account that this contribution is related to operating states representing only a fraction of the total operating time, these results indicate that the core melt probability per hour in the non-power states may, under some conditions, be higher than in the power state. These observations suggest that Defense-in-depth during the non-power states is not so well implemented as in the power states. Looking back to the deterministic safety analyses performed for the operating plants this is not such a surprise. It is clear that in these analyses much more attention has been paid to safety in the power states. A case in point reported by Finland was the lack of a requirement for the lower air lock of the containment to be closed during maintenance of the main circulation pumps (performed during shutdown). The consequence of a rapid uncontrolled draining of reactor coolant initiated during the maintenance activity had not been considered in the original deterministic safety analyses for the plant. However, the results of the PSA drew attention to the fact that if the loss of coolant accident took place and the lower air lock was open, the water would escape out of the containment preventing any core cooling measures and leading to core damage within a short time with an open reactor vessel and open containment. A requirement to keep the air lock closed during the aforementioned maintenance is now in place. Hence, an insight on Defense-in-depth, gained from the PSA, was that safety in non-power states should perhaps be looked at more closely, applying the same Defense-in-depth ideas as the ones used in the past for the power states.

4.3.3 Mitigation of Severe Accidents

Several countries (Belgium, Germany, The Netherlands, Switzerland, UK and USA) reported the use of level 2 PSA to identify hardware and procedural (accident management) modifications that would be effective in mitigating the consequences of a severe accident in progress. The impetus for doing this were the Three Mile Island and Chernobyl accidents. In essence, these experiences challenged the notion that severe accidents that could put the public at risk were incredible and prompted public officials to exploit

PSA tools to determine if new hardware or accident management procedures to mitigate the consequences of severe accidents should be incorporated into the plants. Some of the measures taken included installation of catalytic hydrogen recombiners and use of the fire suppression system to improve the containment heat removal safety function. In the UK, consideration was given to the incorporation of a filtered containment venting system in a PWR to provide further Defense-in-depth for fault sequences in which the core had melted and the pressure inside the containment was increasing slowly. However, the level 2 PSA showed that there was little benefit in terms of risk reduction from the incorporation of such a system.

The measures described above contribute to extending the concept of Defense-in-depth to severe accident scenarios. Indeed, while in the original deterministic approach to reactor safety the main emphasis was on prevention of severe accidents, the above mentioned backfitting introduces an important feature for mitigation of such scenarios which can be thought of as an additional level in the Defense-in-depth-concept.

5. PSA REQUIREMENTS

Question 3 of the CNRA questionnaire (Appendix A) was posed to gain an understanding of what requisites are considered as a necessary minimum to deal with specific PSA applications, including requirements for scope, level of detail, key assumptions, sensitivity analysis, data sources, modelling approach, success criteria and treatment of uncertainty. In addition, any unique features of an application, with specific requirements, were to be highlighted in the response to the questionnaire. Respondents were asked to address the following three specific applications, if they had done work in these areas:

- configuration control during operation and maintenance;
- demonstration of adequate safety level of plants designed to earlier standards
- change in regulatory requirements with regard to in-service inspections, testing and safety classification of systems and components.

Most of the countries based their responses on either their current general PSA approaches or their foreseen PSA scopes and did not discuss specific requirements for specific applications. Many countries indicated that their current general requirements with some modification will be satisfactory. Others indicated that their probabilistic assessment tools will be designed in accordance with their planned applications as each individual application is developed. One country, The Netherlands, has developed guidelines for conducting PSA which indicate the degree to which the objectives of specific applications can be met using various treatments of key PSA components, such as success criteria and data. The USNRC is currently developing general as well as application specific technical requirements for PSA that supports proposals by licensees and applicants in the areas of in-service testing, in-service inspection, technical specifications and graded quality assurance. Some requirements have been established by the USNRC pertaining to test programmes for motor operated valves in boiling water reactors. These requirements are discussed below in section 5.2.3. The response from Spain referenced an IAEA study [IAEA, 1993], on modelling and data prerequisites for specific applications of PSA. This study considers the following applications: design evaluations, backfitting, configuration management, maintenance planning, technical specifications, on-line and off-line incident analyses and assessment and mitigation of ageing effects. The report on the study discusses lessons learned from IAEA sponsored peer reviews which includes a discussion of specific modelling problems frequently observed in PSAs.

Formal procedures and guidelines for conducting PSAs reported by member countries in their responses to the questionnaire are listed below.

- Regulatory Guide YVL 2.8 (Finland)
- Dutch Procedures for Conducting Level 1 PSA (Final Report)
- Dutch Procedures Guide for Conducting Level 2 PSA (Draft)
- Level 3 PSA Guidelines, SVS 1995/25 (The Netherlands)

- NUREG/CR-4550. Vol. 1, Methodology Guidelines for NUREG-1150 (USA)
- IAEA 50-P-4, Procedures for Conducting PSA (Hungarian Republic)
- Draft NUREG-1602 (under development in the USA)

5.1 Common Characteristics of PSAs

There has been a wide range of responses regarding what the technical requirements of the PSA should be; however, some PSA characteristics that are common in many countries can be identified. Common characteristics are discussed below.

5.1.1 Scope of the PSA

There have been two approaches to arriving at the scope of the PSAs currently carried out in the different countries. Some countries have started by setting high level safety goals and have required that PSAs are carried out to address them. In this approach, the emphasis is on completeness in that a full scope PSA is required which addresses all the potential contributions to the risk including those from internal and external hazards and covers all plant states including shutdown. In addition, all extreme events with direct and severe consequences such as reactor pressure vessel rupture also need to be considered.

The alternative approach followed in other countries is to carry out a PSA where the scope is limited initially to areas in which the analysis has achieved a good degree of maturity and for which there is a reasonably good set of data. The scope of the analysis is then increased as PSA methods are developed and the required data becomes available. In general, the initial analysis has considered internal events and the scope has been increased to include internal hazards such as fire and flood, external events such as earthquake and aircraft crash and other plant states such as shutdown and refuelling.

In all countries, level 1 PSAs have been carried out to determine the frequency of a core melt. In many cases, this has been extended to level 1+, which has considered the operation of the active containment systems in mitigating the consequences of the fault sequences identified, or to level 2, to determine the releases of radioactivity which would occur. In a few cases this has been further extended to a level 3 analysis which has addressed the health effects to the public and the environmental consequences. In most countries, level 2 PSAs are the normal standard.

A number of respondents agreed that the PSA should be defined in accordance with the application; in other words, the PSA should be tailored specifically for the application. This could mean for example that a PSA which treats non-power (shutdown) modes of operation would not be required for an application that affected only full power operation of the plant.

5.1.2 Level of Detail

A highly detailed construction of a base PSA model has been emphasised in order to easily maintain a PSA in a "living" mode, allow the quantification of dependencies, especially in electrical and I&C systems, and have a base PSA that can be easily adapted for all future applications.

5.1.3 Key Assumptions

It was agreed that all assumptions introduced should be clearly specified and justified. Assumptions should be as realistic as possible. Where this is impractical, a reasonably conservative approach has been accepted. Assumptions that simplify system modelling should be made only if justified particularly those related to support systems.

Spain reported that they are developing an assumption data base which will permit comparison of assumptions among plants in order to understand differences in some PSA insights and provide a basis for future actions to increase the homogeneity among PSA's.

5.1.4 Data Sources

It was agreed that plant-specific data should be used throughout the PSA for both initiating event frequencies and component unavailabilities, supported by a Bayesian updating of generic data if it is necessary. A continuous plant specific data collection and processing system, set up and maintained by each licensee, is considered important by many countries for achievement of good quality data. Plants in some countries have operating experience feedback programmes which yield plant specific data for use in the PSA. Generic data should be used only when plant specific data do not exist or they are so scarce that reasonable reliability estimates cannot be provided. The licensees in some countries, such as the UK and Finland, are required to determine ageing effects and their impact on the data.

5.1.5 Modelling Approach

There are at present a variety of approaches possible for carrying out a PSA and numerous software packages to support them. These range from the large fault tree approach to the very large event trees/small fault tree approach, all of which can be carried out using one of the many fault tree software packages available.

The preferred approach in most countries is the small event tree/large fault tree approach.

However, in trying to get a correct treatment of dependencies among systems and the initiating event some analysts have turned to the Large Event Tree/Large Fault Tree approach, as in the Spanish case. This means that some support systems have had to be included in both kinds of trees for some loss of support system initiators. Given the high redundancy of most systems, it can be expected that CCFs will contribute significantly to their failure probabilities; and therefore, special attention should be devoted to CCF modelling and quantification.

The human reliability assessment should cover pre-initiator and post-initiator human errors. Errors of commission should be considered to the extent possible; some countries, such as The Netherlands, Belgium, and the UK have already considered some of these errors in some of their PSA's.

Operator recovery actions during faulted conditions are credited only when written procedures and training exist. Credit for non-safety systems is usually given when licensees show their availability and capacity to meet the success criteria in a particular fault condition.

5.1.6 Success Criteria

One of the cornerstones of the PSA is the development of the success criteria for the operation of the safety systems during accidents. The preferred approach in all countries is that these success criteria should be based on best estimate transient analysis. Where this is not possible, conservative assumptions should be made.

In carrying out the PSA, the usual practice is to group the initiating events, choose a bounding fault for the group and to apply the success criteria for the bounding fault to all the members of the group. This is necessary to limit the amount of analysis required to a manageable amount. It is recognised that the grouping/bounding process will inevitably introduce a degree of conservatism into the analysis and it is necessary to ensure that this does not give a strong bias to the PSA results.

5.1.7 Sensitivity Analysis

In conducting a PSA, it is normal practice and, in some cases, a requirement that studies are carried out to determine if the results of the PSA and the conclusions drawn from them are sensitive to the assumptions made and the data used. The assumptions are addressed one at a time and it is generally required that the range of the sensitivity studies should address the uncertainties in data, assumptions and phenomena.

One difficulty mentioned by some countries is the absence of criteria for judging when the results provided by sensitivities are significant. In the UK, research is being carried out to try to develop criteria for judging whether the results of sensitivity studies are significant.

5.1.8 Uncertainty Analysis

An uncertainty analysis determines the distribution of the risk which arises from the uncertainties in all the assumptions made and the data used in the PSA taken together. In some countries, uncertainty analyses are normally carried out to put the results of the PSA in perspective. Such an analysis is not required in the UK.

5.1.9 Updating the PSA

In countries where “living” PSAs are maintained, the PSA models and data are updated regularly. All participants agreed that the PSA should be updated after any substantial changes are made to the design or operation of the plant, the success criteria assumed in the PSA or the data used for initiating fault frequencies, component failure rates, etc. However, in some cases, the PSAs are updated more frequently than this.

5.1.10 Plant Staff Involvement

Carrying out a PSA requires that the analyst have a thorough knowledge of the way that the plant is design and operated. In view of this, it is considered very important in many countries, that the plant staff should be significantly involved in the development of the PSA and also the main user of it, even if the PSA is performed by a contractor.

5.2 PSA Requirements for Specific Applications

Apart from the general PSA requirements discussed above, additional requirements normally apply for specific applications of the PSA (e.g., design reviews, technical specification changes). While some applications can be developed fairly simply from the base PSA results, e.g., ranking of modelled components using their importance measures, other applications could require a significant amount of additional work, (comparison of risks of shutting down the plant versus continued operation at power). Some remarks about specific requirements for specific applications, including the three applications highlighted by the Committee in question 3 on the questionnaire, are presented below.

5.2.1 Configuration Control During Operation and Maintenance

This application is one of high priority in most countries. Many countries reported that they are utilising the PSA for configuration control and maintenance planning and others identified it as an application they are pursuing. PSA-based, on-line “safety monitors” have been installed in plants in the USA, UK and Czech Republic, to name a few countries. Some of these devices employ fast running software that allows risk analysis to be conducted in real-time. For example, a model used at the Dukovany nuclear power station in the Czech Republic employs a single master logic fault tree and can requantify the entire PSA for any plant configuration, without any loss of information, in 2-4 minutes, depending on the computer hardware configuration.

In the Czech Republic, the Safety Advisory System (SAS) has been installed in the Dukovany nuclear power station and in the headquarters of the regulatory authority. It has been used since January 1995 to analyse operational data from each of the four Dukovany units. Assessments with SAS are normally performed by the Dukovany staff each month and on demand by request of the regulatory authority. The SAS is also used as a support tool to evaluate utility requests for extensions to allowed outage times for plant equipment.

Requirements for using PSA for configuration control during operation and maintenance will include a mixture of those that have been applied in general to living PSA and more specifically to areas such as assessment of allowed outage times and system reliability studies. A lot of effort has been devoted to the development of a living PSA in Finland, Sweden [SKI, 1994] and in the UK. In Finland this has culminated in a requirement that utilities submit information from the PSA in support of all safety related system modifications, and in agreements with utilities on how the PSA will be kept living and used for operational safety assessment.

In the UK, the regulatory authority requires the licensees to use the PSA to justify that the allowed outage times and configurations they propose do not result in a significant increase in risk when averaged over all equipment outages and does not lead to the point-in-time risk exceeding any basic safety limits. This is normally done by carrying out a series of sensitivity studies off-line to determine how the risk would change during such outages and building this into the plant operating instructions which are the equivalent of the technical specifications at the Sizewell B PWR and in other countries. For Torness, the results of these sensitivity studies have been included in look-up tables which identify the allowable combinations of equipment unavailabilities and are used by the operator in planning plant outages. For Heysham 2, an on-line system, the Essential Safety Systems Monitor (ESSM) has been provided which uses a PSA model to aid the operator in planning plant outages. A living PSA will shortly be available for Sizewell B which can be used during normal plant operation.

In developing the ESSM and the Sizewell B living PSA, it was found to be necessary to develop a model which would provide a solution in a relatively short timescale and to refine the basic PSA model in a number of ways including the following:

- each train of a system needs to be represented explicitly;
- the way that component failures are combined into super-components needs to be reviewed, and;
- initiating events need to be assigned to particular locations (loops) of the plant

In the USA, a USNRC regulation on maintenance includes the requirement that when equipment is removed from service for purposes of maintenance, an assessment of the impact on safety functions must be performed. This assessment is normally supported by information from a PSA. The USNRC has established a procedure for auditing these assessments when it inspects for compliance with the maintenance regulation..

The USNRC is also currently developing regulatory guidance for use when a PSA is submitted in support of proposed changes to technical specifications, such as longer allowed outage times. This guidance will include specific requirements regarding the PSA that is used to support the request.

5.2.2 Demonstration of Adequate Safety Level of Plants Designed to Earlier Standards

Several European countries, including Spain, Czech Republic, Germany, The Netherlands, Belgium, the UK and the Hungarian Republic reported that PSA is used along with deterministic assessments to conduct a formal periodic safety review (typically every 10 years) . The deterministic part of the review includes a comparison of the design and the operational state of the plant with safety requirements existing at the time of the assessment. PSAs provide valuable insights in the balance of the design, identify important contributions to the core melt frequency and constitute a useful tool to evaluate the effectiveness of any backfits being considered.

Responses to the questionnaire did not identify specific requirements for periodic safety evaluations over and above those considered to be necessary for a state-of-the-art PSA. However, the responses strongly suggest that, because the principal objective of these studies is to assess the toll that time has taken on the safety margin in a specific plant, it is essential that the plant PSA be kept up-to-date in terms of data and technology, and to the extent possible, be capable of treating the effects of plant ageing.

5.2.3 Change in Regulatory Requirements with Regard to In-service Inspections, Testing and Safety Classification of Systems and Components

One of the most popular applications of PSA is prioritising regulated activities with respect to safety. The fruits of this application can be improvements in safety and more effective use of regulatory resources, as well as reduced burden for nuclear utility operators. While such applications exist at some power plant sites, work is on-going in member countries to develop the technical bases to expand such applications, which will yield the necessary PSA requirements along with methodologies for integrating the results of the PSA with other engineering information in the decision process. Indeed, the USNRC in co-operation with members of the US nuclear industry has been involved in several pilot programmes which involve PSA applications of a prioritising nature. These pilot applications include: motor operated valve (MOV) testing in BWRs (in response to concerns raised in Generic Letter 89-10), in-service inspection requirements, in-service testing requirements and quality assurance requirements. The MOV testing application has been completed, while the others remain on-going. The common thread running through these applications is that they all desire information from the PSA regarding the relative safety importance of plant equipment and human activities associated with the equipment. As part of the pilot programmes the USNRC has been evaluating the use of information from the PSA, including importance measures (e.g., Fussel-Vesely, Risk Achievement Worth, Risk Reduction Worth) in combination with information of a more deterministic nature to determine safety importance. These importance measures are standard outputs of a state-of-the-art PSA software packages and have been identified by many countries in their responses as figures-of-merit that they use. The USNRC staff has raised a number of technical issues with pilot licensees on the calculation and use of importance measures as well as other information from the PSA. The resolution of these issues will be reflected in regulatory guidance documents currently being prepared.

A new project dealing with PSA support to regulatory audits has recently been undertaken in Finland by STUK. The aim of the project is to explore how the plant-specific PSAs can best be used in support of audits in such areas as ISI, IST, preventive and corrective maintenance and backfitting activities. The purpose of the study is to clarify the merits of PSA in making the regulatory audits more cost-effective by weighing more and more the risk reduction potential of the objects to be inspected. The strength of PSA in support of regulatory audits for in-service inspections and testing is recognised as laying in the ability to access the importance of various components, systems, and safety functions. The PSA has turned out to be effective in ranking importance of components independent of the complexity of accident sequences they are included in. Based on these features of PSA it is a goal of the project to integrate the task specific deterministic and probabilistic regulatory approaches in a common procedure where possible.

5.2.4 MOV Testing in Response to Generic Letter (GL)-89-10

The goal of the BWR Owner's Group (BWROG) risk assessment for GL-89-10 MOV test programme[4] [BWROG, 1996] has been to develop a relative ranking of a relatively small number of groups of MOVs according to their potential risk contributions rather than to evaluate the absolute value of the risk contribution. Accordingly, the methodology proposed by the BWROG utilises results of calculated importance measures from the PSA which is less precise than a direct modelling approach. When assessing valves for initial testing, an iterative ranking calculation procedure that involves successive requantification of cutsets is required to assure that common cause failure of MOVs across systems due to inadequate valve design and setup for design basis accident conditions has been taken into account. Once the potential for intersystem common-cause failure of MOVs has been addressed through the initial GL 89-10 testing programme, rankings for periodic verification testing can be determined based on standard Fussel-Vesely or Risk Reduction Worth importance measures calculated on an individual valve basis.

Final rankings for MOV testing are determined by a panel of experts that includes personnel with expertise in the areas of plant design, operations, maintenance, probabilistic risk assessments and in-service testing. This panel considers the information from the risk ranking along with generic risk insights, insights regarding external events and shutdown operations not included in the PSA scope and appropriate deterministic restrictions. One particular issue related to the PSA that must be considered by the panel is how maintenance outages have been modelled in the PSA. If actual maintenance practices at the facility are different from those modelled in the PSA, (e.g., configurations are assumed to be random in the PSA, but are not in reality due to such things as on-line rolling maintenance schedules) the panel

4. The BWROG methodology has been approved by the USNRC. A copy of the NRC staff safety evaluation is included with the approved version of the BWROG topical report that describes the method.

must make an assessment of the impact this difference has on the relative risk importance rankings and incorporate it in the decision-making process regarding valve testing.

5.2.5 Evaluation of Potential Backfits

Once design modifications (hardware or procedural) are proposed, their impact on the PSA model (especially CCFs and human errors) should be analysed with care. PSA changes concerning logic models, initiating events, data analysis, special features describing human or component behaviour, boundary conditions or hypothesis of analysis might be necessary. Assessing different alternatives might require substantial effort. Thus, important design changes might need additional fault tree or event tree modelling. Assumptions about testing/maintenance activities and human actions associated with new equipment need to be made. In case of layout rearrangements, dependent failure analysis and external event scenarios might be affected significantly. For systems fulfilling different functions, it should be verified that proposed modifications to improve a particular function do not have negative impact on other functions of the same system. On the other hand, some systems have functions not modelled in the PSA, e.g., functions during refuelling or start up, that must be taken into account when dealing with design or operational changes. Such functions could be jeopardised through theoretical "system improvements". It must be ensured that the proposed actions will not have negative consequences in other areas. The probabilistic analysis should try to address any factor affecting safety for the issue considered.

To evaluate the benefit from proposed modifications, a full requantification (with minimal cut set logic analysis) should be done instead of requantifying the base case minimal cut set expression because the modifications can have an impact on the logic structure of the models.

5.2.6 Evaluation of Technical Specifications

PSA can be used both for the evaluation of allowed outage times (AOT's) and for surveillance test intervals (STI's). The USNRC has produced a handbook of methods for risk-based analysis of technical specifications which some countries referenced as a source of guidance for evaluation of changes to allowed outage times and surveillance test intervals for plant equipment [USNRC, 1994].

Optimisation of AOTs must include a consideration for the risk associated with action statements requiring plant shutdown. A formal treatment of this particular aspect might require additional important effort considering several shutdown stages and human interactions, especially if the PSA does not include low-power and shutdown analysis.

For short-term decisions related to temporary TS changes, a simplified analysis may be acceptable providing that the essential safety aspects are properly addressed.

6. PSA REVIEW PROCEDURES

The questionnaire (Appendix A) requested that members identify their primary method for review of PSAs. It is recognised that there are many possible approaches and the questionnaire identified three possibilities as follows:

- Comprehensive review of a completed PSA by the regulatory authority, including independent verification using analysis conducted by the regulatory authority;
- Independent review of the complete PSA by a utility peer review team, done to standards established by the regulatory authority;
- Audit of selected portions of the PSA based on the application proposed.

The responses to the questionnaire are summarised in Table 6-1.

6.1 Approaches to PSA Review

Inspection of Table 6-1 reveals that comprehensive reviews are performed in all countries reporting. In most cases, the staff of the regulatory authority conducts the review, often with technical support from an outside consultant or a related technical support organisation. Countries which do not yet have the technical capability and resources for conducting reviews normally request support from the IAEA's International Peer Review Service (IPERS).

A few countries indicated that their reviews are conducted in parallel with development of the PSA rather than following completion of the PSA. This practice is often used in first-of-a-kind projects and is generally found in countries which have a less formal relationship with plant operators. The practice has the advantage of allowing issues to be raised early in the process and therefore resolved more expeditiously. Several countries indicated that their review includes independent analysis using methods developed by the regulatory authority to verify some parts of the licensee's or applicant's analysis.

Several countries reported that an independent peer review is conducted by the licensee or applicant. In some countries this is a requirement established by the regulatory authority.

A few countries reported that the regulatory authority conducted separate, independent PSAs for purposes of comparison with PSAs submitted for review.

A few countries reported that they do audits, including calculations, for specific PSA applications. In these cases, the base PSA model has normally been previously reviewed or the role of the PSA in the applications is not significant enough to warrant a full scope review.

6.2 Review Procedures

Most countries reporting, indicated that for their PSA reviews they used internal guidelines they developed based on experience doing reviews for their plants. In many cases these guidelines evolved from PSA procedures guides (e.g., NUREG/CR-2300, NUREG/CR-2815, IAEA Safety Guides 50-P-4 & 50-P-8).

Two formal, published review procedures were described in the responses to the questionnaire and provided to the CNRA working group. They include the IAEA guidelines for the International Peer Review Service [IAEA, 1995] and a set of guidelines produced by the Swiss Federal Nuclear Safety Inspectorate [HSK, 1992].

The IAEA procedure covers level 1, 2 and 3 PSAs and includes guidance for treating external events and common cause failures. The guidance is centred on full power PSA methodology and techniques and is based mainly on experience with US and European light water reactors (LWR). Consequently, application of the procedure for low power and shutdown states and for reactor types other than the above mentioned LWRs must be carried out by interpreting and applying the guideline as far as possible and useful. The guidance does not include specific acceptance criteria; but rather, references guidelines for performing a state-of-the-art PSA as the standards for the review team to judge the acceptability of the study under review. The guidance does not address specific applications of PSA such as technical specifications explicitly; but it is comprehensive and general enough to be applied to a large variety of applications; and this has been done repeatedly in the past.

The Swiss guidance document provides step-by-step procedures for conducting an independent two stage review and assessment of full scope PSAs (Level 1, Level 2 and Level 3) consisting of: (1) a preliminary review; (2) a detailed review and technical assessment of the entire PSA study. The guidance also includes detailed guidelines and criteria for judging the acceptability of the PSA.

In the UK, guidance to assessors is given in the published Safety Assessment Principles (SAPs). In addition, an internal assessment guide on PSA has been drafted. This provides an interpretation of the probabilistic principles and gives more detailed guidance on specific topics that an assessor would need to address. The guidance explains how the PSA should be assessed rather than specifying formal acceptance criteria. The acceptance of a PSA relies heavily on the judgement of the assessor who is carrying out the assessment.

Table 6-1. Responses to Questionnaire

Country	Comprehensive Review	Peer Review by Plant Owner	Audit by Regulatory authority (RA) for given Application	Review Procedures in Use
Australia	Conducted by RA within the scope of safety review and with support of IAEA/IPERS	Requested by RA	N/A	Internal Procedure
Belgium	Conducted by RA in parallel with PSA development	N/A	N/A	Initially based on NUREGs; now mainly experience
Canada	Conducted by RA	N/A	N/A	IAEA-TECDOC-832 and HSK-AN-2517
Czech Republic	Conducted by RA with technical support from contractor	N/A	N/A	Guidelines based on experience
Finland	Conducted by RA.	N/A	N/A	Guidelines based on Experience; Reviews conducted against their Reg. Guide on PSA.
France	Conducted by RA with external technical support	N/A	N/A	Internal Procedure
Germany	Conducted by RA with external technical support	N/A	N/A	Guidelines based on experience
Hungary	By IAEA/IPERS	N/A	N/A	IPERS Guidelines (IAEA-TECDOC-832)
Italy	RA does partial reviews of PSAs for Foreign reactors	N/A	N/A	Guidelines based on experience
Japan	Conducted by RA with assistance from contractors; includes independent calculations	N/A	N/A	Guidelines based on experience

Country	Comprehensive Review	Peer Review by Plant Owner	Audit by Regulatory authority (RA) for given Application	Review Procedures in Use
Korea	Conducted by RA and IPERS	N/A	Independent PSA Calcs	Guidelines based on NUREG/CR-3485, NUREG-1407, NUREG-1335, IAEA Safety Guides 50-P-4 & 50-P-8.
Mexico	Conducted By RA; including independent calcs with RA's PSA.	Utility did Peer Review against their own standards.	N/A	Guidelines based on NRC Generic Letter 88-20 (IPE)
The Netherlands	Conducted by IAEA/IPERS for Initial PSAs	N/A	Conducted by RA for applications of living PSA	IPERS Guidelines (IAEA-TECDOC-832)
Slovak Republic	Conducted by IAEA/IPERS	N/A	N/A	IPERS Guidelines (IAEA-TECDOC-832)
Spain	Conducted by RA	N/A	N/A	Guidelines based on experience
Sweden	Conducted by RA	Required by RA	N/A	Guidelines based on experience
Switzerland	Conducted by RA	N/A	N/A	Formal Procedure HSK-AN-2517
United Kingdom	Conducted by RA as part of developing the safety case for the plant; supported by consultants as required	Required as a condition of the nuclear site license	Addressed by the comprehensive review	Safety Assessment principles for nuclear plants. NII Assessment Guide AG5 on PSA
United States	Conducted by RA with external Technical Support	Done as part of some IPEs; but not currently required	Conducted frequently, especially in the area of Technical Specifications	Guidelines based on experience

7. SUMMARY AND CONCLUSION

7.1 Responses to the Questionnaire

The following observations and conclusions have been drawn from the responses to the CNRA questionnaire:

- all respondents to the CNRA questionnaire have continued, or expanded, their use of PSA in regulation over that reported in 1995;

- many countries responding to the CNRA questionnaire indicated that, regulatory decision-making should be based on a mix of deterministic and probabilistic assessments;

- many countries are using information from plant specific PSAs in support of regulatory decisions in an apparent ad hoc manner;

- while technical methods or guidance for some applications (e.g., TS) have been published, neither the use of formal written guidance for applying PSA in specific licensing decisions (e.g., in-service inspection programme) nor specific plans for developing such guidance were reported in the responses to the questionnaire, with the exception of a few countries. Nevertheless, further development of guidance seems likely since (1) several countries are currently developing such guidance; (2) many countries indicated that insights from risk assessments were being used to some extent in making regulatory decisions in their country; (3) overall the response to this CNRA initiative has been strong (19 countries responded).

- while current regulatory requirements in member nations are based primarily on a deterministic approach to reactor safety, those nations responding to the questionnaire are either now utilising or plan to utilise the insights from risk assessments to the extent possible in making regulatory decisions. Some nations are considering the need for more risk-informed regulatory requirements in certain areas;

- many countries indicated that their current general requirements for conducting a comprehensive PSA, with some modification, will be satisfactory for most applications; and while some applications can be developed fairly simply from the base PSA results, (e.g., ranking of modelled components using their importance measures) other applications will require a significant amount of additional work, (e.g., comparison of risks of shutting down the plant versus continued operation at power);

- most countries responding to the CNRA questionnaire indicated that they use their own internal PSA review guidelines derived from experience;

- countries whose regulatory authority does not yet have the technical capability and resources for conducting a comprehensive review of a PSA application, requests assistance from the IAEA's International Peer Review Service;

- two formal, published review procedures were described in the responses to the questionnaire and provided to the CNRA working group.

Continuing activities reported in response to the CNRA questionnaire are summarised in Table 7-1. The table indicates the following:

- most countries are expanding their use of PSA in regulatory matters;

- several countries are developing general and application specific guidelines, including acceptance criteria, for using PSA in regulatory matters;

- several countries are developing procedures for review of PSA and PSA applications;

- two countries are integrating their living PSA programme with their operational safety programme.

A subset of the countries responding to the questionnaire have identified the following as potential future activities in support of the development of review procedures and criteria for regulatory applications of PSA:

- define criteria based on probabilistic considerations for determining when it is acceptable to optimise deterministic requirements;

- revise existing technical specifications based on PSA insights;

- develop PSA requirements for application to next generation reactor designs;

- establish certification requirements for PSA review teams;

- establish an international committee of experts to develop standards for PSA methods and data used in regulatory decision-making.

Table 7-1. Continuing Activities

Country	Continuing Activities Related to Review Procedures and Criteria
Australia	Utilise HIFAR Level 1 PSA for gathering risk insights; develop a systemic process for peer review of a PSA
Belgium	Establish criteria for applications other than design evaluation, such as technical specifications
Canada	Issue PSA guidelines for comment
Czech Republic	Further PSA Studies (Level 2, shutdown) and develop probabilistic acceptance criteria Continue development of PSA techniques for regulatory applications and use living PSA
Finland	Implement Living PSA and plant safety management applications (config control, TS, ISI, IST) at plants in accordance with RG YVL 2.8; Expand Living PSA to Level 2 for Severe Accident Management Strategies
France	Continue development of PSA techniques for regulatory applications
Germany	PSA Review Guideline being developed
Hungary	Continue development of PSA techniques for regulatory applications
Italy	No activities planned
Japan	Continue development of PSA techniques for regulatory applications
Korea	PSA Application Guideline being prepared; have plans to develop a review procedure
Mexico	Continue development of PSA techniques for regulatory applications
The Netherlands	Development of PSA Procedures Guide
Slovak Republic	Continue development of PSA techniques for regulatory applications
Spain	Developing integrated framework for application of PSA and a PSA applications guide
Sweden	Improve plant PSAs and expand PSA applications
Switzerland	Integrate use of living PSA into daily regulatory and inspection activities
United Kingdom	Revise guidance on use of PSA to be consistent with current thinking
United States	Develop review procedures and criteria for specific applications of PSA per PRA Implementation Plan

7.2 Summary of the CNRA Discussions

Comments from CNRA delegates during the special issues meeting are documented in the summary record of the meeting [NEA, 1997] and summarised here in Table 7-2. From these comments the working group has concluded that even with the many differences in regulatory approaches among member countries, there are some common views among a large majority of delegates regarding the development and use of review procedures and criteria for regulatory applications of PSA. Indeed, the comments of the delegates suggest that large majority of CNRA members place a high priority on ensuring that PRAs utilised in the regulatory decision-making process have the appropriate level of technical quality. In this same vein, many delegates expressed the importance they saw in ensuring the competence of personnel performing PSA in support of regulatory decisions as well as those charged with reviewing the PSA and judging the acceptability of the PSA for a given application. In addition, many delegates felt that appropriate guidelines for judging the acceptability of the PSA supporting a regulatory decision were needed.

Table 7-2. Comments from Delegates at the Special Issue Meeting "Review Procedures and Criteria for Regulatory Applications of PSA"

Switzerland	- we have developed and are using numerical risk guidelines in the regulatory process
UK	- need guidance on balancing deterministic and probabilistic - need to create more comprehensive PRAs - need acceptance criteria or guidelines for accepting PRAs
Czech Republic	- need PSA acceptance criteria and good review guidelines
Hungary	- need to be able to properly assess the overall quality of a PSA - need to be able to understand the reasons for variance in PSA results among similar plants
USA	- PSA must be reliable, consistent and maintained current and up-to-date - quality is dependent on upon the expertise of the staff utilised; training and experience are therefore very important
Spain	- need proper training for both plant operators and regulators in PSA methodology
Belgium	- need to develop standard review plans for different PSA applications
Germany	- PSA has a unique value in the safety process, if it is performed correctly - there is hesitancy in using PSA numbers too vigorously without better confidence in the results.
France	- the quality of PSA results depend on the quality of PSA experts
European Commission	- what is required and is not focused on is validating the PSA model (e.g., testing it against reality).
NEA Secretariat	- need better review guidelines and more consistency in performing analysis

8. REFERENCES

[BWROG, 1996] BWR Owners Group, *Application of Probabilistic Safety Assessment to GL 89-10 Implementation,* NEDC-32264-A, Rev. 2, October 1996.

[HSK, 1992] Swiss Federal Nuclear Safety Inspectorate, *Probabilistic Safety Assessment Review Guidance for Swiss Nuclear Power Plants,* HSK-AN-2517, 1992.

[IAEA, 1993] International Atomic Energy Agency, *Modelling and Data Prerequisites for Specific Applications of PSA in the Management of Nuclear Plant Safety,* IAEA-TEDOC-740, 1993.

[IAEA, 1995] International Atomic Energy Agency, *IPERS Guidelines for the International Peer Review Service,* Second Edition, IAEA-TEDOC-832, 1995.

[NEA, 1995] OECD Nuclear Energy Agency, *Regulatory Approaches to PSA*, NEA/CNRA/R(95)2, 1995.

[NEA, 1997] OECD Nuclear Energy Agency, *Summary Record for the June 16-17, 1997 CNRA Meeting*, NEA/SEN/NRA(9)X, September 1997.

[USNRC, 1994] U.S. Nuclear Regulatory Commission, *Handbook of Methods for Risk-Based Analyses of Technical Specifications,* NUREG/CR-6141, December 1994.

[USNRC, 1995] U.S. Nuclear Regulatory Commission, *Uses of Probabilistic Risk Assessment Methods in Nuclear Regulatory Activities; Final Policy Statement*, 60 FR42622, August 16, 1995.

[USNRC, 1997] U.S. Nuclear Regulatory Commission, *Quarterly Status Update for the PRA Implementation Plan,* SECY-97-076, April 3, 1997.

[SKI, 1994] Swedish Nuclear Power Inspectorate, *Safety Evaluation by Living Probabilistic Safety Assessment,* SKI report 94:2, G. Johanson, J. Holmberg (Editors), January 1994.

APPENDIX A

<u>Questionnaire for the '97 CNRA Special Issue</u>

<u>QUESTION 1</u>: CURRENT/ONGOING PSA APPLICATIONS.

Describe current/ongoing applications of PSA to regulated activities in your country (e.g., In-service Testing and Inspection programmes, configuration control during operation and maintenance, design evaluation, technical specifications and event assessment) A simple reference to a specific section of the CNRA Special Issues meeting report (NEA/CNRA/R(95)2) or responses to the associated questionnaire would be adequate.

<u>QUESTION 2</u>: USE OF PSA IN REGULATORY DECISION-MAKING.

Describe how PSA is used, or planned to be used, in the regulatory decision making process including but not necessarily limited to the following considerations:

I. The relative roles of risk insights developed through PSA and more traditional deterministic rule-based requirements.

II. Special processes or procedures used to integrate or balance risk insights with deterministic rule-based requirements.

III. The use of PSA Level-1. Level-2, and Level- 3 risk insights as related to Defense-in-depth considerations.

IV. Figures of merit (e.g., risk achievement worth, core damage frequency, large early release frequency) used as a measure of risk significance for specific regulatory applications or groups of applications.

<u>QUESTION 3</u>: PSA REQUIREMENTS.

For each specific application or groups of applications identified in the response to question 1, describe the following:

I. The general minimum requirements of the PSA used, including scope, level of detail, key assumptions, sensitivity analysis, data sources, modelling approach, success criteria and treatment of uncertainty.

II. Any unique analysis features or challenges for specific applications (e.g., In-service Inspection as a risk ranking application and the difficulty in specifying pipe break probabilities for different piping segments or locations, or specific methods for analysing extensions to allowed outage times in Technical Specifications and the need to consider mode transition risk resulting from forced shutdowns.) The following three applications highlighted by the CNRA should be specifically addressed:

- Configuration control during operation and maintenance

- Changes in regulatory requirements with regard to in-service inspections, testing and safety classification of systems and components.

- Demonstration of adequate safety level of plants designed to earlier safety standards.

<u>QUESTION 4</u>: REVIEW PROCEDURES.

I. Discuss methods used for review and approval of PSA's, including the acceptance criteria or standards that would be used to decide whether the analysis is acceptable. Consider the review methods listed below as well as any others identified.

A. Comprehensive review of a complete PSA by the regulatory authority (RA), including independent verification using analysis conducted by the RA.
B. Independent review of the complete PSA by a utility peer review team, done to standards established by the RA.
C. Audit of selected portions of a PSA based on the application proposed.

II. Provide references and/or copies of any formal guidelines, review procedures, inspection procedures, regulations, etc., that document the methods described in the response to part I of this question.

<u>QUESTION 5</u>: FUTURE ACTIVITIES.

I. Identify additional activities either ongoing or planned in your country to develop review procedures and criteria for regulatory applications of PSA.

II. Identify additional future work that you believe needs to be done, but not yet actively planned, to develop review procedures and criteria for regulatory applications of PSA.

APPENDIX B

Summaries of Responses to the Questionnaire

Australia
(Nuclear Safety Bureau)

Question 1:

New PSA: Currently a new PSA is being undertaken for the HIFAR reactor recommended as a result of the Research Reactor Review (RRR) undertaken in '93 by an independent committee: It was essential to assess the remaining life possibilities, it would help establish the technical feasibility and cost of upgrade possibilities and it would provide additional estimates of safety margin. Scope: Level 1+ with:

- Full Power and shutdown operations
- Spent fuel handling, transport and storage operations.
- A comprehensive list of plant faults identified in deterministic analysis.
- Internal events including fire, flood, explosions and dropped flasks **(?)**.
- External events and others including those related to human factors.
- It is also intended that it will be a "Living PSA".

Question 2:

I & II. The NSB accepts PSA as being complementary to deterministic assessment and does not accept safety argued solely on a "bottom line" risk frequency number or degraded core frequency number. The safety principles of Defense in depth, safety culture and quality assurance remain the key safety assessment measures. PSA is useful in identifying improvements and a means to correct weaknesses because it provides an ordered and systematic process of analysis.

III. For a new reactor the PSA would be required.

IV. The expectations for PSA are: CDF < 10^{-4}; reliability of mitigating systems < 10^{-2} to 10^{-3}/d; compliance with NSB's draft Safety Assessment Policy.

<u>Question 3</u>:

I. Key assumption and success criteria may be realistic but, in the face of uncertainty, should err on the side of conservatism and be compatible with those in deterministic analysis. The level 1 must use best estimate data and assumptions but more conservative values should be used in the sensitivity studies.

II. As a "Living PSA" concept it should be available to the operators for evaluating plant modifications and changes.

<u>Question 4</u>:

The PSA would be reviewed by the NSB. The formal approve is of the Safety Case.

A. The NSB has not the capability to undertake a comprehensive check or review of the PSA. The areas reviewed are: the success criteria used, the consistency of assumptions and data with deterministic assessment, how uncertainty in assumptions and data is handled, and a comparison of bottom line numbers and sequence probability with previous deterministic estimates and NSB numerical criteria. A fairly detailed review is required.

B. The NSB has indicated it would not undertake a peer review and that an independent peer review should be included as an item in the PSA.

<u>Question 5</u>:

I. Research is needed for the marrying of deterministic and PSA success criteria.
II. More work is needed for the development of a systematic process of peer review.

<u>Belgium</u>
(AIB-Vinçotte Nuclear)

<u>Question 1</u>:

<u>Design Evaluation</u>: The main application is to use the PSA as a complementary tool in the periodic safety reviews, balancing the design, identifying important contributors to CDF, and evaluating the effectiveness of proposed plant modifications.

<u>Evaluation of TS</u>: PSA insights have been used for arguing in TS matters, but this has not yet led to formal modifications (shutdown systems). There is the expectation that in the future this kind of application will be discussed with the utility.

<u>Question 2</u>:

I. The probabilistic approach is expected to introduce a complementary view to the deterministic ones: considering multiples and common cause failures, more systematic analysis of human interventions, analysing a broad number of best estimated scenarios, and analysing new scenarios not considered in the deterministic design.

II. There are no procedures.

III. Level 1: The importance of shutdown risk represents 30 % of the CDF, related to only 10 % of the total time. The consequence is a core damage probability (CDP) per hour higher than in the power state. This reflects that Defense-in-depth during non-power states is not so well implemented as in full power. For non-power conditions, AVN intends to require (in particular for future plants) a deterministic approach applying the same Defense-in-depth ideas as for the power state. LOCA frequencies for shutdown conditions need more improvement.

Level 2: The two partial level 2 PSA studies led to a backfitting to all 7 plants, the installation of catalytic recombiners. This contributes to extending the Defense-in-depth concept to severe accidents.

Level 3: There are no plans to undertake this analysis because of the high uncertainties.

IV. The CDF has been used in a relative way. Importance measures will be added.

Question 3:

I. Level 1+ in all conditions. AVN accepted that internal and external hazards could be considered out of the scope. Discussions with the utility are foreseen to extend the scope to fires and floodings. AVN accepted that only transitional states that represent less than the 1 % of the operating time were out of the scope. The methodology should correspond to the state-of-the-art.

Fault Trees (FTs) in enough detail to allow quantification of dependencies, especially in electrical and I&C systems (CCFs). The use of specific data in both Initiating Event (IE) frequencies and component unavailabilities. The human reliability should cover pre and post-initiator human errors. Errors of commission should be considered to the extent possible. AVN insisted on the use realistic assumptions and success criteria (extensive use of thermohydraulic calculations. The PSA should be updated periodically.

II. Design evaluation: General requirements are considered adequate.

Accident Management: Accident progression Event Trees are being used.

Event Assessment: A plant specific model is judged indispensable.

Evaluation of TSs: For Surveillance Test Intervals more detailed information is needed on the time dependency of the failure probability.

Specific applications mentioned by CNRA:

- Configuration control during Operation and Maintenance: Not used.
- Changes in regulatory requirements (ISI, IST & ranking): Not used.
- Demonstration of adequate safety level of plants designed to earlier safety standards: See Design Evaluation.

Question 4:

I. Type A. Objectives: To evaluate the scope and the methodology used with respect to the state-of-the-art, to verify in detail the modelling of the plant, to have a good knowledge of strength and weaknesses of the PSA.

Organisation: AVN opted for an on-line review in parallel with the execution because they were the first projects, the regulatory body wanted to improve their knowledge, to work in the same way, and an on-line review allows a much deeper analysis of the PSA. Detailed description of the process followed:

Approval: AVN drafts an Evaluation Report with all questions and comments remaining pending. An action plan must be agreed upon for further treatment of these open points. One can not really say that the PSA is "approved".

II. Review Procedures: No internal review procedures have been written.

Question 5:

I. Review Procedures: There are no plan to undertake any activity related to this in the near future.

Criteria for Regulatory Applications: The main application of the PSA so far has been on design evaluation. Minimum requirements on the PSA's and criteria for each type of regulatory application will have to be discussed.

II. The use of PSA in the periodic safety reassessment as a complement to the deterministic approach. The question is: to what extent can the PSA be used to relax deterministic requirements. It is clear that PSA can not only be used to impose new requirements, but care must be taken to not undermine the concept of Defense-in-depth.

For future plants the PSA will be used from the design phase on. AVN has no well defined criteria for deciding how far they can go by relaxing deterministic requirements based on probabilistic considerations.

Canada
(Atomic Energy Control Board of Canada)

Question 1: None.

Question 2:

PSA is planned to be used in Regulatory Decision-Making. Analysis of PSA conditions initiated. Foreseen applications:

- Use of ranking to require modifications or classify safety systems.
- Identification of Non-Environmental qualified components that need qualification.
- Use of decrement/increment CDF or release for plant modification claims.

Question 3:

Configuration Control: Quick configuration change evaluation. Level of detail commensurate with the tool.

Change in Regulatory requirements: Models can be very detailed. Key factor: Regulator's confidence in the PSA results.

Demonstration of adequate safety level: PSA must be very detailed with plant specific data.

Question 4:

I. No specific answer.

II. First PSA under review using a Draft Review Plan based on internal working group, HSK guide and IAEA-TECDOC-543.

Question 5:

I. Draft PSA Guidelines sent to utilities. External review is about to start.

II. There is the intent of establishing three working groups:

- Probabilistic versus deterministic criteria.
- Safety goals and derived criteria.
- Requirements for a PSA in the licensing file.

Czech Republic
(State Office for Nuclear Safety)

Question 1:

The Czech Republic State Office for Nuclear Safety (SONS) has prepared a comprehensive programme to improve the operational safety of the Dukovany VVER/440 V213 NPP's (EDU). A Level 1 PSA (internal events, full power) was initiated in 1989, and finalised in 12/93 by the Nuclear Research Institute (NRI). An upgraded Level 1 PSA EDU Study was completed in 12/94 by SAIC and NRI. Discussions of both results have helped to improve understanding of them. In 1995 NRI prepared upgraded Dukovany PSA Study.

SAIC prepared (under contract from SONS) a PSA-based assessment of the EDU TS for Dukovany plants.

SONS contracted in 1992 SAIC to prepare a Risk Monitor System (SAS-Safety Advisory System). The Master Logic Fault Tree (MLFT) model is capable of recalculating all the PSA without any loss of information in 2-4 minutes. It can be used to evaluate proposals for TS.

A Level 2 PSA (external events and shutdown states) was finished for Temelin NPP (ETE) -under construction- in co-operation with NUS, and includes a Risk Monitor (NUS).

A fire PSA was finished for Dukovany NPP, a Level 2 PSA for Dukovany NPP is on-going (it will be finished in fall of 1997) and shutdown PSA analyses have started. The shutdown analyses are scheduled to completed by the end 1998.

PSA analysis to support research reactor LVR-15 periodic safety review was prepared in 1996.

Question 2:

Currently, there are 4 operating VVER/440 V-213 units at Dukovany and 2 VVER-1000 units under construction at Temelin. Deterministic approach is used for licensing and operation, but it has been recommended for Temelin NPP's to prepare a Level 2 PSA as a support for deterministic decisions.

Selected failures of Dukovany have been analysed by the PSA model. Since 1995 SONS gradually completed a 10-year review of all four units Dukovany safety, including the development of a revised Operational Safety Analysis Report. Some SONS decisions regarding future operation of the units were based on the results of the PSA. The SAS was used in 1995 to analyse actual operational data, and is also used to evaluate requests for extensions to allowed outage time (AOTs).

The report prepared by SAIC recommended 27 changes to the Dukovany TS based on risk insights: 6 areas were identified where the safety could be greatly enhanced, 19 areas where plant availability and maintenance efficiency could be improved by relaxing existing requirements, 2 areas which were not included in the current TS.

Question 3:

The first attempt at using probabilistic criteria in safety regulation was a recommendation to demonstrate that unreliability of the emergency core cooling system is lower than 10^{-3}.

The SAS risk monitor is used by utility and regulator. Risk profiles for plant configurations are checked during operation and maintenance every month or in case of a utility request to extend an AOT.

Specific methods for analysing extensions to AOTs in TS (see response to question 2).

Question 4:

A IAEA peer review (IPERS) evaluated the Temelin PSA Level 1 and Level 2 in agreement with IAEA-TECDOC-832.

A preliminary IAEA review was performed during preparation of the Dukovany PSA study. The first in-depth review of Dukovany PSA was made by SAIC.

Question 5:

Several activities are in preparation including: EDU shutdown analysis, EDU PSA Level 2, updating and reassessment of the EDU PSA model and the risk monitor, assessment and discussion of probabilistic acceptance criteria, next usage of risk monitors, on-line connection between the SONS and the Dukovany site to upgrade the SAS model.

Finland
(STUK)

Question 1:

Design and Construction Stage: System Level PSA.

Operation Stage:

- Evaluation of Plant Modifications: Risk Reduction plant modifications. Risk impact evaluation required for each modification. "Living PSA" available for each plant.

- In-service Testing and Inspection Programmes: Very limited. Surveillance Test Interval modifications (Diesel Generators).

- Configuration Control during Operation and Maintenance: Preventive maintenance re-scheduled (Risk reduction from 5% to 1%).

- Technical Specifications: Temporary exemptions to TS. On-going some AOT analysis (RHR). New TS items based on shutdown PSA.

- Emergency Operating Procedures: New EOP's from PSA insights. Improvement of training.

- Event Assessment and Risk Follow-up: Systematic retrospective study made.

- Re-assessment of Safety Classification: Importance calculations on-going.

Question 2:

I. PSA used whenever it provides better insights without explicit criteria (maintenance, testing & inspections), to assess "meaningfulness" of deterministic criteria non-essentials (many TSs). Future exemptions.

II. Both approaches applied in parallel for regulatory decisions adding an independent view for judgement.

III. Never used to compromise Defense-in-depth, only to confirm the level reached.

IV. R.G. YVL 2.8 sets numerical design objectives for new NPP's:

- Reliability objectives RPS < 10^{-5}/d, ECCS < 10^{-4}/d in SLOCA, FW < 10^{-4}/d, Containment isolation < 10^{-3}/d.

- CDF < 10^{-5}/year. LRF £ 5 x 10^{-7}/year.

Question 3:

I. R.G. YVL 2.8 about PSA requirements concern both operating and new NPP's.

Scope: Level 1 & 2. Internal, floodings and harsh weather IE. Full power, low power and transitions.

Level of Detail: Highly detailed. Yearly updated and after substantial changes.

Key assumptions: Any assumptions need to be introduced and specified.

Data Sources: Plant specific data with continuous collection. Generic data if none.

Modelling approach: No formal presumption.

Success criteria: Related calculations required and best-estimated recommended.

Sensitivity and uncertainty: They are an integral part of PSA requirements.

II. On-line configuration control not used, but "Living PSA" for checking in advance.
Exemptions or optimisation of LCO: Comparison between Shutdown and Full Power risk made to support TS reconsideration (AOT extension for RHR systems). Continued operation is safer than shutdown in a few special cases where RHR systems are affected by common cause failures.

Question 4:

I. NUREG/CR-3485 at first (too intensive and rigid), thereafter the general framework not in detail. 5 or 6 different area experts: IE set, IE rates, Event trees, Fault trees to basic events, quantitative comparisons, alternative human reliability methods.

II. No formal approval, but formal comments and PSA's are always exposed to comments and changes.

Question 5:

I & II. New Level 2 PSA methodology and code have been developed by STUK. They will be used in reviewing utility results. Also, a new project dealing with PSA support to regulatory audits has recently been undertaken by STUK. The aim of the project is to explore how plant-specific PSAs can best be used effecting specific regulatory tasks such as ISI, IST preventive and corrective maintenance and backfitting activities.

France

(Directorate for the Safety of Nuclear Installations, DSIN)

Question 1: Current/ongoing PSA Applications.

Design Evaluation: level 1 PSA, ongoing level 2 and Fire PSA

Evaluation of Plant Modifications: automatic water makeup during midloop operation.

Periodic Safety Review of the 900 MWe series plant design: each sequence>10E-7 per reactor-year was investigated, resulting in some backfits.

Technical Specifications: ongoing evaluation of Allowed Outage Times (AOT); need to balance risk between power and shutdown operations.

Emergency Operating Procedures: various EOP improvements; some new EOPs implemented, especially during shutdown.

Event Assessment: precursor programme since 1994 at utility; some events (about 10 per year) are assessed by Regulatory Authority (RA).

Maintenance Activities: ongoing Reliability Centered Maintenance (RCM) programme at its early stage.

Question 2: Use of PSA in Regulatory Decision-making.

PSA is a tool that is used on a cases-by-case basis in conjunction with deterministic assessment:

- supplements deterministic evaluation for new reactor designs
- used for evaluation of plant changes and event assessment in operating reactors

"Global" safety objectives exist: unacceptable consequences from a reactor accident should not occur with a frequency greater than 10E-6 per reactor-year for all events and less than 10E-7 per reactor-year for any one event family.

PSA has helped strengthened Defense-in-depth through the development of risk-informed procedures for accidents beyond the design basis and assessment of containment vulnerabilities.

Core damage frequency and importance measures are the figures-of-merit currently in use.

Question 3: PSA Requirements.

Technical requirements have not been established for general PSAs nor application specific PSAs.

Applications with specific challenges for PSA are:

- determination of human factor gain due to procedure improvements or training, which is important when evaluating the need for automatic versus manual protective action.

Off-line PSA used in the development of configuration requirements for shutdown operations.

Question 4: Review Procedures.

Reactor designs are standardised in France. The regulatory authority performed the PSA for the 900 MWe design and the utility performed the PSA for the 1300 MWe design. There was in-depth mutual review of the work by both organisations, to achieve consistency in data and assumptions.

For specific applications, the utility usually performs the PSA calculation and the regulatory authority reviews it. In accordance with PSA policy, there is no acceptance criteria or standards used to decide whether the analysis is acceptable.

Question 5: Future Activities.

There are no plans to develop review procedures and criteria for regulatory applications of PSA in France.

Germany
(Federal Office for Radiation Protection)

Question 1:

Incident analysis, precursor studies, decision making on backfitting, derivation of accident management measures, periodic safety review and design evaluation. See '95 Special Issues Meeting answers (3 & 4).

To support decisions on ISI & IST programmes.

Question 2:

I. PSA is used to supplement the deterministic approach, assessing the safety level and the well-balancedness of the design.

II. Periodic Safety Reviews (PSR) every 10 years. PSA provides the plant safety level and high frequencies or releases trigger consideration of remedial measures. PSA supports but does not determine regulatory decision making. Nuclear standards (KTA-rules) define test intervals, but are open to alternate values substantiated by reliability analysis.

III. Accident management measures from level 2 & 3 are considered a fourth level in Defense-in-depth.

IV. Frequency of hazard states and CDF show the safety level. LER is also considered.

Question 3:

I. The philosophy is to have a PSA for a variety of applications. PSA guidelines (not yet approved) describe good practices for scope, analysis steps and models. Objective: "Identification of Event sequences that can present a hazard to core cooling and vulnerabilities."

Scope: Level 1+ (Level 1 extended to the active containment functions), accident management measures can be taken into account. IE limited to LOCA's, ISLOCA's, SGTR, Transients, Secondary leaks, ATWS and Internal floodings. Human, system function and common cause dependencies.

Level of Detail: Adequate modelling.

Data Sources: Specific data where available.

Success Criteria: Defined for the sequence.

Sensitivity and Uncertainty: Done.

II. PSA applications: Main objective is identification of Plant Vulnerabilities and Judgement of Level of Safety; specific PSA applications are decided case-by-case.

Question 4:

I. Method A supported by external experts. Independent verification depends on the PSA.

II. Documents under discussion.

Question 5:

I. Developing PSA review guidelines.

II. PSA review guidelines will be updated and extended.

Hungary

(Hungarian Atomic Energy Commission)

Question 1:

Identification of weaknesses and prioritisation of upgrading measures from AGNES project (Advanced general and new evaluation of safety for Paks Unit 3). Periodic safety review of Paks Units 1 & 2 completed.

Question 2:

I & II. PSA will be used as complementary approach to Defense-in- depth.

III. They only have level 1.

IV. CDF. However, much credit is being given to the risk insights from sensitivity analysis, as opposed to relying only on the "bottom line" CDF result.

Question 3:

I. AGNES model has covered general requirements for regulatory purposes. Simplified model has been used for risk supervisor. Data base with generic and specific values, more precise plant specific data in the future.

Scope: Level 1 with internal events at full power. Low power and shutdown conditions under way, fire risk and internal flooding in preparation.

II. Only the 3rd application. The demonstration of adequate level of safety was the most important aim of AGNES.

Question 4:

I. Because of lack of internal expertise, IPERS mission has been requested from IAEA. Individual experts assigned to specific areas: event trees, human reliability, failure data, IE frequency.

II. IAEA 50-P-4,1994 and NUREG/CR-4550.

Question 5:

I. Not at present.

II. Review and upgrading TSs.

Italy
(ANPA)

Question 1:

ANPA is presently engaged in the revision of: AP-600 PSA, EUR PSA methodology (rev. B), TSO/PWR PSA, and moreover: Support to various foreign Regulatory Bodies (Eastern Europe) for revision of PSA of existing NPP's and personnel training.

Question 2:

I & II. PSA is only applied to new designs: to improve and assess new NPP's.

- The trend for future reactors is to use an approach to safety essentially deterministic, discouraging compliance with probabilistic safety targets.

- Risk insights from PSA are taking into account for feedback upgrading, cost-effective actions during design or operating phase.

III & IV. Not applicable to the current Italian situation.

Question 3:

I. PSA must model the plant adequately to the aim established for the study and must permit drawing of conclusions for risk reduction. The review criteria cited in Q4 are applicable as PSA requirements.

II. Not fully applicable to the current Italian situation.

Question 4:

I. The Regulatory Authority is presently engaged in the partial review of foreign NPP PSA's following: IE, success criteria & time windows for operator actions, ET's adequacy, FT's adequacy, data base adequacy, CCF, human reliability, correctness of quantification, overall traceability, independent sensitivity analysis, adequacy of guidelines used, independent requantifications of accident sequences.

II. No reference is provided.

Question 5:

No particular future activity is foreseen beside that described above.

Japan

(Nuclear Power Safety Policy Division, Agency of Natural Resources and Energy, MITI)

Question 1:

Some application has been developed voluntarily by utilities, some of them are strongly encouraged by the regulatory authority:

- Comparison of alternative design in new reactors.
- Improvement of operational procedures and operator training programme:
- Accident management:
- Periodic safety review:
- Prioritisation of research

Question 2:

I & II. PSA is not required, but provides supplementary information to the deterministic evaluation, specially in examining the severe accident issues. Deterministic has priority over probabilistic.

III. The Regulatory Authority strongly encourages utilities to perform voluntarily a level 2 PSA (level 1 including containment performance assessment) for internal hazards during full power operation, and a level 1 at shutdown conditions.

IV. CDF, CFF, and importance measures (RRW, RAW, F-V, etc.).

Question 3:

I. There are no regulatory requirements on PSAs. However the Regulatory Authority reviews whether the methodology, data and results are adequate from the objective point of view.

II. There have been identified no unique analysis features or challenges for specific applications.

Question 4:

I. The regulatory Authority checks the methodologies, data and results of PSA submitted whether they are adequate from the points of the objectives of current PSA and the state-of-the art of PSA methods. The RA independently performed the PSA for each typical PWR and BWR by giving a contract to a government affiliated organisation, comparing the methodologies, data and results, checking specially the differences between the generic PSA and the specific for each plant.

II. No formal guidelines, review procedures, inspection procedures, regulations, etc., are provided by the RA, but the following guidelines are admitted as appropriate and the RA reviewed if the PSA is in accordance with them:

- "Report on the guidelines for performing a PSA level 1/2", Nuclear Safety Research Association, 1992.7 & 1993.10. Both drafted through the contribution of academy, and governmental organisation, utility and vendor specialists.

Question 5:

The RA and the utility are investigating the possibility of further applications and developing necessary PSA related technology, but no specific regulatory area and no specific plan to develop any review procedures and criteria have already been decided.

Korea

(Korea Institute of Nuclear Safety)

Question 1:

PSA applications are in the feasibility study phase, with a consensus on the necessity of PSA as a tool in regulatory decisions. Risk Based Regulation including optimisation of AOT/STI and prioritisation of safety issues, and Risk Based Inspection Research Projects were launched and have been conducted by the Korea Institute of Nuclear Technology (KINS). There have been some regulatory activities on PSA applications, e.g., the evaluation of the necessity of the safety depressurisation system (SDS) for the RHR function in YGN-3&4, and the search for vulnerabilities in some plants (Kori 3&4).

Question 2:

Although, there is not strict requirements for the utilisation of PSA in the regulatory decision-making process, it is a decision support tool for licensing review.

I. Even though deterministic approach has a major role in the regulatory decision-making process, regulatory authority is adopting the integral safety assessment approach which combines both approaches.

II. For new plants is required to address the reliable features and procedures in preventing and mitigating severe accidents.

III. It will be required for future plants to incorporate probabilistic studies into the design requirements for strengthening of defence-in-depth.

IV. The ongoing research, which deals with Risk Based Inspections, utilise RAW as a figure of merit.

Question 3:

Full Scope Level 1 should be implemented for design evaluations or prioritisation of design features, including sensitivity/importance/uncertainty analysis. The success criteria should be determined by best-estimate thermal-hydraulic evaluations.

Question 4:

I. The general safety criteria requires that all reasonable steps must be taken in the design stage to reduce CDF and mitigate consequences. The review method is to follow the comprehensive review of a complete PSA by the regulatory authority including independent verification (IPERS).

II. Five previous PSA were reviewed by KINS, based on U.S. NRC and IAEA practices as: NUREG/CR-3485, NUREG-1407, NUREG-1335, IAEA Safety Series N.50-P-4, N.50-P-8, and so forth.

Question 5:

I. A draft PSA application guideline has been prepared as a part of a research project, including:

- Scope of PSA.
- Figures of merit and acceptance criteria.
- Assessment principles.
- Procedural Framework.
- Use of PSA modelling in other application areas.

There is a plan to develop PSA application/review procedures including external events.

II. Regulatory Authority is preparing the specific technical requirements of PSA's for the next generation of Korean Reactors. It will contain the necessary PSA scope, results, and acceptance criteria.

Mexico

(Secretary of Energy: National Commission for Nuclear Safety)

Question 1:

PSA application programme started:

- Risk based evaluation of LERs: regulatory authority own PSA.
- Risk based inspections: Prioritisation of inspection tasks.
- Operator Licensee Examinations: Without formal task, PSA main accident sequences has been used in SMR examinations.
- General Optimisation of TS's (LCOs): Evaluating impacts of AOT's
- Risk based configuration management.
- Maintenance: Laguna Verde identification of SSCs.

Question 2:

I. Use PSA results as a support of the deterministic approach.

II. No procedures, but they will have to be produced.

III. RA's level 1 PSA and the on-going level 2 are planned to be used for the improvement of plant operating procedures, weaknesses identification, proposed modification assessment, development of accident management guidelines, etc.

IV. RRW, RAW and CDF.

<u>Question 3</u>:

I. Minimum PSA requirement: Level 1 PSA that includes systemic event trees, fault trees at component level, generic data base incorporating operating experience, accident sequence evaluation at minimal cutset (MCS) level, sensitivity and uncertainty analysis and analysis of potential interaction between containment status and continued core cooling.

II. TS's application: Analysis for the continued operation at power or forced plant shutdown.

Risk based configuration management and maintenance applications: It is required the aggregation of basic events that include different failures or unavailabilities modes.

The three applications highlighted by the CNRA questionnaire do not require changes beyond above established.

<u>Question 4</u>:

I. Comprehensive review by Regulatory Authority. Utility was requested to perform an IPE. Some results were re-quantified by RA. RA's PSA is used for independent verification. Independent peer review by utility.

II. No specific standards. Fulfilment of the GL 88-20.

<u>Question 5</u>:

I. None.

II. RA has to develop review procedures and acceptance criteria:

- Improvements in PSA methodology and applications.
- Development of safety goals, regulatory analysis guidance (i.e. Cost-benefit analysis), risk acceptability criteria.
- Development of standards in interpretation of PSA results and their implications.

Netherlands
(Nuclear Safety Department: Ministry of Social Affairs and Employment)

Question 1:

Borssele PSA was completed: Level 3, all POSs, internal and external, human errors of commission and omission included.

SAM's were assessed and some implemented into the EOPs.

A Borssele SAMG specific programme will be initiated in the near future.

Dodewaard level 3 PSA (full power) and the level 1 PSA for shutdown mode were developed.

Borssele started to use PSA for other applications than those which can be characterised as identification of weaknesses, backfitting, A.M., and design.

Question 2:

PSA's play an important role in NPP licensing: PSA is necessary for a construction license and for the required periodic safety review (PSR) of an existing NPP, not only in prevention and mitigation of accidents but also in a compliance/verification process. In '80s a Government Policy Statement was issued and it included a PSC for new hazardous industries. Recently it has been declared to be applicable to existing NPP's.

- A 10 yearly backfitting rule was formulated for the existing NPP's and was extended to beyond design basis area. Level 1 + plays an important role.

- Currently in Borssele LPSA is applied in: Proposed modification assessment, risk follow-up (monthly and yearly basis), support in new maintenance concept, support of Ageing management project, support of large backfitting programme, and support of Severe Accident Management (SAM) programme.

- Borssele is planning to use LPSA for: Optimisation of TSs, assessment of shifting maintenance activities to power POS's, STI's for non-TS components.

- Recent uses of PSA are to prioritise regulatory inspection tasks by importance ranking, to support emergency planning and preparedness.

- Foreseen applications are: SAMG development, finalisation of draft PSA-guidelines, configuration control during low power and shutdown states.

Question 3:

I. At the onset of Borssele PSA only general requirements, the scope and objectives were discussed. NUREG/CR-2300 & NUREG/CR-2815 were adequate. E.g., assumptions should be realistic: CCF limits, recovery action when written procedures exist, available time realistic, success criteria based on plausible and agreed assumptions, sensitivity and uncertainty analysis to check them.

Parallel a Dutch PSA procedures guide (level 1 & 2, later extended to 3) was developed highly benefited from the on-going PSA, but too late to be used.

Current situation: Complete level 3, all POSs, internal, area and external events, errors of omission and commission (only Borssele) for current and after-backfitting plant.

IAEA was asked by the regulatory body to review PSA and to train the regulatory staff in the art of reviewing. Results of this IPERS review was the implementation of all POS's and errors of commission.

PSA guidelines should be "alive"; but they have to be not so much prescriptive: scope, boundary conditions and the general outlines. It is recommended that for consequences the code COSYMA, MACCS, or CONDOR will be used.

Question 4:

The regulatory body has to be involved into the project as much as possible, in addition to guidance and review, and without losing too much of its independency.

At the onset NUREG/CR-2300 and NUREG/CR-2815 were adequate at that time. MAAP-3 was restricted (only in combination with other level 2 packages).

Independent reviews by IPERS: level 1, shutdown, external events, level 2 and a final review showed that PSA was of high quality.

Question 5: No more than the already mentioned.

Slovak Republic

(Nuclear Regulatory Authority of the Slovak Republic)

Question 1:

Bohunice NPP (2 units) PSA has been completed, Mochovce (2 units) PSA is being developed. Results used in safety evaluation of design, assessing the Basic Engineering for upgrading.

PSA is going to be used in a new version of TS's improving safety configuration. Event assessment in special cases. CDF is being used as a safety indicator in NPP's assessment. After an approval of the methodology CDF should be used as a safety goal.

Question 2:

I. The deterministic approach is required, the probabilistic one is useful to implement individual safety improvements, prioritisation of upgrading measures, analysis of individual contribution to the risk reduction, assessment of residual risk, comparison with interim indicative safety targets and checking the safety level in comparison with other NPP's.

II & III. No specific answer.

IV. Acceptance criteria from regulatory body are expressed in terms of radiological consequences. Best-estimate methods are accepted for very low probability IE (10^{-4}).

Question 3:

PSA Regulatory guidelines are being developed based on IAEA guidelines: Procedures for conducting PSA (Safety series Nº 50-P-4), The role of PSA (SS Nº 106). PSA Level 1 will be required as a part of the SAR.

"Living PSA" under development and Risk Monitoring made by NPP's will be available in two years (Q1).

Safety Goals under discussion: Safety system reliability < 10^{-3}, RPS failure < 10^{-5}, CDF < 10^{-4} (for backfitting criteria) and screening criteria for external events 10^{-7}/r.y. (Q2.4)

Question 4:

I & II. Independent review for Bohunice were made. IAEA provided assistance in reviewing through IPERS missions. Independent review by Peer review team will be used in future practices.

Question 5:

I & II. None activity in development of review procedures, but they would welcome any assistance to their regulatory body.

Spain

(Nuclear Safety Council, CSN)

Question 1: See '95 responses.

Spanish PSA programme under development. The scope and requirements have been gradually increased to the most recent PSA that includes level 2, external events and non-full power state analysis (The final scope of this part is now being established by pilot projects). The PSA's has been required shifted in time to accommodate human resources, the acquisition of experience and the progress of methods and tools. Level 3 is not foreseen. The CSN has begun to ask for PSA updates to meet the latest requirements.

Parallel a regulatory review is being performed helping the prompt development of applications:

- Improvement or evaluation of design/procedures: It has followed any PSA. Changes in the support systems and actuation circuitry. Initiative by the utilities, aware of design weaknesses after their PSA. PSA final report usually includes a list of design improvements to be analysed. Sometimes the CSN has recommended design improvements from PSA insights.

- Improvements of procedures has been the more frequent PSA application, since they can lead to a significant risk decrease with relative low investment. New procedures has been developed too e.g., for testing the PZR PORV's without air for Feed & Bleed.

- Improvement of TSs: Many utilities have analysed and submitted AOT's changes. The evaluation have been made case by case. A temporary exemption to comply TS's supported by PSA arguments has been given to a plant whose dam water level has become too low until the river flows normally.

- Analysis of incidents and Operating experience: Pilot event analysis has been performed based at first in generic PSA models and later in specific ones. CSN is participating in an international project to set up the methodology for PSA-based incident analysis. PSA insights are being used in the incident review panel.

- Evaluation or improvement of operator training programmes: New aspects of accident sequences have been included in Operator Training Programmes. PSA insights are being considered for the CSN in the preparation of exams for new RO & SRO.

- Maintenance Programme applications: Two pilot studies are being performed to integrate PSA insights into the maintenance programme, supporting the implementation of a Maintenance Rule.

- Qualification requirements: PSA insights have been used to change qualification requirements for SSC at some plants.

- Analysis of compliance with deterministic regulations: Fire PSA insights have been used in relation with the 10 CFR 50 Ap.R weighing different protective measures alternatives, supporting the exemption to install them or advising safety requirements beyond this regulation.

Question 2:

I & II. The regulatory process is basically deterministic. Nevertheless, PSA insights are increasingly being taken into account in the last years, providing an additional input to the decision analysis. No formal criteria have been established to define the relative weight. Decisions are made on a case by case basis. Different situation can be distinguish:

- PSA application for Design/procedure improvements: It should not create any conflict with traditional deterministic requirement. No regulatory approval is needed for changes not classified as unreviewed safety issue (10 CFR 50.59) provided that the change really improve plant safety.

- PSA application to guide regulatory actions: e.g., incident analysis, inspections, examination of plant operators. No conflicts exist with traditional procedures.

- PSA applications to alleviate regulatory burdens: Eventually, at the cost of certain risk increase, e.g., TS's modifications, Ap. R exemptions. The deterministic analysis can establish the existence of a margin for probabilistic consideration. In such cases a probabilistic assessment can shape a regulatory decision. The relative weight is case specific. PSA arguments can be used to refuse acceptable options from deterministic point of view. Only negligible risk increases can be accepted, or it should be compensate with alternate measures.

III. Decisions can be made on a probabilistic basis in order to reduce regulatory burdens, but always preserving the Defense-in-depth philosophy.

IV. No formal safety criteria or figures of merit established. CDF in an absolute or relative way, and the subsequent importance measures.

<u>Question 3</u>:

I. The Spanish PSA requirements are as high as reasonable achievable at the time (See '95). The analysis is performed with the state-of-art methods and the highest achievable level of detail, commensurate with the subject importance, availability of data, existing limitations, assumptions made, etc. The objective is a depth and homogeneous analysis:

- Boolean models are generated mostly by "small ETs/large FTs", the success criteria are derived on a best estimate basis, performing enveloping thermohydraulic calculation for almost every accident sequence.

- Reliability data is obtained from the own or national sources, supported by Bayesian update of generic data if necessary. Extensive data is retrieved from own plant experience: operating hours and demands, maintenance, surveillance outages, repair works; consulting maintenance records, logbooks, etc. A national reliability national data bank is under development to support future updating.

- Sensitivity & uncertainty analysis are performed to cope with the lack knowledge about data, assumptions, phenomena, etc.

- A data base is going to be built at the CSN to compile the relevant analysis assumptions, criteria, methodologies, etc. in order to understand differences in some PSA insights and provide a basis for future actions to increase the homogeneity among PSAs.

II. Any specific application need some tuning of PSA models, or the development of additional models:

<u>Evaluation/improvement of design/procedures, backfitting</u>: Logic models, IEs, data analysis, human or component behaviour, boundary conditions or hypothesis may need changes. In case of layout re arrangements, dependent failure analysis and external event scenarios might get affected significantly. Some systems have functions not modelled in the PSA (during refuelling or start up) that must be considered, because they could be jeopardise through theoretical system improvements. It must be ensure that the proposed action will not have negative consequences in other areas and the probabilistic analysis should try to address any safety factor for the issue.

<u>Evaluation of TSs</u>: It is developed according basically to the NUREG/CR-6141. For STI's and strategies, failures per demand must be change and time dependent analysis must be performed. The impact in common cause failures should be assessed. AOT's optimisation must consider the risk in shutdown conditions.

<u>Configuration control during operation and maintenance</u>: There is no real own experience. A Spanish utility is developing a risk monitor system which can help in planning maintenance activities or identify violations in TSs. It needs further improvements: to consider the effect of adverse conditions outside the plant or failure/outages of non-safety related systems in the IE frequency, the effect of unavailable fire barriers of detection/suppression systems.

ISI: Spanish organisation are following or involved in international activities or pilot experiences. After that some methodology and application guides will be produced.

Demonstration of safety level of the oldest plants: It has been one of the major application. The first PSA in Spain was required in the frame of a "Systematic Evaluation Plan" in order to improve the old generation of plants. This leaded to further PSA requirements to perform in-depth review of design and operating practices.

Question 4:

I. Spanish situation closer to the option A. See '95 answers.

II. No formal review guidelines, though, they might be published in the near future to undertake the review of PSA updates and applications. The review took into account international known guides, but was strongly based on the knowledge and experience of the reviewers in four fundamental areas: NPP technology (design, operation, regulation, etc.), PSA techniques, PSA development and PSA review. This knowledge and expertise lead the review process, not easily reflected in review guides.

Question 5:

A wider implementation of PSA methods in regulatory activities is foreseen and being planned, guidance, criteria and training is necessary. Soon a new edition of the PSA Integrated Programme will be issue (it leads in practice PSA activities), and the development of application guides is included. This guides should indicate requirements, methodology, presentation of results, decision criteria, essential aspects of general applications or specific ones.

Changes in current regulations are needed. A commission between the industry/regulatory body has been created to find a consensus on the way to include progressively PSA insights. Research and development projects are being planned too. Training programmes have been started in order to increase the understanding and acceptance of PSA techniques and to make easy communication between PSA experts and other experts in the regulatory body and the industry.

Sweden

(Swedish Nuclear Power Inspectorate)

Question 1:

A number of PSA's are to be reviewed regarding quality, scope and completeness, following up on recommendations made in earlier versions and discussion about the results and what to do with identified weaknesses. There are also ongoing activities to improve future versions of PSAs:

- A collection of data for updating the T-book and I-book (IE).
- Research programmes that deal with LOCA frequency and external events.
- Participation in the International CCF Data Exchange (ICDE).

Question 2:

PSA can be used for various purposes: Identification of weaknesses, evaluation of changes in systems and procedures, evaluation of in-service and inspection programmes, evaluation of proposed changes in TS's such as maximum allowable time for repairing and maintenance, evaluation of significant events, follow up on actual safety level due to events. The first two are the dominant areas today.

Question 3:

They do not have any formal requirement, striving for continuous improvements. The study must be up to "what can be expected at this time".

Question 4:

The utilities are required to review their PSA before it is finalised. After that, the Regulatory Authority does a complete review. The last one was based on a document called " A probabilistic safety assessment review guidance for Swiss (**?**) nuclear power plants" Nov. 92.

Question 5:

See Q3 & Q2. When it comes to application they will probably see an increased use in various applications.

Switzerland

(Swiss Federal Nuclear Safety Inspectorate)

Question 1: See '95, Chapter II 3.0 & 4.0

Plant specific PSA's are an important part of the Periodic Safety Reviews (PSR's) foreseen each 10 years, including a complete update of the PSA (actually more frequently).

All utilities are using PSA's for optimisation and backfits. The PSA expert is member of the backfit team. The Swiss Federal Nuclear Safety Inspectorate (HSK) includes PSA results and insights as an important part of the decision making process. E.g., assessment of the benefits of partial automation of the change of the recirculation mode in Beznau.

PSA-based improvements of TS's are becoming more important for all NPP's. Improvements have been identified mostly from the shutdown study. Changes are under investigation about shutdown in case of 2 RHR unavailable.

Most Accident management planning actions are based on PSA results. E.g., the installation of H_2 recombiners in Beznau is not risk-justified, with improved SAMG and filtered containment venting the probability of hydrogen combustion-induced containment failure is close to 0.

HSK has started a "Living PSA" project with the intention to investigate events/incidents and precursors, to help in developing a PSA-based safety indicator programme, to optimise inspection task, to support ageing analysis and to optimise configuration control during operation and maintenance.

Question 2: See '95 Chapter II 1.0 & 2.0, to some extent Chapter I.

I. The requirements are documented in a set of guidelines (deterministic-based) periodically updated which supplement international safety standards. These are mandatory for new NPP's, and operational NPPs have to be backfitted to the extent reasonably practicable and have to apply plant specific supplemental measures, not necessarily cost-benefit-based. Exemptions can be obtained by demonstrating that specific requirements do not result in a measurable safety improvement. Under this, PSA is viewed as a complementary tool.

Any dominant risk insight from PSA's have to be addressed by the licensee.

HSK thinks that PSA insights and results have to complement and to some extent replace deterministic requirements. The deterministic requirements have to be based on best-estimate analysis taking into account uncertainties.

II. There are no formal procedures to integrate risk insights with deterministic requirements. Many accident management improvements are solely based on PSA insights. There is the intention to review the current safety guidelines and procedures, in the light of the insights gained through the PSAs. The goal is to achieve a set of risk-informed and safety-balanced recommendations.

III. The PSAs have confirmed the importance of Defense-in-depth for prevention and mitigation. The concept is still valid and supported by PSA insights. It is important to have a safety-balanced plant, which means an optimisation of each level of Defense and that public risk is not only the measure for decision-making, but also the CDF and the reliability of safety functions.

HSK will not accept any change which would result in a weakening of an important safety function (shutdown, heat removal, containment isolation).

IV. See Appendix 2. Based on HSK's proposal, which has to be assessed further, they believe that for Swiss NPP's a mean CDF-value of 10^{-5} is achievable and, based on the results, is already achieved. HSK also proposed a limiting curve for radioactive releases in the form of a CCDF curve. Swiss plants also fulfil the proposed safety curve after some backfits to improve the mitigation of severe accidents.

Question 3:

I. See '95 Chapter I. Regarding the safety review, guidance ERI/HSK 92-1115 is an integral part of the response.

II. HSK has not yet developed formal requirements or guidelines. See Q1 & Q2. The Living PSA will address most of the specific PSA applications mentioned on the question. Current practices at HSK take into account PSA insights and results on a more or less daily basis. This is possible because of the relatively small regulatory body and the fact that detailed plant-specific PSA studies are available for all plants and have been reviewed by HSK/ERI or are under review. See Ap.2.

Question 4:

See '95 Chapter. Regarding the PSA review, guidance ERI/HSK 92-1115 as an integral part of the response.

HSK is convinced that only by independent analysis, sound and reasonable decisions can be made using plant-specific PSA studies.

Question 5:

HSK has already developed a PSA review guidance and has also proposed criteria for regulatory applications of PSA. See HSK/ERI 92-1115 and Ap.2.

Further development are not foreseen. The next step will be to integrate the results of the "Living PSA" project into their daily regulatory and inspection activities.

Final Comments:

The questionnaire is very much focused on formal regulatory guidelines and recommendations. This approach may be appropriate for countries with a large nuclear power programme; however for a country with small programme, a less formal approach that can evolve with time has been very effective.

HSK strongly believes that PSA applications should not be too formal in order not to stop further developments. Their approach shows the importance of a complete, up-to-date and "living" plant-specific PSA study reviewed in detail by the regulatory organisation.

Uncertainties are inherent to both deterministic and probabilistic methods. The goal for the regulator is a well balanced plant in view of safety and risk. For this, both probabilistic and deterministic have to be best-estimate and the uncertainties have to be exposed. HSK strongly believes that in this way deterministic analysis complements and is a precondition for the probabilistic. Knowing the best-estimate value together with uncertainties reflects the level of confidence of the real plant behaviour and should be the basis for any decision-making.

Conservative analysis (both probabilistic or deterministic) could lead to wrong conclusions, producing unnecessary burdens without any improvements in safety. HSK believes that this approach should not be used any more.

"In order to promote the applicability of PSA for regulatory use, an international group of experts should be installed with the task to establish and periodically revise standards concerning acceptable methods, events to be considered and the procurement of input data for PSA".

United Kingdom

(HM Nuclear Installations Inspectorate)

Question 1:

Regulatory requirements for a PSA: Attached to the license there is a PSA requirement. Licensing and inspection is carried out by the Nuclear Installations Inspectorate (NII). The level of safety that it has to be achieved is expressed in the Safety Assessment Principles for Nuclear Plants (SAPs), giving criteria for both deterministic/engineering and PSA. However, a licensee can propose alternative and justified methods.

Uses of PSA:

Comparison with probabilistic risk criteria given in the SAPs: These relates to the maximum effective dose to a member of the public (five dose band), individual risk of death, a large release of radioactivity, plant damage, and an inadvertent critically excursion in a plant other than a nuclear reactor. For each SAP's defines a basic safety limit (BSL). If the risk exceeded the BSL the plant would not be allowed to operate.

To ensure that the risk is as low as reasonably practicable: If the risk is below that BSL, the requirement is to show that the risk is as low as reasonable practicable (ALARP). A basic safety objective is defined which is the point at which the NII assessor need not seek further safety improvements from the licensee, but there is a statutory obligation on the licensee to identify whether there are measures which could be implemented to reduced the risk further.

In addition there is a subsidiary criterion which requires that no single class of accident should contribute more than one tenth of the total frequency (risk balanced). This is useful in making judgements based on a partial PSA.

Design evaluation: The PSA is used to carry out a design evaluation to identify weaknesses in the design or operation and the improvements, including: redundancy, diversity, separation, segregation, protection and qualification for safety systems, and the way the plant is operated, in particular the configuration control under test or maintenance periods. E.g., several systems has been added to magnox reactors.

To address changes in the level of safety during plant operation for testing, maintenance and repair.

Allowed outage times and configuration control during operation and maintenance: NII requires the licensees to use the PSA's to justify that outage times and allowable plant configurations they proposed are acceptable. There are currently two on-line systems to help the operators to ensure that a proposed outage is acceptable:

- The Essential Safety System Monitor (ESSM at Heysham 2) provides direct information.
- A large number of PSA runs is tabulated (Torness) within a computer based system used interactively by the operators.

NII is encouraging the licensees to use the new PSA's as part of the periodic safety reviews to ensure that outages are properly controlled.

In-service testing and inspections: No requirement. Informal feed-back.

Event assessment: Very little is done in this area.

Emergency planning: The normal approach is to define a reference accident for each site with a frequency greater than 10^{-5}/y. There is a requirement to demonstrate that the emergency plan can be extended to larger accidents. The level 2 is used to provide source term, release characteristics and frequencies.

Level of PSA required:

Licensees often limit the extent of the PSA assuming that the core damage sequences would lead to the higher off-site doses (>1000 mSv) or a large release, so they meet criteria without carrying out a level 2 PSA. Though there are some level 3 PSA and provides the risk for a number of potential societal detriments, there are no criteria for societal risk.

The PSA's do not address the criteria of individual risk of death for workers at this time.

For plants others than nuclear reactors the approach is to carry out a HAZOP to identify the fault sequences which could lead to a dose to workers, a release of radioactivity or a criticality incident. The level of analysis is similar to a level 1. Estimates are made of the releases of radioactivity, the doses to workers and members of the public and the individual risk of death.

Question 2:

I. & II. Based on their experience they state that insights from deterministic and probabilistic principles are generally in agreement:

- Failure to meet single failure criterion means low reliability.
- Failure to meet diversity means weakness in the reliability for frequent faults.
- Failure to meet segregation means large contribution from energetic events.
- Failure to meet qualification means large contribution from environmental conditions and earthquakes.

However, there have been cases where both principles are not in agreement (One indicates there is a weakness and the other doesn't. There is no formal procedure to reconcile these differences and they have been resolved in a case-by-case basis, usually with the emphasis being placed on the weaker argument:

- NII accepted the licensee proposal not to modify ECCS in order to provide more RWST redundancies based on a non-significant reduction in the risk.
- NII accepted to make modifications to the secondary systems at power against deterministic rules, based on probabilistic and cost-benefit arguments.
- NII rejected a proposal to operate for short periods of time with the level of redundancy on the secondary shutdown system reduced. In spite of reasonable risk-based arguments, the fact that the primary protection would not remain in place dominated the last decision.

III. Level 1 PSA: To determine weaknesses in the design and operation for all the nuclear plants.

Level 3 PSA for Sizewell B: The level 2 showed that containment provides an additional Defense-in-depth level. Also, it showed that there was very little benefit from the incorporation of a filtered containment venting system and it was not included. The main use of the level 3 is in emergency planning but it has not been considered in Sizewell B because this requirement is determined by Sizewell A (Magnox).

Level 2 + for the naval refuelling facilities: It has been used for emergency planning.

IV. Risk criteria: CDF for comparison with the SAP criteria.

Other figures of merit: RAW, RRW, Fussell-Vesely and Birnbaum importance. These represent the starting point for the consideration of improvements and the demonstration of ALARP.

Point-in-time risk: As well as considering the risk averaged over all the modes, there is a need to ensure that the point-in-time risk during particular operations is acceptable (the combination of equipment allowed to remove from service at the same time), and it is not sufficient to argue that the duration of the activity would be so short that the contribution to the average risk would be small.

Question 3:

I. Scope of the PSA: SAP's criteria are related to the total predicted frequencies:

- All modes of operation.
- All sources of radioactivity.
- All internal events and internal hazards (fire and failure of pressurised systems.
- All external hazards including earthquakes, aircraft and extreme weather conditions.
- All extreme events such as the rupture of the RPV.

However, the actual scope of many PSA's submitted falls short of this at the present.

Level of detail: Failure of individual components. However, pipework failures are not normally included.

Key assumptions:

- Best estimate assumptions and data, where this is impracticable a reasonably conservative approach should be adopted.
- The failure probability due to common cause failures should not be lower than 10^{-5}.
- Operation actions in fault condition apply only if written procedures exist.
- Credit only for safety classified systems and non-classified if it demonstrates that it would be operable.

Sensitivity analysis: The studies should cover the uncertainties in the data and the models which support the PSA. In practice they address the data, but not all the assumptions made, in a systematic way. In addition, we have no criteria for judging when the results are significant. This is currently the subject of a project.

Data sources: In the assessment NII would determine the suitability. Plant specific data supported by other sources is preferred. In the absence, data from similar plants supported by generic data, and this one is the last resource. The licensees are required to collect specific data and to analyse to determine ageing effects. This data will be used in future up-dating.

Modelling approach: In the assessment NII would determine the suitability. There is no consensus in the best approach.

Success Criteria: They should be best-estimates. However, to limit the extent of the transient analysis required conservative success criteria could be used.

Uncertainty Analysis: NII does not require it.

II. Configuration control during operation and maintenance: The basic PSA's have been used for configuration control during outages by carrying sensitivity studies and reflecting the results into the plant operation procedures. However, for an on-line facility the PSA has to be refined:

- Each train need to be represented explicitly.

- Super-components will need to be reviewed.

- IE will need to be assigned to particular locations.

Changes in regulatory requirements with regard to ISI, IST and safety classification: The PSA has not been used in a systematic way. NII requires that the safety classification is reflected in the failure probabilities. In addition, PSA identifies the need of additional classified equipment.

Demonstration of adequate safety levels of plants designed to earlier standards: The licensees are reluctant to carry out a seismic PSA for reactors that were not specifically designed. The same occurs to shutdown PSA, instead of arguing that timescales are as long as the level of risk is low. Discussions are ongoing and these issues will be resolved.

Extensions to allowed outages times: Requested have been presented trough sensitivity studies.
Mode transition risk resulting from forced shutdowns: No estimates of risk has been made. Sizewell B uses bounding arguments to try to account for this.

Question 4:

I. The PSA is carried out in parallel with all the other assessment work on the safety case. The degree of the assessment takes account of the level of risk, the complexity and political considerations. E.g., Sizewell represented a new type of plant and there were public concern following TMI. This implied a detailed assessment, an independent peer review and an additional analysis to determine the overall importance of safety systems. E.g., A relatively detailed assessments has been carried out for the magnox reactors, the high risk plants on the Sellafield site and the plants leading up to the licensing for manufacture of atomic weapons. For other plants with lower level of risk, the assessment has been limited to the PSA areas judge to be more significant.

There are no standard procedures to review PSA. However, the assessment process includes: the scope to address all the SAP's criteria, completeness, methods and models, IE determined systematically, common cause failures adequate, data acceptable, grouping of IE's in an acceptable way, core damage sequences estimated in an acceptable way and more significant ones included, sufficient sensitivity studies about assumptions and data, weaknesses identified and improvements proposed, and met ALARP criterion.

A fully detailed analysis is not required for older plants for small contributor sequences, and the level of detail depends on the judgement of the assessor. In early stages the PSA will need subsequent updates because of the lack of information.

In addition, the PSA which are produced by licensees are reviewed within their own organisation or independent external organisation before being submitted to NII. No PSA has been repeated to contrast results, but it has for some parts.

II. Guidance to NII assessors is given in the SAP's and other internal guidance to support the SAPs, which provides an interpretation of the principles given in the SAP's and gives some more detail. Some of this relates to PSA but it is currently being amended to bring it up to date. They explain how the PSA should be assessed but they do not give formal acceptance criteria. This relies heavily on the judgement of the assessor who is carrying out the assessment. There are no agreed standards for PSA in UK.

Question 5:

I. The currently review of the guidance on PSA.

II. NII is encouraging licensees to adopt a greater uniformity to carry out a PSA and to assign the data values to PSA for similar type of plants.

United States

(U.S. Nuclear Regulatory Commission)

Question 1:

Current applications of PSA to regulated activities in the USA are described in the 1995 Nuclear Energy Agency report (NEA/CNRA/R(95)2 entitled, "Regulatory Approaches to PSA," and include the following: analysis of new reactor designs, incident analysis and generic precursor studies, optimisation of technical specifications, improvement of operator training programmes, analysis of probabilistic safety indicators, prioritisation of inspection activities, optimisation of quality assurance programmes, evaluation of the effectiveness of existing regulations and cost/benefit analysis of new proposed requirements. Enhancements of these applications and applications currently under development are described in the NRC PRA Implementation Plan, which was first published in 1994 and is now updated quarterly.

<u>Question 2</u>:

I. The USNRC has a formal policy statement which calls for the use PRA in regulatory matters in a way that complements the NRC's deterministic approach and supports the NRC's traditional Defense-in-depth philosophy. To implement this policy, the NRC's framework for applications of PRA calls for consideration of deterministic elements (e.g., test and analysis, quality of design, codes and standards, Defense-in-depth) and probabilistic elements, and integration of the results in the decision-making process. The integration process for specific applications may involve a reassessment of the bases of existing regulations. Such a reassessment would address increased technical knowledge and data since the regulations were established and would take advantage of the risk insights derived from probabilistic risk assessments.

II. The USNRC is currently considering ways in which information from the various levels of PRA can be used to determine the degrees of redundancy and diversity remaining after a change has been implemented. The minimal cutsets produced by the PRA are useful in this regard because they can clearly reveal the effects of a plant change that significantly reduced redundancy in a key safety function. Examining the way a proposal is modelled in the PRA can reveal the extent to which the change can impact accident initiators, mitigative system availability and reliability and containment performance which relate directly to Defense-in-depth. In addition, the NRC staff will establish diverse decision criteria such as core damage frequency and large early release fraction which cover separate independent barriers to the release of radioactivity.

III. The NRC staff recently issued guidance for two applications regarding the use deterministic and probabilistic information in an integrated fashion for decision-making. They are: NUREG-1526 which relates to implementation of the Maintenance Rule and addresses the use of PRA insights in determining the risk significance of the systems, structures and components (SSC) in the plant in setting performance goals commensurate with safety; and NRC evaluation and approval of the BWR Owners Group methodology for prioritising motor operated valves for the testing described in NRC Generic Letter 89-10.

The NRC staff is currently developing regulatory guidance documents for utilising PRA in other reactor-related activities. The staff is developing a series of application-specific RG's and SRP's that address specific issues associated with specific applications, including: changing allowed outage times in technical specifications; and prioritising systems, structures and components for in-service testing, in-service inspection and graded quality Assurance. The staff is also developing an RG and an associated SRP that cover a broad range of common technical areas. Drafts of these documents will be available for public comment in early 1997.

IV. The USNRC has two qualitative safety goals which are that nuclear power plant operations should not result in significant additional risks to individuals or to society and two quantitative objectives for use "in determining achievement of the qualitative goals." These quantitative health objectives (QHOs) were defined in terms of a percentage (0.1%) of the total accidental and cancer death rates experienced by the public. In addition, and for reasons of practicality, subsidiary objectives have been formulated in terms of the frequency of core damage accidents and the performance of containment structures under accident conditions. The QHO's and subsidiary objectives have been used by the NRC staff only in the context of generic regulatory decisions, such as generic backfit decision-making. Figures-of-merit used in generic backfit decision-making include core damage frequency and conditional containment failure probability.

Question 3:

The NRC does not currently have specific requirements nor formal regulatory guidance for utilities or the NRC staff to use when performing probabilistic risk assessments in support of regulatory activities. Development of such guidance is in progress as part of the NRC's current effort to develop new Regulatory Guides and Standard Review Plans addressing the use of PRA in regulated activities. This new guidance will specify basic PRA attributes needed to support particular applications including such things as: model scope (e.g., accidents initiated at full power versus those initiated during shutdown operations); level of detail (e.g., systems, components, phenomena, human action, etc.); use of plant-specific versus generic data; treatment of common-cause failures; treatment of human performance; selection of realistic success criteria, truncation criteria, treatment of uncertainties and the use of importance measures.

Question 4:

I. The NRC does not currently have procedures for formal review and approval of probabilistic risk assessments submitted by licensees or applicants in support of regulatory activities. Development of such procedures is in progress as part of the NRC's current effort to develop new regulatory guidance addressing the use of PRA in regulated activities.

There are areas which in the past the NRC has utilised PRA input in decision-making (e.g., changes to technical specifications, reviews of new reactor designs). In all cases the scope and depth of the technical review of the PRA has been based on the particular application, with emphasis on the importance of the PRA information to the overall basis for decision-making. In cases where the PRA results have played a significant role in supporting the NRC's decision, a comprehensive review was performed by the NRC.

II. Procedures and documents included by reference.

Question 5:

I. See last paragraph under Question 2, Part III above.

II. All future work regarding review procedures and criteria for regulatory applications of PRA will be planned and scheduled as part of the agency's ongoing PRA Implementation Plan.