SCIE-91-88

# FINAL REPORT

## OFFICE OF NUCLEAR REGULATORY RESEARCH

## RESEARCH ASSESSMENT METHODOLOGY

### Task IV - Results

SUBMITTED IN RESPONSE

TO

USNRC CONTRACT NO. NRC-04-87-089

(S.B.A. CONTRACT NO. SB 08710219)

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# 1.0 INTRODUCTION

## 1.1 Purpose

The purpose of this document is to report the results of the application of the research prioritization methodology. Designed for use in the prioritization of NRC research, the initial methodology was presented in November at the end of Task I of NRC contract No. NRC-04-87-089 (Ref. 1), and the methodology was further evolved during the Task II trial (Ref 2) and the Task III review.

## 1.2 Objective

The objective of research prioritization is to provide the Director of the Office of Research (RES) with the information required to allocate the FY89 RES budget in a manner which reflects the current strategy of the agency. While the overriding mission of the NRC to ensure the public health and safety has remained steadfast since 1954 when the Atomic Energy Act created the Atomic Energy Commission, the year-to-year challenges which the agency, and therefore RES, must resolve are constantly changing.

Little more than a decade ago the nuclear industry was in a period of rapid growth. Many new power plants were being constructed, and plans for still more were on the drawing boards. Licensing these plants presented challenges to which the Office of Research responded by developing new, generally applicable, analytical capabilities to expedite the licensing process. Today, these same tools, which have evolved apace with the growth of technological knowledge, are still providing the agency with a state-of-the-art capability to analyze nuclear power plant designs and anomalies in nuclear power plant operation.

However, the major challenges facing the agency today are different. Now, a mature nuclear industry presents the NRC with such diverse challenges as aging of power plants, protection against severe accidents, protection of workers in contaminated areas, and the disposal of nuclear waste. Over time, the focus of the agency has shifted in order to be able to better deal with the changes in the industry which it regulates.

In order to better anticipate and accommodate change the NRC has initiated a strategic planning process. The first NRC Strategic Plan (Ref. 3) presents nine overall goals and detailed strategies. The goals were used to provide the basic structure upon which the research prioritization methodology was constructed, hence, the results of the prioritization reflect the current mission of agency.

No attempt is made to ascribe quantitative values to the results of research prioritization. While numbers more readily lend themselves to analysis, they also too readily obscure the reasoning upon which they are based, making it difficult to trace a judgement back to the basic premises and facts upon which it was based. In this methodology it is essential that the premises be fully apparent so that they can be evaluated and the conclusions tested in order to arrive at fully-informed consensus judgements.

## 1.3 Acronyms, Abbreviations, and Definitions

**Safety Assurance** - an attribute of a research activity which describes the research's relevance to the NRC mission. This relevance is defined by mapping the research back to a set of questions derived from the NRC's Strategic Plan and basic policy statements, and grouped in accordance with the following definitions:

> **Category A (Vital)** questions are those associated with major contributors to risk which could lead to changes having a direct and substantial impact on the health and safety of the public or on national policy regarding generation of power or utilization of by-products thereof, or special nuclear materials. The answers to these questions could impact directly the licensing of proposed operations, or the regulation of existing operations, including termination or restart of licensed operations.

> **Category B (Important)** questions are those associated with moderate contributors to risk, the answers to which help ensure continued safe operation, and which address potential safety issues. These questions are concerned with inspection and auditing of operations, analysis of operating

are concerned with inspection and auditing of operations, analysis of operating experience, and evaluation of potential shortcomings of proposed and existing operations. The answers to these questions frequently result in regulatory changes.

**Category C (Vigilant)** questions are those which must be answered to confirm licensing decisions, improve NRC's capabilities to perform licensing and enforcement functions, offer important insights into the health impact and safety of operations, or are exploratory in nature, seeking new knowledge and understanding. Independent assessment of safety concerns and the explorations of safety improvements are also addressed by these questions.

**Usefulness** - an attribute of a research activity which describes the research's timeliness, its probability of application, and its probability of successful completion. For the research prioritization methodology there are three assessment levels for usefulness:

HIGHLY USEFUL: The activity will clearly produce information needed to answer one or more safety assurance question, and the information will become available consistent with established schedules;

VERY USEFUL: The activity is expected to produce information useful in answering one or more safety assurance questions, and the information is expected to be available on a timely basis;

USEFUL: The activity is expected to produce information bearing on resolving safety assurance questions

**Appropriateness** - an attribute of a research activity which describes the degree to which the NRC should fund the research. For the research prioritization methodology there are three assessment levels for appropriateness:

HIGHLY APPROPRIATE: There are compelling reasons for the U. S. Government to undertake the activity. Furthermore, among government agencies NRC has the primary responsibility for this activity. Potential compelling reasons are:

(a) the research requires special skills not supported elsewhere,
(b) the research requires special facilities that no one else supports,
(c) the research is classified,
(d) the research provides independent information (e.g. to confirm licensing requirements,or to establish need & definition of new licensing requirements.),
(e) the research is key to obtaining needed information from other countries

VERY APPROPRIATE: It is appropriate for NRC to undertake the activity. Furthermore, there are no other organizations (industrial or governmental) with clear responsibility for the activity. Without NRC support the activity would not be pursued;

APPROPRIATE: It is appropriate for NRC to fund the activity, however, either industry or another government agency shares responsibility for, or will benefit from, the activity and could participate in funding the program

**Resources** - An attribute which describes the resource requirements for the activity. For the research prioritization methodology there are four elements included in the resources attribute:

COST-TO-DATE: The cumulative costs spent on the activity prior to FY88

COST-TO-COMPLETE: The estimated costs required to bring the activity to completion (and the year of completion)

FY88 COSTS: The budgeted costs for the current fiscal year

FY89 COSTS: The estimated budget for the upcoming fiscal year

## 2.0 DESCRIPTION OF METHODOLOGY

The research prioritization methodology is predicated upon the fact that rational decisions can only be made upon the basis of an explicit value system. Decisions involve choosing among alternatives, and the only rational basis for choosing one alternative over another is to choose that which provides the greatest value. NRC research is no exception to this rule: there is value to be derived from the results of research, and this value is the basis upon which choices are made.

The methodology ascribes value for each research activity in accordance with its relationship with a system of attributes. Defined by experts knowledgeable in nuclear regulation, analysis, and research, these attributes evolved during the course of the prioritization process to represent a consensus viewpoint[1] of how to measure the value of research results. The attributes which came out of this process are[2]:

**Safety Assurance** - a measure of how well the research conforms with the NRC mission to ensure public health and safety

**Usefulness** - a measure of how likely it is that the results of the research will be used, and that the results will be timely.

**Appropriateness** - a measure of how proper it is for the government, and the NRC in particular, to fund the research.

**Resources** - a measure of the sunk costs, current year's cost, next year's proposed cost, and estimated costs to complete. (This is the only purely quantitative attribute used in the methodology.)

(Complete definitions for each of these attributes are contained in section 1.3 and in Appendix B.)

Figure 2-1 provides a graphic depiction of the general steps in the methodology. The first step has already been partially described in the discussion of prioritization attributes. But there is another part to the first step: the formulation of a list of questions which the NRC must resolve in order to continue meeting its mission. Such a list provides a frame of reference against which to measure research value.

The list of questions which the NRC must resolve provides an absolute frame of reference for research. The questions pose problems which the agency endeavors to answer, irrespective of whether it is already doing research to find answers or not. To fully appreciate the implications of this viewpoint it is only necessary to consider a methodology in which the value of the research is assessed by comparing one research project against another. The results would show only a relative ranking and would not provide any indication as to whether needed research is not being done, or whether there is research being conducted or planned for which there is no current need.

In contrast, the list of safety assurance questions defines a basis for measuring the completeness of the entire program of research. Questions for which there is no associated research indicate potential gaps in the existing research programs. Research which does not appear to address a particular question indicates work which may no longer serve a purpose. Either result delves beyond merely arranging the order of the current research, and provides a measurement of the completeness of the research program as a whole.

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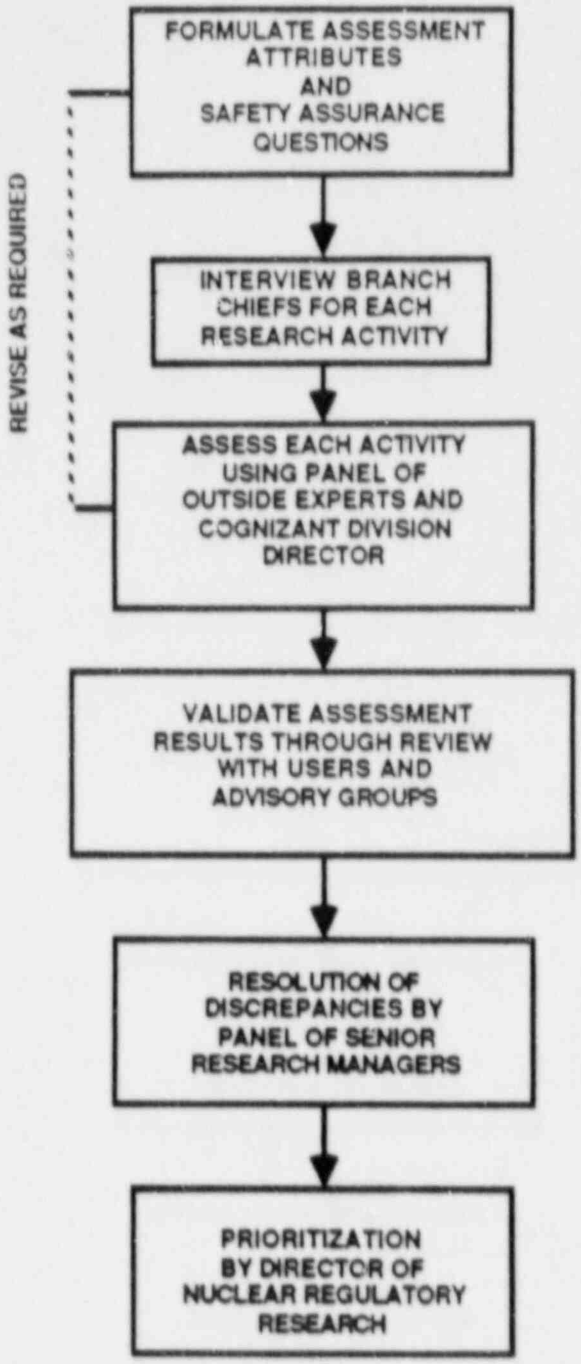
[1] The initial attributes were defined during the first meeting with the contractor in October 1987, and refined by the contractor and NRC managers during the application of the methodology.

[2] There is no hierarchy to the attributes implied by the order in which the attributes are presented. Weighting of the attributes, if any, is left to the perogative of NRC's Director of Nuclear Regulatory Research.

**Figure 2-1**
**Research Prioritization Steps**




To be a viable yardstick for assessing the completeness of the research, however, the list of safety assurance questions should be an accurate reflection of the current goals of the agency. To ensure that this was the case, the NRC strategic plan was analyzed using the technique of successive decomposition to break the general requirements (goals in this case) down into more specific sub-requirements (strategies), as illustrated in Appendix A.

From this analysis the first list of NRC questions was formulated[1]. These questions (presented in Appendix B) indicate areas which the NRC must address to meet the goals set forth in the strategic plan. Addressing these questions may not necessarily require the participation of RES, but the questions indicate potential areas of research.

Concurrent with the formulation of the attributes and the questions, a panel of expert was designated, with membership as shown in Table 2-1. These experts provided the external viewpoints which were crucial to the success of the methodology (as will be described shortly). Each judge brought to the process a familiarity with those areas of research within their area of specialization, but it was their general knowledge of the mission of the NRC and their unbiased view of specific research projects which were the purpose of their involvement.

In the second step of the methodology, interviews were conducted with RES Branch Chiefs in order to gain detailed information about each research activity included within the scope of the project. The interviews, which were designed to provide reliable information regarding the safety assurance, usefulness, appropriateness, and resource aspects of the various activities, yielded a significant portion of the information upon which the later assessments were made. Each interview was conducted by one of the experts named in Table 2-1 using the questionnaire contained in Appendix C.

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[1] The initial list of questions was developed by the contractor to provide a basis for discussion. The final list transmitted by the NRC Project Officer (Ref. 4) is the end result of three separate reviews by NRC RES Division Directors

In the third step of the prioritization, each research activity was assessed in accordance with the four attributes formulated during step one. These four assessments, illustrated in greater detail by Figure 2-2, were performed by a panel consisting of two experts from Table 2-1 and the NRC Division Director responsible for the research in that area. The membership of the panel meetings is shown in Table 2-2.

The outside experts provided unbiased viewpoints about the research, while the Division Director brought to the process a detailed familiarity with the work. For each activity covered, a consensus assessment was achieved with regards to safety assurance, usefulness, appropriateness, and resources. These assessments were documented in the Summary of Activity sheets presented in this report as Appendix D. With the completion of this step, contractor involvement in the initial assessment of the research has been completed.

At the time this report was written, the validation of the assessments was underway. During the validation step the assessments will be reviewed and challenged by NRC staff and management, and by advisory groups. Each review will broaden the perspective and improve the assessment. The end result will be an assessment of NRC research which has been validated[1] by the people using the results, by experts in each area of research, and by the people responsible for the work. Figure 2-3 presents a more detailed schematic of how this process is currently envisioned.

In the final step, the Director of Nuclear Regulatory Research will be able to draw from the assessments presented by the Activity Summaries to perform the prioritization. Because of the previous steps in the process the Director will have at his disposal:

- a clear description of the purpose of each research activity,
- an assessment of the safety assurance significance of the research (including the relevance of the research to the NRC mission),
- an assessment of the potential utility of the research results,
- an assessment of the appropriateness of NRC involvement,
- and a description of the resources required for the research.

Moreover, the Director will have the benefit of knowing that the assessments represent more than a single viewpoint. Because the methodology seeks consensus viewpoints it forces each assessment to be tested several times so that the final judgments include perspectives from both the users of the research as well as those performing the research.

[1] In the context of this work the term "validation" refers to the careful examination of the assumptions (or premises) upon which the assessments are based.

**Table 2-1**
**Panel Of Experts**

| EXPERT | BACKGROUND | AFFILIATION |
|---|---|---|
| Dr. David Aldrich | Risk Assessment and Research | SAIC |
| Dr. Roger Blond | Risk Assessment | SAIC |
| Dr. Roger Mattson | Safety and Environmental Regulation | SCIENTECH |
| Dr. Lawrence Ybarrondo | Safety Research | SCIENTECH |

Figure 2-2
Expert Assessment of Research

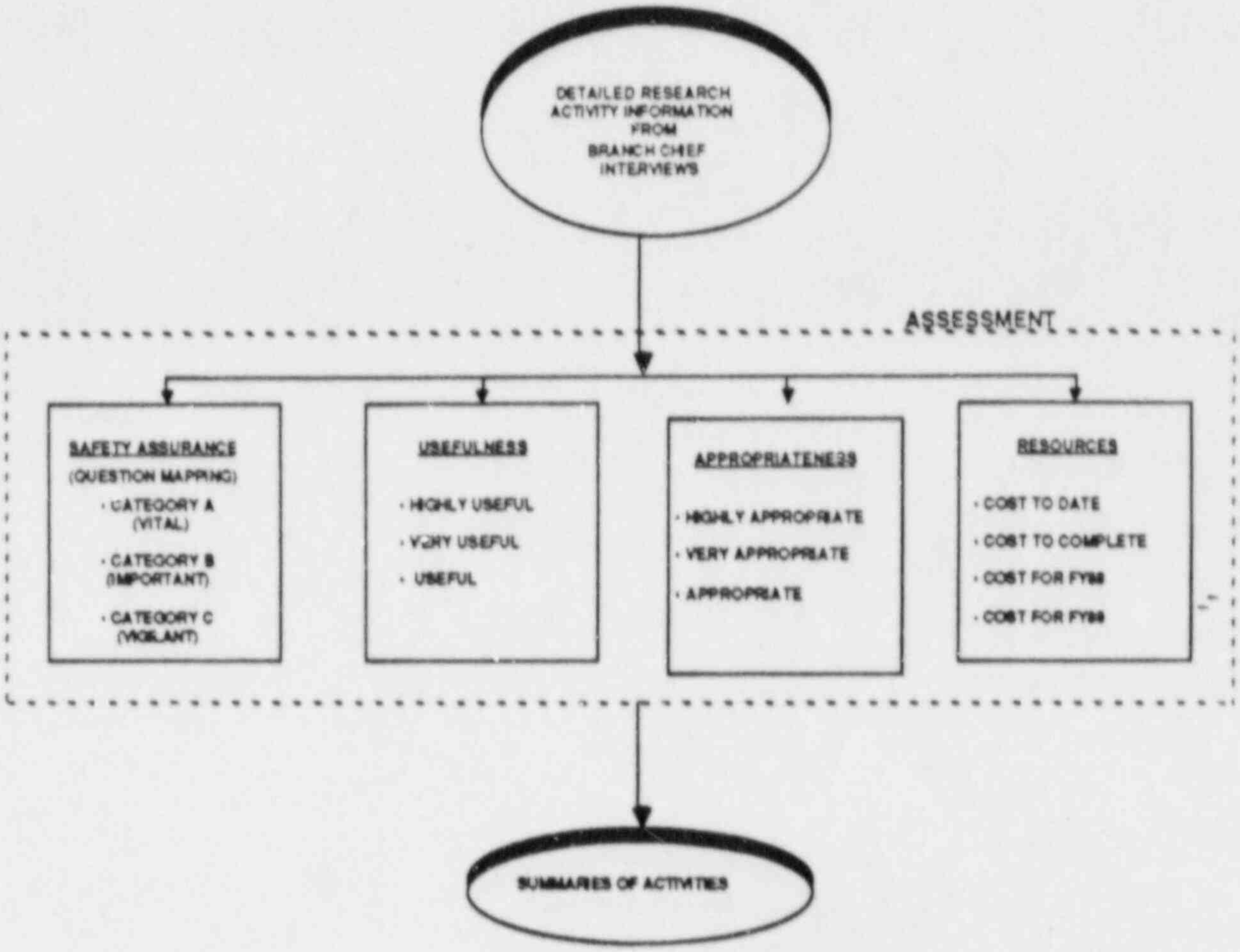


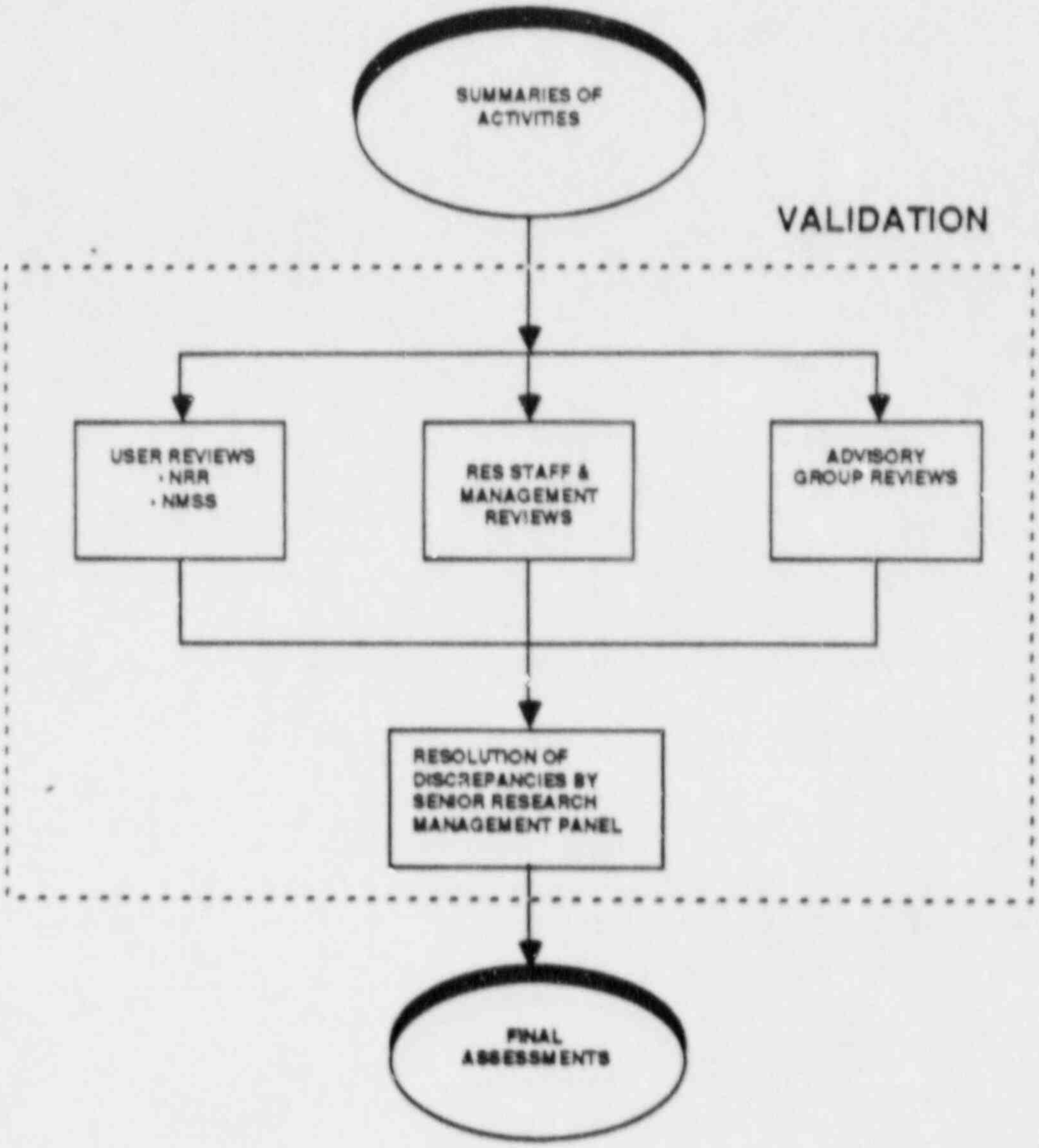
**Table 2-2**
**Branch Chief Interviews**

| BRANCH CHIEF | BRANCH | ASSESSMENT PANEL |
|---|---|---|
| Andy Murphy* | Structural & Seismic Engineering | Blond, Mattson, Ybarrondo |
| Mel Silberberg* | Accident Evaluation | Blond, Mattson, Ybarrondo<br>Houston, Blond, Ybarrondo† |
| Charles Serpan | Materials Engineering | Arlotto, Aldrich, Mattson |
| Milton Vagins | Electrical & Mechanical Engineering | Arlotto, Aldrich, Ybarrondo |
| Louis Shotkin | Reactor & Plant Systems | Sheron, Aldrich, Blond |
| Frank Coffman | Reliability & Human Factors | Sheron, Blond, Ybarrondo |
| Frank Costanzi | Waste Management | Costanzi, Aldrich, Mattson |
| Tom King | Advanced Reactors & Generic Issues | Morris, Blond, Ybarrondo |
| Robert Alexander | Radiation Protection & Health Effects | Morris, Aldrich, Blond |
| Joseph Murphy | Probabilistic Risk Analysis | Houston, Blond, Aldrich |

* The assessments in Earth Sciences, and part of the Accident Evaluation assessments, were conducted during the Task II trial of the methodology. During the trial the assessment panels did not include the Division Director.

† Four activities under Mr. Silberberg not included during the trial were assessed at a later date

Figure 2-3
Validation of Assessments



# 3.0 PRESENTATION OF RESULTS

## 3.1 Summaries of Assessments

The detailed results of the prioritization, to this point, are presented in the Summaries of Activities located in Appendix D. A more condensed version of the results is also presented in the two tables contained in this section. Respectively, these tables are

(a) A summary of the assessments for each activity (Table 3-1).

(b) A cross-reference of the activities and the questions to which each activity responds (Tables 3-2).

Table 3-1 lists the research activities and summarizes the assessments made by the assessment panels presented in Table 2-2. The far left column shows the page in Appendix D where a more detailed description of the activity and the assessments can be found.

Tables 3-2 illustrates how the various research activities respond to the safety assurance questions.

## 3.2 Observations

(DELETED FROM FINAL REPORT)

TABLE 3-1
Assessment Summary

| Page | ACTIVITY | Safety Assurance | Usefulness | Appropri-ateness | Resources - Millions of Dollars | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Costs to Date | FY88 Costs | FY89 Costs | Costs to Complete |
| | | ● Vital<br>◒ Important<br>○ Vigilant | ● Highly Useful<br>◒ Very Useful<br>○ Useful | ● Highly Appropriate<br>◒ Very Appropriate<br>○ Appropriate | | | | |
| D-2 | Pressure Vessel Safety | ● | ● | ◒ | 100.0 | 6.4 | 8.2 | 75.0 |
| D-4 | Piping Integrity | ● | ● | ◒ | 20.0 | 2.4 | 3.4 | 10.0 |
| D-6 | Inspection Procedures and Techniques | ● | ● | ● | 24.3 | 1.6 | 2.5 | 20.0 |
| D-8 | Chemical Effects | ◒ | ◒ | ◒ | 25.0 | 1.7 | 2.2 | 15 |
| D-10 | Aging | ● | ● | ● | 11.0 | 5.5 | 8.5 | 39.0 |
| D-12 | Equipment Qualification | ○ | ○ | ◒ | N/A | N/A | N/A | N/A |
| D-13 | Earth Sciences | ○ | ● | ○ | 50.0 | 3.6 | 4.1 | 20.0 |
| D-14 | Component Response to Earthquakes | ● | ● | ● | 12.0 | 3.0 | 3.7 | 10.0 |
| D-15 | Validation of Seismic Analysis | ◒ | ● | ● | 3.0 | 1.5 | 1.3 | 4.5 |
| D-16 | Seismic Design Margin Methods | ● | ● | ● | 1.5 | 0.6 | 0.9 | 1.0 |
| D-17 | Structural Tests | ● | ● | ● | 18.0 | 2 | 3.6 | 10 |
| D-18 | HLW Materials & Engineering | ● | ◒ | ● | 10-15 | 1.0 | 1.0 | 10.0 |
| D-19 | HLW Hydrology & Geochemistry | ● | ● | ◒ | 15.0 | 1.0 | 1.0 | 10.0 |
| D-20 | HLW Compliance Assessment | ● | ● | ● | 10.0 | 1.4 | 1.4 | 15.0 |
| D-21 | LLW Materials & Engineering | ◒ | ● | ● | 6.0 | 1.5 | 1.2 | 6.0 |
| D-22 | LLW Hydrology & Geochemistry | ◒ | ● | ● | 6.0 | 0.7 | 0.7 | 4.0 |
| D-23 | LLW Compliance Assessment | ◒ | ● | ● | 5.0 | 0.7 | 0.8 | 5.0 |
| D-24 | Core Melt Progression & Hydrogen Generation | ● | ◒ | ◒ | 50 | 5.7 | 5.7 | 5.0 |
| D-25 | Core-Concrete Interactions | ● | ● | ● | 21.0 | 1.7 | 1.8 | 10 |
| D-26 | Direct Containment Heating | ◒ | ◒ | ● | 2.2 | 1.2 | 1.7 | 12 |
| D-27 | Code Models Validation & Analysis | ● | ◒ | ◒ | 35 | 3.9 | 6.6 | 46 |
| D-28 | Hydrogen Transport & Combustion | ◒ | ◒ | ◒ | 11.0 | 0.7 | 0.7 | 3.8 |
| D-29 | Steam Explosions | ○ | ◒ | ● | 5.0 | 0.2 | 0.2 | 1.5 |
| D-31 | Fission Product Behavior & Chemical Form | ◒ | ◒ | ◒ | 26.0 | 1.0 | 1.3 | 7.0 |
| D-32 | Natural Circulation | ◒ | ◒ | ◒ | 1.3 | 0.4 | 0.7 | 2.3 |
| D-33 | Review of PRA's | ● | ◒ | ● | 0.4 | 0.9 | 1.6 | 1.6 |

TABLE 3-1(Continued)

| Page | ACTIVITY | Safety Assurance | Usefulness | Appropriateness | Resources - Millions of Dollars | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Costs to Date | FY88 Costs | FY89 Costs | Costs to Complete |
| | | ● Vital<br>◒ Important<br>○ Vigilant | ● Highly Useful<br>◒ Very Useful<br>○ Useful | ● Highly Appropriate<br>◒ Very Appropriate<br>○ Appropriate | | | | |
| D-34 | Severe Accident Management | ● | ◒ | ○ | N/A | 0.2 | 0.4 | 1.5 |
| D-35 | Risk Model Development | ◒ | ◒ | ● | 1.1 | 1.6 | 1.6 | 8.3 |
| D-36 | Risk Uncertainty Methodology | ○ | ○ | ● | 1.1 | 1.5 | 1.2 | 5.6 |
| D-37 | Risk Rebaseline Analyses | ◒ | ○ | ● | 2.7 | 3.8 | 2.2 | 11.4 |
| D-38 | Risk Based Management Methodology | ○ | ○ | ○ | 2.2 | 1 | 1.8 | 2 |
| D-39 | MIST & OTSG Testing (B&W) | ○ | ◒ | ● | 14.0 | 2.3 | 3.9 | 6.0 |
| D-40 | 2D/3D | ○ | ◒ | ○ | 85.0 | 2.7 | 1.7 | 5.0 |
| D-41 | ROSA-IV | ○ | ◒ | ● | 4.5 | 0.8 | 1.3 | 2.0 |
| D-42 | Continuing Experimental Capability | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| D-43 | Basic Studies | ◒ | ● | ◒ | N/A | 1.0 | 2.4 | N/A |
| D-45 | Thermal- Hydraulic Codes | ○ | ● | ● | 60.0 | 2.7 | 5.0 | 7.7 |
| D-46 | T/H Technical Support Center | ○ | ● | ● | 2.0 | 0.9 | 1.7 | N/A |
| D-47 | Human Factors Research | ◒ | ○ | ○ | —— | 1.6 | 1.8 | N/A |
| D-48 | Human Error Data Collection & Analysis | ○ | ○ | ○ | 6.0 | 0.9 | 1.1 | N/A |
| D-49 | Performance Indicators | ● | ● | ● | 2.0 | 0.8 | 0.9 | 2.0 |
| D-50 | External Event Safety Margins | ● | ● | ● | 0.4 | 0.3 | 1.5 | 5-6 |
| D-51 | Individual Plant Examinations | ● | ● | ● | 1.2 | 1.5 | 2.5 | 10-15 |
| D-52 | Dependent Failure Analysis | ○ | ○ | ○ | 1.2 | 0.2 | 0.3 | 2.0 |
| D-53 | Plant & System Risk & Reliability | ◒ | ○ | ○ | 3.0 | 1.5 | 2.5 | 5.0 |
| D-54 | Review DOE Advanced Reactor Concepts | ● | ● | ● | 2.2 | 1.0 | 1.0 | 4.0 |
| D-55 | Severe Accident Policy Implementation | ● | ● | ● | N/A | 0.2 | 0.2 | 0.3 |
| D-57 | Reduce Uncertainty in Health Risk Estimates | ○ | ● | ● | 3.4 | 0.7 | 1.1 | 3.7 |
| D-59 | Health Physics Tech. Improvements | ○ | ● | ● | 0.4 | 0.2 | 0.6 | 1.4 |
| D-61 | Dose Reduction & Standards Development | ○ | ● | ◒ | 1.5 | 0.8 | 1.2 | 3.1 |
| D-63 | Fuel Cycle, Transportation | ◒ | ● | ● | 0.5 | 0.4 | 0.4 | 0.1 |

## TABLE 3-2
## QUESTION MAPPING OF RESEARCH ACTIVITIES

| Category | SAFETY ASSURANCE QUESTIONS \ CURRENT RESEARCH ACTIVITIES | PRESSURE VESSEL SAFETY | PIPING INTEGRITY | INSPECTION PROCEDURES AND TECHNIQUES | CHEMICAL EFFECTS | AGING | EQUIPMENT QUALIFICATION | EARTH SCIENCES | COMPONENT RESPONSE TO EARTHQUAKES | VALIDATION OF SEISMIC ANALYSIS | SEISMIC DESIGN MARGIN METHODS | CONTAINMENT INTEGRITY | HLW MATERIALS AND ENGINEERING | HLW HYDROLOGY & GEOCHEMISTRY | HLW COMPLIANCE ASSESSMENT... | LLW MATERIALS AND ENGINEERING | LLW HYDROLOGY & GEOCHEMISTRY | LLW COMPLIANCE ASSESSMENT... | CORE MELT PROGRESSION & HYDROGEN GENERATION | CORE CONCRETE... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DIVISION OF ENGINEERING | MATERIALS ENGINEERING | | | | ELECTRICAL & MECHANICAL ENGINEERING | | STRUCTURAL & SEISMIC ENGINEERING | | | | | WASTE MANAGEMENT | | | | | | | |
| CATEGORY A QUESTIONS | A-1 What should the NRC require to ensure that a utility maintains... | | | | | ● | | | | | | | | | | | | | | |
| | A-2 How should NRC determine what unacceptable vulnerabilities... | ● | ● | ● | ● | ● | ● | | ● | | ● | | | | | | | | ● | |
| | A-3 What short term containment failure modes exist... | | | | | | | | | | | | | | | | | | ● | ● |
| | A-4 What is the best estimate of the course and consequences... | | | | | | ● | | | | | | | | | | | | ● | ● |
| | A-5 What information and actions are needed for the timely resolution... | | | | | ● | | ● | | ● | ● | | | | | | | | | |
| | A-6 How can NRC determine whether the quality of construction... | | | ● | | ● | | | | | | | | | | | | | | |
| | A-7 On what basis should the NRC grant an extension of an operating... | | | | | ● | | | | | | | | | | | | | | |
| | A-8 What severe accident prevention and mitigation capabilities... | | ● | | | | | | | | | | | | | | | | | |
| | A-9 What changes need to be made to regulations and what should be... | | | | | | | | ● | | | | | | | | | | | |
| | A-10 What controls should be used to prevent life threatening exposures... | | | | | | | | | | | | | | | | | | | |
| | A-11 What is the threat of hostile action... | | | | | | | | | | | | | | | | | | | |
| | A-12 What are the relevant issues and proper techniques to characterize... | | | | | | | | | | | | ● | ● | ● | | | | | |
| CATEGORY B QUESTIONS | B-1 What additional knowledge concerning the response... | | | | | | | | | | | | | | | | | | ● | |
| | B-2 What additional knowledge concerning the behavior of materials... | ● | ● | | ● | ● | | | | | | | | | | | | | | |
| | B-3 How should NRC evaluate and disseminate operating experience... | | | | | ● | | | | | | | | | | | | | | |
| | B-4 What are the safety concerns and actions...regarding aging... | ● | | | | ● | | | | | | | | | | | | | | |
| | B-5 How should the safety goal policy be applied to existing reactors? | | | | | | | | | | | | | | | | | | | |
| | B-6 How can human factors, reactor controls, and artificial intelligence... | | | | | | | | | | | | | | | | | | | |
| | B-7 What long term containment failure modes exist... | | | | | | | | | | | | | | | | | | | |
| | B-8 What information and actions are needed for the timely resolution ... | | | | | | | | | | | | | | | | | | | |
| | B-9 What source terms should be considered in design, siting... | | | | ● | | | | | | | | | | | | | | ● | ● |
| | B-10 What are the safety issues and what resolution is required... | | ● | | | | | | | | | | | | | | | | | |
| | B-11 What information and actions are needed in support of the review... | | | | | | | | | | | | | | | | | | | |
| | B-12 How should NRC assure adequate safety of nuclear materials... | | | | | | | | | | | | | | | | | | | |
| | B-13 How should nuclear power plants and fuel cycle facilities be... | | | | ● | | | | | | | | | | | | | | | |
| | B-14 What should be the level of radioactive contamination that is BRC? | | | | | | | | | | | | | | | | | | | |
| | B-15 What are the relevant issues and proper techniques to ensure... | | | | | | | | | | | | | | | ● | ● | ● | | |
| CATEGORY C QUESTIONS | C-1 What confirmatory or exploratory research should the NRC pursue... | | | | | ● | □ | ● | ● | ● | ● | | | | | | | | | |
| | C-2 How can the completeness and precision of probabilistic safety... | | | | | ● | | | ● | ● | | | | | | | | | □ | |
| | C-3 What improved techniques should be used by the NRC to identify... | | | | | | | | | | | | | | | | | | | |
| | C-4 How should the regulatory structure be improved or developed... | | | | | ● | | | | | | | | | | | | | | |
| | C-5 How should appropriate radiation protection standards... | | | | | | | | | | | | | | | | | | | |
| | C-6 How can implementation of ALARA be improved? | | | | | | | | | | | | | | | | | | | |
| | C-7 What is the environmental impact of operating nuclear facilities... | | | | | | | | | | | | | | | | | | | |

● STRONG RELATIONSHIP

□ WEAK RELATIONSHIP

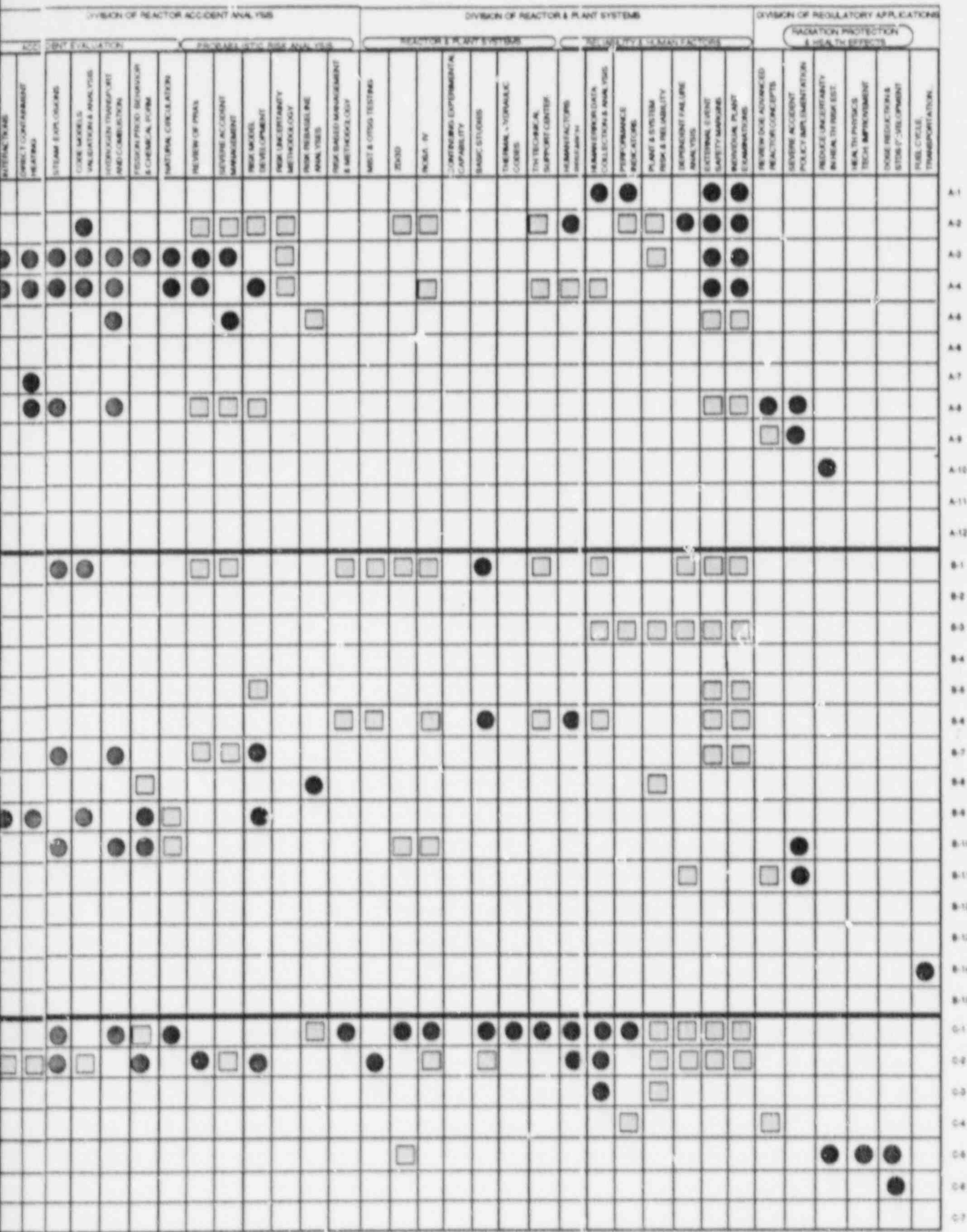



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TABLE 3.2

QUESTION MAPPING OF RESEARCH ACTIVITIES

| SAFETY ASSURANCE QUESTIONS / CURRENT RESEARCH ACTIVITIES | |
|---|---|
| CATEGORY A QUESTIONS | |
| A-1 [illegible] | [illegible] |
| A-2 [illegible] | [illegible] |
| A-3 [illegible] | [illegible] |
| A-4 [illegible] | [illegible] |
| A-5 [illegible] | [illegible] |
| A-6 [illegible] | [illegible] |
| A-7 [illegible] | [illegible] |
| A-8 [illegible] | [illegible] |
| A-9 [illegible] | [illegible] |
| A-10 [illegible] | [illegible] |
| A-11 [illegible] | [illegible] |
| A-12 [illegible] | [illegible] |
| CATEGORY B QUESTIONS | |
| B-1 [illegible] | [illegible] |
| B-2 [illegible] | [illegible] |
| B-3 [illegible] | [illegible] |
| B-4 [illegible] | [illegible] |
| B-5 [illegible] | [illegible] |
| B-6 [illegible] | [illegible] |
| B-7 [illegible] | [illegible] |
| B-8 [illegible] | [illegible] |
| B-9 [illegible] | [illegible] |
| B-10 [illegible] | [illegible] |
| B-11 [illegible] | [illegible] |
| B-12 [illegible] | [illegible] |
| B-13 [illegible] | [illegible] |
| B-14 [illegible] | [illegible] |
| B-15 [illegible] | [illegible] |
| CATEGORY C QUESTIONS | |
| C-1 [illegible] | [illegible] |
| C-2 [illegible] | [illegible] |
| C-3 [illegible] | [illegible] |
| C-4 [illegible] | [illegible] |
| C-5 [illegible] | [illegible] |
| C-6 [illegible] | [illegible] |
| C-7 [illegible] | [illegible] |

● [illegible]

□ [illegible]

## 4.0 REFERENCES

1. Draft Report, Office of Nuclear Regulatory Research, Research Assessment Methodology, SCIE-303-87 Rev A, USNRC Contract No. NRC-04-87-089, November 1987.

2. Report, Office of Nuclear Regulatory Research, Research Assessment Methodology, Task II - Trial of Methodology, SCIE-365-87, USNRC Contract No NRC-04-87-089, January 1987

3. USNRC Strategic Plan, COMSECY-87-8, July 29, 1987.

4. Letter, from: James W. Pittman, Project Officer, Research Prioritization Contract, Office of Nuclear Regulatory Research, to: Larry J. Ybarrondo, President, Scientech, Inc. April 7, 1988.

# APPENDIX A: NRC STRATEGIC PLAN ANALYSIS

The NRC Strategic Plan is a critical factor in research prioritization: it provides the structure upon which the list of safety assurance questions is built. In order to ensure that all aspects of the Strategic Plan are properly addressed a thorough analysis of the plan is conducted, using the technique of successive decomposition. Familiar to software engineers and specification writers, this technique results in a multi-layered map of the requirements for a product; a responsive, focused, effective research program, in this case. Applied to the Strategic Plan, the resultant maps illustrate the basic hierarchy of the plan:

- Overall Goals
- Specific Goals
- Strategies

For example, under the overall goal, for Operating Reactors (Section 3.0 of the Strategic Plan), the specific goals are grouped according to their correspondence to Accident Management, Accident Mitigation, and Generic Safety Issues. Under each of these three groupings strategies for realizing the goals are delineated.

Although all sections of the Strategic Plan are analyzed in this manner, only Sections 3.0 through 8.0 are presented herein. Sections 1.0 and 2.0 have not been included since they contain only introductory material and do not describe specific goals or strategies. Sections 9.0 through 11.0 pertain to management goals and do not indicate areas of research.

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## 3 OPERATING REACTORS (OVERALL GOAL)

ENSURE THAT LICENSEES OPERATE NUCLEAR POWER PLANTS SAFELY AND ARE ADEQUATELY PREPARED TO RESPOND TO ACCIDENTS

### Accident Prevention

**GOALS**

Ensure regulatory program that provides for all operating plants achieving:

(1) low frequency of challenges to safety systems
(2) high availability of plant equipment
(3) highly trained, motivated, supported operating personnel
(4) timely learning from own and other's experience
(5) low sensitivity of design to safety system challenge

**STRATEGIES**

(a) Define standards & measure of performance
(b) Identify plants not satisfying standard of performance
(c) Continue efforts to evaluate plant performance & evaluate other means to improve NRC's ability to identify potential plant problems
(d) Define range of NRC initiatives to bring about timely corrective actions for plants not meeting performance standards
(e) Utilize corrective action program to encourage licensees to achieve goals
(f) Continue programs to take plant-specific or generic actions, consistent with the Backfit Rule, to ensure compliance with the goal
(g) Improve programs to ensure that plant maintenance practices or modifications do not inadvertently reduce existing safety margins
(h) Continue review of changes to plant licenses, designs, procedures, etc., to ensure safe operation
(i) Continue licensee & vendor audits using mixed team of inspectors
(j) Continue operator qualifications verification by initial, replacement & requalification examinations
(k) Use PRA's to identify & correct design vulnerabilities
(l) Determine how to use the Safety Goal in the regulatory process
(m) Study alternative strategies for improving QA practices of operating reactors
(n) Continue cooperative programs with other organizations and countries to learn from operating experience
(o) Determine level of safety needed for seismic hazards.
(p) Determine the impact of aging on plant performance
(q) Understand thermal hydraulic response during complex events.
(r) Behavior of materials in nuclear environments

### Accident Mitigation

**GOALS**

(1) Ensure that in the event of a severe core damage accident the containment & mitigation systems, including equipment and operators, provide for a low probability of release of radioactive materials
(2) emergency response minimizes exposures to the public, including workers

**STRATEGIES**

(a) Determine probability of early failure, bypass leakage, or inadvertant openings for containments
(b) Resolve and revise regulatory requirements for accident mitigation through the Safety Goal, Source Term, and Severe Accident Program
(c) Maintain and improve the NRC Operations Center, providing for effective response to nuclear incidents and accidents

### Generic Safety Issues

**GOALS**

Identify and resolve priority safety issues. Require improvements consistent with the backfit rule

**STRATEGIES**

(a) Prioritize generic safety issues using safety benefit/cost basis
(b) Resolve high & medium issues and implement those meeting backfit requirements
(c) Enhance program to integrate related generic issue resolution to achieve the greatest safety improvement for the least cost
(d) Address, as practical, issues addressing numerous licensees by rulemaking to reduce plant differences

## 4 POWER PLANT OPERATIONAL READINESS (OVERALL GOAL)

**ENSURE THAT NUCLEAR POWER PLANTS UNDER CONSTRUCTION ARE DESIGNED AND CONSTRUCTED PROPERLY AND READY FOR SAFE OPERATION**

### Construction and Licensing

**GOALS**

Identify quality related problems that could impact the safe operation of all remaining nuclear power plants under construction and ensure timely licensing decisions when reviews and inspections indicate that a plant is ready for safe operation

**STRATEGIES**

(a) Propose program requiring applicants for operating license to review
(b) Propose requirement for licensees to include third-parties in QA reviews. Require CEO to certify that construction was completed in accordance with application
(c) Continue auditing using mix of inspectors from site, region, and headquarters with emphasis on quality of completed construction
(d) Continue to encourage use of readiness reviews by licensees
(e) Continue to encourage ombudsman programs
(f) Continue to schedule and complete license reviews and inspections based on applicant's estimated construction completion dates

### Transition from Construction to Operations

**GOALS**

Reduce the potential for operating events associated with the transition from construction to operations

**STRATEGIES**

(a) Initiate program of integrated system tests during preoperational testing
(b) Require utility programs for transition from construction to operation
(c) Lengthen duration of low power operating period prior to authorization of power operation to demonstrate the operability of all primary and secondary system equipment, procedures and operating staff
(d) Focus on fulfillment of design and operational requirements during preoperational test inspections
(e) Require special regional/headquarters NRC team inspections prior to licensing to assess operational readiness

5 FUTURE REACTOR LICENSING (OVERALL GOAL)

PREPARE FOR FUTURE REACTOR LICENSING ACTIVITIES

**Standardization**

GOALS

Achieve the safety benefits and economies associated with standard industry approaches to the detailed design of the entire plant, as well as construction, quality assurance, pre-operational testing, training, and operations for future plants

STRATEGIES

(a) Explore means to provide incentives to encourage standardization
(b) Determine elements of a successful standardization program
(c) Initiate program to develop standard design (DOE sponsored)
(d) Pursue enactment of Regulatory Reform Legislation
(e) Issue requirements/guidance for implementing Commission's policies applicable to standardization
(f) Give priority to reviewing the safety of standard design applications and other related documents of which further standardization

**Advanced Reactor Designs**

GOALS

Minimize the complexity and uncertainty of the licensing environment for advanced reactors

STRATEGIES

(a) Encourage early interaction among applicants, vendors, and government agencies
(b) Initiate program to specify NRC views concerning desired characteristics of advanced reactor
(c) Issue comments on implication of advanced design for safety, the regulatory process, and the associated fuel cycles
(d) Develop licensing criteria making use of applicable existing and future regulations for advanced designs
(e) Develop requirements for safety margins to be expected from advanced designs

**Licensing Renewal and Decommissioning**

GOALS

Develop a regulatory approach to evaluate requests to decommission reactors and other nuclear facilities and renew operating licenses

STRATEGIES

(a) Continue programs in conjunction with industry to determine technical and policy issues associated with renewing operating licenses, resolve the issues, and define review criteria and process for requests to renew operating licenses
(b) Continue programs to define acceptable alternatives, requirements, and criteria for decommissioning before receiving a request for decommissioning

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## 6 NUCLEAR MATERIALS SAFETY AND SAFEGUARDS (OVERALL GOAL)

ENSURE THAT THE USES, TRANSPORTATION, STORAGE, AND DISPOSAL OF NUCLEAR AND RADIOACTIVE MATERIALS ARE SAFE AND ARE PROVIDED WITH ADEQUATE SAFEGUARDS

### Safety of Non-Reactor (Material) Licensees

**GOALS**

Ensure that the regulatory program for non-reactor licensees provides for:

(1) Reducing radiological risk to public and workers as low as practicable
(2) Accountability of radioactive material in its use and disposal
(3) Minimization of releases and unauthorized removal of radioactive materials from place of use
(4) Adequately selecting and training personnel and providing appropriate equipment and facilities
(5) Learning from own and other's operational experiences
Safely transporting radioactive material

**STRATEGIES**

(a) Define and improve standards and measures of performance
(b) Initiate program to identify noncompliant licensees
(c) Define initiatives to produce corrective action for noncompliances
(d) Audit licensee compliance
(e) Compliance and safety improved by timely and aggressive enforcement actions
(f) Perform timely reviews of license applications

### Adequacy of Risk for Materials Licensees

**GOALS**

Ensure that the range of risks associated with non-reactor uses and transportation of nuclear and radioactive material is recognized in the NRC regulatory approaches for non-reactor licensees

**STRATEGIES**

Determine ways to improve NRC's ability to differentiate between different levels of occupational and public risks associated with non-reactor uses and transportation of nuclear and radioactive material:
(a) Initiate program to develop regulatory approach commensurate with risk level
(b) Initiate program to establish financial assurance requirements commensurate with risk

### Agreement States

**GOALS**

Assure that the regulatory programs of the NRC and Agreement States are designed and implemented to achieve compatibility to protect the public health and safety

**STRATEGIES**

Enhance cooperative approach to make the Agreement States program compatible with NRC programs
(b) Periodically review Agreement States program to ensure adequacy and compatibility
Initiate higher-level program to develop interaction between Agreement States and NRC on programmatic & safety matters
(d) Initiate program to actively encourage states to join the Agreement States Program

### Safeguards

**GOALS**

Ensure that the NRC safeguards regulatory program provides for licensees:

(1) Accountability and protection for SNM
(2) Maintaining systems for sabotage deterrance
(3) Protection of SNM in transit
(4) Selection & training of personnel, equipment, facilities
(5) Learning from own and other's operation experiences

**STRATEGIES**

(a) Define standards and measures of performance
(b) Initiate program to identify noncompliant safeguards programs
(c) Define initiatives to produce timely corrective action for licensees program
(d) Define range of actions to provide incentives to encourage full compliance to safeguards goal
(e) Cooperate & interact with other agencies to assess threat to environment and protective measures
(f) Continue inspection & review of safeguards changes by licensees
(g) Assist in efforts to strengthen international safeguards
(h) Conduct reviews in support of nonproliferation & IAEA physical security objectives
(i) Continue cooperative programs with other organizations and countries to learn from their operating experience

### Construction of New Materials Facilities

**GOALS**

Identify quality-related problems that could impact safe operation and ensure timely licensing decisions when reviews and inspections indicate the facility is ready for safe operation

**STRATEGIES**

(a) Initiate program to assure quality of work from design to construction & identify weaknesses
(b) Encourage use of readiness reviews to identify issues
(c) Encourage ombudsman programs
(d) Schedule and complete license reviews & inspections based on applicant's estimated construction completion dates

### Non-Radiological Risks

**GOALS**

Ensure that the non-radiological risks inherent in the uses, transportation, and disposal of radioactive and nuclear material are recognized and regulated by the appropriate agency

**STRATEGIES**

Initiate program to identify range of non-radiological risks associated with use of radioactive material and coordinate with other agencies, jurisdictions, and inspecting organizations to assure associated hazards are identified and regulated by the appropriate agency

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## 7 MANAGEMENT & DISPOSAL OF NUCLEAR WASTE (OVERALL GOAL)

ENSURE THAT NUCLEAR WASTE IS SAFELY MANAGED AND DISPOSED

### High-Level Waste Management

**GOALS**

Ensure that the NRC has a high-level waste regulatory program that provides for the Administration's high-level waste disposal program achieving:

(1) proper siting, design, construction, & operation of a high-level waste repository by DOE
(2) safe closure, prevention of inadvertent human intrusion, and reasonable assurance of long-term performance without the need for active maintenance by DOE,
(3) meeting the statutory timeframes for NRC actions

**STRATEGIES**

(a) Establish technically sound and usable system for defining and categorizing wastes.
(b) Develop performance criteria and review capability to ensure waste isolation
(c) Ensure timely regulatory guidance on technical issues & timely identification and resolution of issues
(d) Continue active program of interaction & cooperation with states, Indian tribes, and interest groups
(e) Continue current program to examine & streamline repository licensing process
(f) Develop & implement inspection program to support review of HLW repository
(g) Develop & implement QA requirements/guidance based on lessons learned from reactor licensing

### Low-Level Waste Management

**GOALS**

Ensure that the NRC program for low-level waste and uranium mill tailings provides for the safe management & disposal of all types of low-level waste and uranium mill tailings

**STRATEGIES**

(a) Continue current program to (1) develop regulations & guidance for use by applicants, state agencies and NRC, (2) regulate uranium recovery facilities active mill tailings sites, (3) review DOE uranium mill tailings remedial action program & prepare to license reclaimed sites, (4) evaluate need for financial assurance criteria for both uranium recovery and LLW programs, & (5) develop regulations & guidance for decommissioning
(b) Ensure that regulatory decisions affecting LLW disposal, uranium mill tailings, and uranium recovery activities are consistent with current national priorities
(c) Continue to provide active leadership & technical assistance to states and compacts to facilitate timely development of safe LLW disposal facilities
(d) Develop & implement inspection & QA program to support both LLW and uranium recovery programs
(e) Continue to discourage long-term storage as a substitute for disposal

### Integrated Approach to Waste Management

**GOALS**

Ensure that the NRC has an integrated approach to waste management and disposal so that waste generation activities can continue consistent with safety and environmental protection

**STRATEGIES**

(a) Continue current program for early outreach to other jurisdictions, interested parties, and waste generators to understand their interests so that issues can be identified and resolved in a timely manner.
(b) Continue current program for maintaining a system for inventory and forecast of waste generation to enable timely and adequate management and early warning of capacity problems
(c) Continue to maintain an awareness of possible delays in waste disposal programs so that safe interim alternatives to disposal can be indentified and developed
(d) Continue programs that allow early identification and resolution of jurisdictional issues with other agencies and jurisdictions, such as EPA

## 3 RESEARCH AND REGULATION DEVELOPMENT (OVERALL GOAL)

ENSURE THAT RESEARCH PROVIDES THE TECHNICAL BASES FOR TIMELY AND SOUND RULEMAKING AND REGULATORY DECISIONS IN SUPPORT OF NRC LICENSING AND INSPECTION ACTIVITIES

### Research in Support of Users

**GOALS**

Provide the technical bases necessary to achieve NRC goals and implement the programs & strategies, including the performance of waste facilities, & the safety assessment of existing plants and future designs with respect to:

(1) safety goals, severe accidents & source terms
(2) continuing to meet license conditions as affected by aging or natural occurrences
(3) behavior under complex operational transients
(4) human performance factors important to risk

**STRATEGIES**

(a) Identify strategies & programs whose implementation requires research & develop and schedule needed program
(b) Prioritize research according to safety significance
(c) Continue & enhance utilization of available research from DOE, foreign countries, industry, etc.
(d) Initiate program to use review groups in planning & developing research programs
(e) Institute annual review of research program
(f) Utilize Safety Research Philosophy as the basis for determining & judging the value of the research program

### for Unanticipated Needs

**GOALS**

Ensure research provides a basis for timely response to unanticipated needs

**STRATEGIES**

(a) Identify technical areas not addressed by research, in direct support of current licensing and inspection activities, in which there is a wide range of uncertainty in existing information
(b) Establish joint programs with DOE, industry, etc., to address areas requiring long-term research
(c) Provide continuity in funding & staff to assure that long-term research meets its objectives

### Research Applications

**GOALS**

Improve the focus of research needs and the effectiveness of research applications

**STRATEGIES**

(a) Establish contacts with user offices to foster early identification of issues having safety significance
(b) Provide technical assistance to user offices
(c) Integrate knowledge & information developed in specific research projects or programs to provide answers to questions posed by user offices

### Technical Competence

**GOALS**

Establish & maintain technical competence in research of sufficient breadth and depth needed to support the agency's independent assessment of the safety, safeguards, and environmental protection related to the licensing and regulation of commercial reactors and other facilities and materials subject to NRC regulations

**STRATEGIES**

(a) Establish research advisory panel to identify the basic & specialized competencies necessary & sufficient for independent assessment of safety, safeguards, & environmental protection
Incorporate programmatic elements to maintain these competencies in new & ongoing research
(b) Broaden the base of technical expertise available to assure ready access to advances in science & technology & maintain necessary knowledge base & flexibility to shift emphasis in response to new issues
(c) Actively recruit high-caliber people with active research experience to bolster the management of research
(d) Develop policies & procedures to enhance capability to place research contracts at universities & other not-for-profit organizations on a timely basis. A long-range objective will be the performance of a greater portion of research at universities than is now the case

### Regulation Development

**GOALS**

Ensure that all rules, regulatory guides, petitions, and standards development activities meet high standards of quality and timeliness

**STRATEGIES**

(a) Perform regulatory analysis of all rulemakings, guides, and proposed backfits agency wide to assure that all new rules & guides conform to agency backfit regulations
(b) Conduct independent reviews of all rulemaking to ensure that high quality & sound rules are developed within the timeframe specified in the Commission's guidance
(c) Review existing regulations, guides, & generic issues, & modify or eliminate those of marginal importance to safety
(d) Develop, document, & implement policies & procedures for effective, coherent, & consistent regulations

# APPENDIX B: NRC SAFETY ASSURANCE QUESTIONS

In any complex technology area the ability to make informed decisions depends upon the quality of information available to the decision-maker. For decisions the NRC will be required to make in the future, there are underlying questions which will first have to be answered to enable an informed decision. Not all questions require research in the traditional sense of the laboratory environment, but for some questions this will be the only means to gain the information essential to continued compliance with the agency's mission of ensuring the protection of public safety. It is this latter category of questions with which this task is concerned.

Preparing a list of the overall safety assurance questions requires a familiarity with the mission of the NRC and the current regulatory process, as well as an insight as to the future of the agency, which can be satisfied only by a body having wide-ranging perspectives. For these reasons the questions are prepared in an iterative fashion which allows a consensus judgement to be built.

The NRC Strategic Plan provides a structure around which the initial set of questions is prepared. These initial questions are further developed, with consideration of the guidance from various Commission Policy statements and relevant NAS recommendations, by RES Division Directors to obtain a list of questions which are:

- **complete**, in terms of addressing all of the issues, both now and in the future, upon which the agency may be expected to make decisions
- **comprehensive**, inasmuch as the scope of each question provides for the envelopment of sub-tier questions of a more specific nature
- **concisely stated** so as to minimize contention regarding the pertinent issues posed by the question

The questions are dynamic in nature; as the perception of the mission of the agency changes new questions will arise from time to time. As decisions are made the results of the decisions will affect the interrelationship of the questions. Eventually the question list will have to be revisited to incorporate such changes.

The questions are divided into three (3) groups, in accordance with their perceived value to the NRC mission of safety assurance, consistent with the following definitions:

<u>Category A</u> (Vital) questions are those associated with major contributors to risk which could lead to changes having a direct and substantial impact on the health and safety of the public or on national policy regarding generation of power or utilization of by-products thereof, or special nuclear materials. The answers to these questions could impact directly the licensing of proposed operations, or the regulation of existing operations, including termination or restart of licensed operations.

<u>Category B</u> (Important) questions are those associated with moderate contributors to risk, the answers to which help ensure continued safe operation, and which address potential safety issues. These questions are concerned with inspection and auditing of operations, analysis of operating experience, and evaluation of potential shortcomings of proposed and existing operations. The answers to these questions frequently result in regulatory changes.

<u>Category C</u> (Vigilant)questions are those which must be answered to confirm licensing decisions, improve NRC's capabilities to perform licensing and enforcement functions, offer important insights into the health impact and safety of operations, or are exploratory in nature, seeking new knowledge and understanding. Independent assessment of safety concerns and the explorations of safety improvements are also addressed by these questions.

Beyond this ranking based on safety assurance, the questions are further organized in accordance with the areas of the NRC Strategic Plan from which they are derived (or to which they will contribute, in the case of questions derived independent of the Strategic Plan.). Sections 3 through 8 of the Strategic Plan present the overall safety assurance goals of the NRC for the various activities it regulates (Sections 9 through 11 of the Strategic Plan relate to how the NRC conducts its business and are not addressed herein.) For each of these sections the applicable safety assurance questions are defined herein; where no such questions could be defined at the time of writing, the phrase "No Applicable Questions" appears instead.

The questions contained herein are the end result of three reviews, conducted at the Division Director level, the first of which started with the initial question list supplied by the contractor. The final question list[1] represents the consensus viewpoint, at the Division Director level, of the questions to which the NRC must respond if it is to comply with its mission of ensuring public health and safety.

[1] The final question list was prepared by the NRC and submitted to the contractor under cover letter from James W. Pittman, Project Officer, Research Prioritization Contract, Office of Nuclear Regulatory Research, to Larry J. Ybarrondo, President, Scientech, Inc., April 7, 1988.

## VITAL QUESTIONS

Strategic Plan Section 3
### Operating Reactors

#### Goal: Accident Prevention

A-1 What should the NRC require to ensure that a utility maintains its nuclear power plant in an adequate state of operational readiness, and how (and what) should NRC monitor to ensure that this is accomplished?

A-2 How should NRC determine what unacceptable vulnerabilities to accidents (due to factors such as external events, sabotage, aging, complex transients, multiple failure events, etc.) exist at individual plants and how can they be improved?

#### Goal: Accident Mitigation

A-3 What short term containment failure modes exist at individual plants and what is an acceptable accident mitigation capability for containments?

A-4 What is the best estimate of the course and consequence of the most likely severe accident scenarios and what should NRC do to improve accident management and emergency planning capabilities?

#### Goal: Generic Safety Issues

A-5 What information and actions are needed for the timely resolution and implementation of requirements associated with Unresolved Safety Issues and high priority generic safety issues?

Strategic Plan Section 4
### Operational Readiness

A-6 How can NRC determine whether the quality of construction and operations are adequate to assure compliance with regulatory requirements?

Strategic Plan Section 5
### Future Reactor Licensing

A-7 On what basis should the NRC grant an extension of an operating license for an existing nuclear power plant?

A-8 What severe accident prevention and mitigation capabilities should be required of future nuclear power plants?

A-9 What changes need to be made to regulations and what should be the requirements for certification of standard plant designs?

Strategic Plan Section 6
## Nuclear Materials

A-10 What controls should be used to prevent life threatening exposures to medical or industrial radioactive sources or materials in licensed operations?

A-11 What is the threat of hostile action against nuclear materials and facilities, and what is the best available technology for safeguarding such materials and facilities?

Strategic Plan Section 7
## Management and Disposal of Nuclear Waste

A-12 What are the relevant issues and proper techniques to characterize and assure performance of the site and engineered barriers for high level waste disposal?

# IMPORTANT QUESTIONS

Strategic Plan Section 3
## Operating Reactors

### Goal: Accident Prevention

B-1 What additional knowledge concerning the response of nuclear reactors to complex operating events and accidents does the NRC require?

B-2 What additional knowledge concerning the behavior of materials in nuclear power environments does the NRC require?

B-3 How should NRC evaluate and disseminate operating experience information to contribute toward accident prevention?

B-4 What are the safety concerns and actions NRC should take regarding the aging of components, systems, and structures important to safety?

B-5 How should the safety goal policy be applied to existing reactors?

B-6 How can human factors, reactor controls, and artificial intelligence be improved to better assure safety in normal operations and anticipated operational occurrences?

### Goal: Accident Mitigation

B-7 What long term containment failure modes exist and what should be done to address these?

## Goal: **Generic Safety Issues**

B-8 What information and actions are needed for the timely resolution and implementation of requirements associated with medium priority generic safety issues?

Strategic Plan Section 4
## Operational Readiness

(No applicable questions)

Strategic Plan Section 5
## Future Reactor Licensing

B-9 What source terms should be considered in design, siting, and emergency planning?

B-10 What are the safety issues and what resolution is required to support the review and certification of standard plants (ALWR's)?

B-11 What information and actions are needed in support of the review of advanced reactors?

Strategic Plan Section 6
## Nuclear Materials

B-12 How should NRC assure adequate safety of nuclear materials in transportation and storage?

B-16 (Previously C-5) How should appropriate radiation standards for workers and the public be derived, measured, and implemented?

Strategic Plan Section 7
## Management and Disposal of Nuclear Waste

B-13 How should nuclear power plants and fuel cycle facilities be decommissioned and disposed of?

B-14 What should be the level of radioactive contamination that is Below Regulatory Concern (BRC)?

B-15 What are the relevant issues and proper techniques to ensure adequate siting, licensing, and monitoring of LLW disposal facilities?

# VIGILANT QUESTIONS

Strategic Plan Section 3
## Operating Reactors

### Goal: Accident Prevention

C-1 What confirmatory or exploratory research should the NRC pursue to confirm past licensing decisions, improve analytical tools, better characterize areas of potential concern, etc? (This would include items such as seismic monitoring and code improvement.)

C-2 How can the completeness and precision of probabilistic safety assessments be improved? What reliance can be placed in such assessments?

### Goal: Generic Safety Issues

C-3 What improved techniques should be used by the NRC to identify and prioritize potential generic safety issues?

Strategic Plan Section 4
## Operational Readiness

(No applicable questions)

Strategic Plan Section 5
## Future Reactor Licensing

C-4 How should the regulatory structure be improved or developed for future regulation of existing and future plants?

Strategic Plan Section 6
## Nuclear Materials

C-5 (Now B-16)

C-6 How can implementation of ALARA be improved?

C-7 What is the environmental impact of operating nuclear facilities and how can it be cost effectively mitigated?

Strategic Plan Section 7
## Management and Disposal of Nuclear Waste

(No applicable Questions)

# OTHER ASSESSMENT ATTRIBUTES

## Usefulness

HIGHLY USEFUL: The activity will clearly produce information needed to answer one or more safety assurance question, and the information will become available consistent with established schedules

VERY USEFUL: The activity is expected to produce information useful in answering one or more safety assurance questions, and the information is expected to be available on a timely basis.

USEFUL: The activity is expected to produce information bearing on resolving safety assurance questions.

## Appropriateness

HIGHLY APPROPRIATE: There are compelling reasons for the U. S. Government to undertake the activity. Furthermore, among government agencies NRC has the primary responsibility for this activity. Potential compelling reasons are:

(a) the research requires special skills not supported elsewhere,
(b) the research requires special facilities that no one else supports,
(c) the research is classified,
(d) the research provides independent information (e.g. to confirm licensing requirements,establish need & definition of new licensing requirements.),
(e) the research is key to obtaining needed information from other countries

VERY APPROPRIATE: It is appropriate for NRC to undertake the activity. Furthermore, there are no other organizations (industrial or governmental) with clear responsibility for the activity. Without NRC support the activity would not be pursued.

APPROPRIATE: It is appropriate for NRC to fund the activity, however, either industry or another government agency shares responsibility for, or will benefit from, the activity and could participate in funding the program

## Resources

COST-TO-DATE: The cumulative costs spent on the activity prior to FY88

COST-TO-COMPLETE: The estimated costs required to bring the activity to completion (and the year of completion)

FY88 COSTS: The budgeted costs for the current fiscal year

FY89 COSTS: The estimated budget for the upcoming fiscal year

# APPENDIX C: INTERVIEW PROCEDURE

The following interview procedure and questionnaire evolved out of the trial research prioritization. The procedure outlines the method used during the setup and conduct of the interviews. The questionnaire is used by the interviewers to prompt for information used by the expert experts in assessing the research activities.

## C.1 Pre-Interview

Experience gleaned from the trial research prioritization process indicates that there are several factors which can have a great influence on the success of the interviews with NRC staff. These factors are at the control of the interviewer, and can be used to advantage in conducting a successful interview.

### C.1.1 Environment

The ideal environment for the interview is a large room with comfortable furniture, moderate temperature, and windows. The one interview conducted in a small, windowless office was the least satisfactory. We suspect that the setting contributed to the apparent discomfort of the person being interviewed.

### C.1.2 Interview Setup

Experience in the trial prioritization effort demonstrates that it is absolutely vital to make sure that the person being interviewed has a very clear idea of the methodology, and their part in it, before turning on the camera and starting the questions. Without this understanding it is unlikely that the participant will be relaxed enough to speak freely - resulting in a very brief interview which yields little new information.

In the most successful interviews we spent, on average, around fifteen minutes explaining the prioritization methodology to the person being interviewed prior to turning on the camera. This was done using the Research Prioritization Process diagram from the draft methodology report as a visual aid.

It is also beneficial to skim through the questionnaire with the interviewee prior to the actual interview so as to give a flavor of the kind of questions that are going to be asked. This prevents any major surprises and seems to greatly aid the communication of information during the interview.

In general each of the following items need to be explained to the interviewee prior to taping:

- The methodology starts with the formulation of a list of questions which research must answer to ensure that the NRC can continue to meet its mission.
- The mission of the NRC is to ensure the protection of the public health and safety.
- The interviewees have the opportunity to add to this question list through their responses to the first set of questions.
- The interview is conducted in order to provide the experts with additional information upon which to base assessments of the research. It is not the only source upon which judgements will be made - the experts are already well-versed in some areas of the NRC's business.
- The experts will make the actual assessments
- Videotaping is done to ensure a comprehensive and accurate record. Should the experts disagree over assessments the tape provides them with the means to review the record for clarification without having to schedule a repeat session.
- The process is predicated upon the use of expert judgment.
- The assessments offered by the experts represent a relatively unbiased consensus concerning the research that the NRC needs to perform as part of meeting its mission.
- The experts will not be making decisions about the allocation of the research

budget. Budget decisions will be made by the NRC.

- The interviewee will be able to review the results of the assessments and comment on them.

### C.1.3 On-Camera Behavior

Although it is important to establish an atmosphere in which the interviewee feels at ease, it is the responsibility of the interviewers to ensure that the participants have the opportunity to present themselves, and the agency they represent, in a professional manner. Accordingly, the interviewers should brief the interviewees on the manner in which certain actions and language can be perceived when replayed to different audiences. With this preparation, the interviewees can tailor their on-camera image to avoid distracting from the content of what is being said.

### C.1.4 Camera Setup

So as to avoid drawing excess attention to the camera it is best to have it set-up prior to the interviewee's arrival. Any tinkering with the camera tends to draw attention and can add to the anxiety of a person already having misgivings about having the interview taped. Within a couple of minutes of turning the camera on they will usually relax.

Few rooms enable a camera angle which will capture more than the main interviewer and the interviewee. About 10-12 feet between camera and subjects is needed, as a minimum.

An external microphone must be used to ensure picking up everything, particularly from the less voluble interviewee. The attached microphones on camcorders are inadequate to provide the sound quality required.

### C.1.5 Interview Prologue

The first part of the interview is a prologue to identify the tape. Specifically, the interviewer on camera cites the following:

- Date
- Purpose of the tape
- The person being interviewed
- That person's title and area of responsibility

## C.2. Interview Questions

The interview questions are prepared so as to allow a consistent format to be followed while obtaining all the information required. By and large the questions focus on determining the contribution of the research to safety, usefulness of the research and the appropriateness of the research to be conducted using NRC funds.

Depending upon the interviewee, it may not be necessary to sequentially go through each and every query. The more loquacious interviewees are likely to cover the immediate question as well as the some of the subsequent questions in one fell swoop. If it is clear that the question has been answered it is not necessary to ask it again out of rigid adherence to the questionnaire.

### C.2.1 Question Area Setup

For each of the question areas the interviewer sets up the line of questioning with a brief description of the area, including:

- The purpose of the line of questioning
- Where applicable, a definition of the attribute to which the questions pertain

Information of this nature is contained in the small text that precedes each question area in the following questionnaire.

## C.3. Questionnaire

### NEW RESEARCH

Questions in this area are posed in order to identify research areas not already identified by the Research Question list.

N.1 Outside of your own area of responsibility, do you see the need for any research which is not currently being performed?

N.2 What problem would be resolved by this research?

N.3 Who would be the predominant user of the results of this research?

N.4 How would the results of the research be used?

N.5 How should the research be funded? By the NRC, industry, or through some cooperative fund-sharing arrangement?

N.6 What is your rough estimate of the cost of the research?

N.7 When should the research be performed? How vital is it to the continued assurance of public health and safety?

N.8 Are there any other areas for which research should be performed? (Redo N.2-N.7 for each)

### CURRENT RESEARCH

Questions in this area are posed to get some background information on current research

C.1 Describe the research activities in your area of responsibility and discuss how the results of the research will be used

C.2 What is the current status of the research?

C.3 Who is performing the research?

C.4 When was the research started?

C.5 When do you believe it will be finished?.

## SAFETY ASSURANCE

Answers to these questions will aid in the assessment of the Safety Assurance significance of the research.

S.1 If you were to place your research in one of the three categories of (a) Vital to safety assurance, (b) Important to safety assurance, or (c) Vigilant of safety assurance, where would you put it?

S.2 What is the risk level associated with the identified problem(s) in your research areas (compared to other areas), and how much of a reduction do you anticipate achieving?

## USEFULNESS

Answers to these questions will aid in assessing the usefulness of the research

U.1 Have the results of the research already been put to regulatory use in licensing judgments, regulations, policy documents, or the like?

U.2 Within the NRC, who is the user for the research? (Specify organizations and individuals.)

U.3 Describe your frequency of interaction with the user, the level of interaction (management, staff...), and the type of interaction (meetings, letters...)

U.4 Is there a written statement of the results to be delivered to the user?

U.5 Outside of the NRC, who else could make use of the research results?

## APPROPRIATENESS

Appropriateness is a measure of whether the research should be (a) entirely funded by the NRC, (b) jointly funded by the NRC and other organizations, or (c) questionable as to whether it should be funded by the NRC.

A.1 Is complementary or similar research being conducted outside of the NRC?

A.2 Who benefits the most from the results of the research? The NRC? Industry? Others?

A.3 Who do you think should share in the funding of the research? Industry? Foreign organizations?

## RESOURCES

These questions help determine the resource level of the research.

R.1 Is the current budget sufficient to successfully perform the research?

R.2 If not, then what level of funding would be necessary?

## WRAP-UP

W.1 Has a cost/benefit analysis been performed concerning the results of the research?

W.2 Where does your research fit into the NRC Strategic Plan?

# APPENDIX D: SUMMARY OF ACTIVITIES

Presented herein are the Summaries of Activities. These summaries are the assessments of NRC research activities, as prepared by the panel of experts, augmented with factual data following a review of the assessments by NRC management. No change in the assessments has been made as a result of the NRC management review, but in certain cases the information contained in the summaries has been modified in order to ensure accuracy and clarity. There is one summary for each research activity assessed during the panel meetings listed in Table 2-2. Each summary describes:

- The purpose of the research
- The assessed safety assurance significance of the research
- The assessed usefulness of the research
- The assessed appropriateness of the research (for NRC funding)
- The resource requirements for the research

As an aid to the reader, the page numbers for the activity summaries are also located in the first column of Table 3. When reviewing Table 3-1 more information about a particular activity can be found by turning to the appropriate summary in this appendix.

**SUMMARY OF ACTIVITY**

PROGRAM ELEMENT: REACTOR VESSEL AND PIPING INTEGRITY
Assessment Panel: Arlotto (NRC), Aldrich (SAIC), Mattson (SCIENTECH)
Branch Chief: Charles Serpan

PRESSURE VESSEL SAFETY

The purpose of reactor vessel safety research is to provide appropriate, well-validated analytical procedures to assure vessel safety during normal service and accidents. The most critical facet of pressure vessel integrity is embrittlement of the vessel steel caused by neutrons escaping from the fuel core during normal service. Embrittlement shows up as an increasingly higher temperature at which the steel is susceptible to brittle fracture, and as a decreasing level of available "upper shelf" toughness for fracture resistance. Large size irradiation specimens and test vessels are used to develop a base of information on the factors causing the embrittlement, because thick-section materials respond differently in fracture tests than small scale laboratory specimens.

To date, the research has provided definitive validation of linear elastic fracture mechanics (LEFM) methodology used in the ASME Code for design and operation of vessels, through tests on six-inch thick 39-inch diameter vessels. The analysis methodology and materials basis for the screening criterion in the PTS rule were also set from this research. The embrittlement research has defined the trends to be expected for increases in nil-ductility transition temperature (NDT) for vessels currently in service, resulting in a Regulatory Guide that is acknowledged worldwide. Work on crack growth rate, combined with that from some 40 other laboratories around the world has produced two updates of the ASME Code Section XI curves used for safety analyses of cracks found during inservice inspections. Critical work yet to be done in irradiation effects will extend the data base for the PTS rule by including tests of the effect of stainless steel cladding on crack extension, and of the reduced toughness in "low upper shelf" materials.

Establishment of the time and temperature conditions for reversal of embrittlement through annealing will be important for attaining initial 40-year service life, and for assuring safety for license extension. Also to be completed in an integrated fracture analysis method that goes beyond LEFM to include elastic-plastic and fully ductile fracture, because such methodology is inherent in both the PTS and the "low upper shelf" toughness safety evaluations. Vessel work cannot be safely closed off because the material continues to degrade in service through radiation embrittlement, and new facets of that embrittlement continue to emerge.

Safety Assurance - The embrittlement trends, screening criterion of the PTS rule, and fracture toughness criteria in federal regulations, all set limits on the pressure-temperature operation of nuclear plants thus greatly reducing the vulnerability of reactor vessels to unexpected, catastrophic brittle fracture (A-2). Embrittlement, if not understood and regulated, could prevent a plant from attaining its 40-year life (B-2) or could preclude safe license extension (B-4). Overall, this activity is assessed as CATEGORY A (VITAL).

Usefulness - The proposed research will provide the basis for approval of heatup and cooldown curves for plants, for the screening criterion embrittlement limit to preclude fracture in a pressurized thermal shock accident, and for safety evaluation of cracks found during inservice inspections. The work is the basis of or provides validation of virtually every aspect of reactor vessel regulation, and is assessed as HIGHLY USEFUL.

Appropriateness - NRC has tacitly assumed leadership in safety research for reactor vessels because vessel failures are not acceptable. Industry certainly has the responsibility to justify the safety of pressure vessels in operation, and thus should contribute significantly to provide a more complete data base. Such industry efforts ,however, would not negate NRC's need for independent and conclusive work in this area. This activity is assessed as VERY APPROPRIATE.

Resources - Special skills in heavy section steel metallurgy, fracture mechanics, and irradiation effects, and test facilities for fracture testing of multi-ton pressure vessels and specimens up to 30 feet long are needed for this activity. The Heavy Section Steel Technology (HSST) program, which has conducted this work since the late 1960's, will be needed for base-line support in the future to help plants reach normal 40-year life, and if plants are to be re-licensed for additional service. Resources include $100 million through FY87, $75 million to complete by FY98, $6.4 million for FY88, and $8.2 million for FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: REACTOR VESSEL AND PIPING INTEGRITY
Assessment Panel: Arlotto (NRC), Aldrich (SAIC), Mattson (SCIENTECH)
Branch Chief: Charles Serpan

### PIPING INTEGRITY

The purpose of this research is to provide NRC with experimentally validated analysis methods and criteria for evaluating potential cracking and fracture of nuclear reactor system piping during normal service and accidents. Currently focused on piping for the primary systems of BWRs and PWRs, the fracture criteria and analysis methodology are also applicable to secondary piping. Primary system piping in BWRs is typically made from wrought stainless steel which has been shown to be susceptible to intergranular stress corrosion cracking (IGSCC). Stress corrosion cracks can propagate to a size large enough to fracture under severe accident loads. Fatigue cracks can grow in PWR piping and could grow to a critical size if undetected by nondestructive examination or by leakage. Piping is not subject to radiation embrittlement, but the fracture toughness of cast stainless steel in some PWRs can be reduced significantly through aging for long times at normal service temperature. Nonetheless, piping usually operates in the ductile regime, and any cracks are expected to develop into detectable leaks before growing so large that they could lead to unexpected fracture: this is known as "Leak Before Break" (LBB), and is an important part of piping regulation.

An important accomplishment of the piping research has been experimental validation of the industry-proposed "fixes" to mitigate and prevent IGSC cracks in BWR stainless steel piping and welds. The need was urgent because licensees were applying procedures designed to stop cracking, and were making repairs and replacements of severely cracked pipe without a technical basis that adequately proved the safety of the "fixes". The NRC's confirmatory research clearly demonstrated both the good and the less desirable aspect of the "fixes" so that the actions could be accepted by the NRC with assurance of continued safety. At the same time, it was necessary to validate the fracture analysis procedures to allow decisions on what size crack was tolerable, and what had to be repaired or replaced to assure that subsequent crack growth would not lead to a critical-size crack before the next inspection. The analysis was validated by bending tests of cracked, full-size pipe under internal pressure and at operating temperature. The results of these tests laid the basis for significant changes in the ASME Code Section XI IWB-3640 rules for evaluation of cracked stainless steel pipe - the rules accepted by NRC for safe regulation of that material. The piping research also provided material property data, pipe fracture experience, and analysis procedures vital to accepting the LBB philosophy embodied in the change to 10 CFR 50 General Design Criterion 4 eliminating the dynamic effects of the double ended guillotine break from the design basis.

In the research yet to be conducted, the rules for fracture analysis of cracked carbon steel pipe will be developed, and it will be shown how to predict the fracture of cast stainless steel pipe having a significant toughness loss.

Safety Assurance - This research is needed for the resolution of safety questions A-2 (existing unacceptable vulnerabilities), A-8 (severe accident prevention and mitigation), B-2 (behavior of materials), and B-10 (future licensing). Piping failure remains a vulnerability of existing plants which can lead to severe accident conditions; leaks, cracks, and breaks in piping are among the most likely venues for breach of the primary pressure boundary which lead to a small or large-break LOCA. Improved understanding of crack growth rates will give the NRC a better understanding of the limits of vulnerability in this area. Because of the research's relationship to resolution of questions A-2 and A-8 this activity is assessed as CATEGORY A (VITAL).

Usefulness - The research is directly responsible for validating the basis for the ASME code rules used to evaluate the acceptability of cracked pipe for continued service, or the need for repair or replacement. The research has provided experimental fracture evidence, and has confirmed the acceptability of "fixes" for BWR pipe (originally proposed by Japanese and US industry). At the same time, the research pointed out areas of concern where some of the "fixes" were detrimental, or where limits were needed for safety. Thus, results concerning existing plant vulnerabilities and materials behavior continue to be incorporated into regulations, codes, and standard procedures as they become available; results pertinent to future licensing will be timely. Overall, this activity is assessed as HIGHLY USEFUL.

Appropriateness - Piping research is very much confirmatory, in that the industry has spent over 10 times NRC's investment in the BWR pipe cracking issue. Furthermore, industry proposals for LBB were made to NRC before the start of serious work on pipe fracture, and once the ASME Code rules for pipe flaw evaluation were in place, it became clear that confirmatory work was urgently needed. Therefore, while it is the responsibility of the NRC to ensure that the public safety is not at risk due to the peaceful use of nuclear energy, it is also the responsibility of the regulated industry to conduct the necessary fundamental research to prove that the safeguards are adequate. For piping integrity, NRC research provides the information needed to confirm industry findings. For this reason the activity is assessed as VERY APPROPRIATE.

Resources - Cumulative costs for this activity through FY87 are $20 million. Costs for FY88 are $2.4 million. Costs proposed for FY89 are $3.4 million. It is estimated that completion of the activity, in 1993, will require $10 million beyond the FY87 total.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: REACTOR VESSEL AND PIPING INTEGRITY
Assessment Panel: Arlotto (NRC), Aldrich (SAIC), Mattson (SCIENTECH)
Branch Chief: Charles Serpan

### INSPECTION PROCEDURES AND TECHNIQUES

The purpose of this research is to find ways to improve the reliability of inspection techniques used for examining cooling system components such as pipes and tubes. Metal components of reactors have very large capacities to resist fracture if they have no cracks or flaws. But the presence of even small cracks or flaws can greatly increase the likelihood for failure of a component during normal service or in an accident. Thus, it is mandatory to nondestructively inspect such components before service to find service-induced defects. Once they are found, nondestructive testing (NDT) techniques must be capable of accurately sizing them because flaw size is an important factor in predictions of flaw growth and in fracture mechanics calculations used for failure analyses. Reliability of both detection and characterization (determining flaw size, location, and type) are critical for safety assurance, and for maintenance of safety margins. The focus of the NRC research is on reliability of non-destructive examination procedures; the most recent emphasis has been on ultrasonic inspection (UT) of stainless steel pipe and welds in support of the intergranular stress corrosion cracking (IGSCC) problem in BWRs. Expansion of the effort into cast stainless steel has been necessary because of the exceptional distortion and attenuation of the UT signal caused by the inhomogeneous coarse grained macrostructure, making the material virtually uninspectable. Carbon steel of pressure vessels is more easily inspected by UT, but the very thick sections and stainless steel cladding present special problems that reduce inspection reliability. Steam generator tubes comprise fully half of the primary system pressure boundary, and are inspected by eddy current test (ECT) probes traveling inside the Inconel tubes. Degradation modes for these tubes include denting, intergrannular stress corrosion cracking, intergranular attack, wastage, pitting, wear under anti-vibration bar and fatigue cracking.

A recent significant achievement has been the preparation of mandatory appendices in ASME Code Section XI, for performance demonstration qualification of inspectors, procedures, and equipment for UT examination of primary system components, including piping, nozzles, and vessels. A reliability data base and improved techniques have been established by the NRC research program. This culminates nearly a decade's work for evaluation of NDT techniques practiced in the field and in upgrading the accuracy of detection and sizing of flaws in components. Yet to be developed, however, is the technical basis for upgrading inspection of reactor vessels, and multi-metallic weld joints. The reliability of, and techniques for, ECT inspection of steam generator tubes has been established in the recently completed Steam Generator Group Project. Regulatory Guides for inservice inspection (ISI) and tube plugging are being revised, and the ASME Code Section XI is upgrading, based in part on this research, ECT inspection procedures and preparing new ECT performance demonstration qualification requirements. Work still needs to be done, to recognize signals produced by copper plating rather than accept them as genuine flaws and to allow evaluation of flaws that may be masked by the copper.

Continuous monitoring of acoustic emission signals for detection of onset of cracking and continued crack growth during operating service has been demonstrated in a number of laboratory and intermediate scale tests and in pre-operational tests of a reactor, and will be demonstrated further in an operating PWR. Procedures for such monitoring are in the acceptance process for inclusion in ASME-XI.

Inspection criteria for license renewal, including timing, frequency, and location of inspections, need to be developed (question A-9). Establishment is also needed of non-intrusive tests to measure the mechanical properties of critical components to assure that strength, ductility and fatigue life are adequate, as claimed by the license renewals (questions B-2, B-4).

Safety Assurance - The research addresses safety assurance questions A-2 and A-6. Non-destructive examination is the best method for determining the flaw state, and thus, the vulnerability of reactors to accidents (question A-2). Pre-service and periodic in-service inspections are the very best method for determining compliance with requirements for the quality of construction (question A-6). The single most critical aspect of component safety is if a flaw exists and how big that flaw might be. A large fraction of conservatisms and margins stem directly form uncertainty over flaws. The ability to locate and assess problems, (flaws) before they reach criticality gives NRC the ability to take action to protect public health and safety before potential problems become accidents. Because the research is focused directly on these issues, the research is assessed as CATEGORY A (VITAL).

Usefulness - The results are the key basis for upgraded code and Reg. Guide requirements and procedures for inspection of reactor pressure vessels piping and steam generator tubes. Technology for continuous monitoring is available now for use, and is being codified. the results have been essential in forming positions for inspection requirements and for non-intrusive property measurements, so the future results will be timely. Accordingly this activity is assessed as HIGHLY USEFUL.

Appropriateness - Effective regulation of nuclear power plants is not possible without reliable methods of inspection. For the NRC to fulfill the governmental responsibility to ensure the safe use of nuclear power it is essential that the NRC have at its disposal the most reliable inspection techniques afforded by modern technology. Moreover, it is the responsibility of the NRC to continually assess and improve these techniques so as to ensure that the risk to public health and safety is as low as practicably achievable. This activity is assessed as HIGHLY APPROPRIATE.

Resources - Cumulative costs for this activity total $24.3 million through FY87. Cost for FY88 is $1.6 million. Proposed cost for FY89 is $2.5 million. Completion of the activity in 1995 is estimated to require an additional $20 million beyond the FY87 total.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: AGING OF REACTOR COMPONENTS
Assessment Panel: Arlotto (NRC), Aldrich (SAIC), Mattson (SCIENTECH)
Branch Chief: Charles Serpan

### CHEMICAL EFFECTS

The purposes of this research are 1) to measure the mechanical properties of materials in components of the Shippingport Atomic Power Station (SAPS) that have experienced up to 20 years of exposure and aging under real service conditions for comparison to properties measured under accelerated conditions in laboratory experiments, 2) to collect data on decommissioning of reactor facilities as a basis for better estimates of costs and inventories of radioactive and contaminated materials needing storage or disposal, 3) to evaluate the effects of decontamination of reactor components to determine how quickly recontamination occurs, if it follows the same trends, and if the decontamination solutions themselves cause other problems such as initiation of cracks in the cleaned components , and 4) to determine the fission product removal effectiveness of ESF Ice Condenser Systems.

Currently, a number of cast and wrought stainless steel samples have been taken from SAPS for study in other ongoing programs to determine toughness losses and the possibility of service-temperature-induced sensitization that could lead to IGSCC. Immediate work is planned for removal of material from the shield tank to obtain validation of a proposed dose rate effect of embrittlement that could have long range effects on the reactor vessel support structures of many PWRs. Further sampling of the reactor vessel itself for validation of embrittlement models will take place in the future when the vessel is delivered to the Hanford Reservation for final burial. Much Data collected from the SAPS and from German reactors have been valuable in setting the minimum funding reserve that utilities will need for final decommissioning and disposal of their reactor plants; this amount, and the options for how it is to be set aside have been very important issues in the shaping of the final rule on decommissioning. Much remains to be done to determine the longer term effects of decontamination solutions on components in this relatively new task; however, the processes are being used so information is needed to assure that unexpected cracking and failures do not arise. So far, excellent data have been taken of the simulated fission product removal effectiveness for validation of the codes. The facility is so efficient that industry is reviewing the possibility of sponsoring additional tests once the NRC program is complete.

Although the work is this activity is diverse in nature, it addresses many current and future needs of the agency in areas of aging license renewal and decommissioning.

<u>Safety Assurance</u> - The SAPs work will be especially important in determining if our predictions of material properties due to aging are correct, and thus will provide a measure of the plant vulnerability to accidents (question A-2) and material behavior (question B-2); this work is therefore assessed as CATEGORY A (VITAL). The decommissioning research is one of the main contributors to question B-14 and is therefore assessed as CATEGORY B (IMPORTANT). Decontamination research actually has input into question B-2 on behavior of materials in nuclear environments, and B-14 on radioactive contamination levels; therefore, it is judged to be CATEGORY B (IMPORTANT). The Ice Condenser ESF research has input into question B-9 on source terms for emergency planning; it is thus assessed as CATEGORY B (IMPORTANT). Overall, the activity is assessed as CATEGORY B (IMPORTANT) on the basis that more B questions are addressed than any others.

<u>Usefulness</u> - The Shippingport research will be needed for the resolution of the aging issue and is assessed as HIGHLY USEFUL, but with the following caveat: Current funding may be insufficient to pursue an aggressive research program capable of providing results timely for use in license renewal. The decommissioning research is the only government input to questions of costs and radioactive inventories, both of which are significant economic factors for industry; the

independent nature of this work makes it HIGHLY USEFUL The decontamination research will produce results needed to address the effects of corrosive materials on crack initiation and growth, and is therefore assessed as HIGHLY USEFUL. The Ice Condenser work may produce information bearing on better defining the source term for this plant type, but a release mechanism study in itself does not contribute to risk reduction unless the information is applied to change the system; thus the research is assessed as USEFUL. Overall, the activity is assessed as VERY USEFUL.

Appropriateness - The Shippingport and decontamination research address current aging issues facing NRC, and combined with decommissioning, all three also effect future licensing. Thus, all are properly performed by the NRC.. Although industry has the responsibility to produce the data required for license renewal in accordance with NRC requirements, these activities have strong confirmatory features to them and are classified as VERY APPROPRIATE. The Ice Condenser research is appropriate for both the NRC and industry to perform, but because it has important input into severe accident consequences, it is addressed as APPROPRIATE.

Resources - Cumulative costs through FY87 total $25 million. Costs for FY88 is $1.7 million. Costs proposed for FY89 are $2.2 million. Completion of the activity in 1994 is estimated to require an additional $15 million beyond the FY87 total.

**SUMMARY OF ACTIVITY**

PROGRAM ELEMENT: AGING OF REACTOR COMPONENTS
Assessment Panel: Arlotto (NRC), Aldrich (SAIC), Ybarrondo (SCIENTECH)
Branch Chief: Milton Vagins

## AGING

The United States now has approximately 100 nuclear power plants in operation and a few of these reactors have been operating in excess of 20 years. As the population of Light Water Reactors (LWR) has matured and advanced in age, the need for a research program that would provide a systematic assessment of the effects of plant aging was recognized. The Nuclear Plant Aging Research (NPAR) Program (The Aging Activity) provides the basic data required to understand the effects that aging has on the safety function of electrical , mechanical and structural components of commercial nuclear plants.For the NPAR Program, aging refers to the cumulative degradation of a system or component that occurs with time, which if unchecked can lead to an impairment of continuing safe operation. The NPAR Program provides systematic research effort to: learn from operating experience and expert opinion; identify failures due to age degradation; predict safety problems resulting from age-related degradation; and develop recommendations for surveillance and maintenance procedures that will alleviate aging concerns. At the present time NPAR consists of 15 separate, but integrated individual projects that are studying the effects of aging on 12 individual mechanical and electrical components and 6 systems, composed of such components. Additionally, a further 15 components and 7 systems have been targeted for study in the coming years.

Safety Assurance - This activity addresses questions A-1, A-2, A-5, A-6, A-7, A-9, B-2, B-3, B-4, C-1, C-2 and C-6. The effects of the aging of structures, systems and components of nuclear power plants could result in a degraded plant condition which would have a substantial impact on the health and safety of the public. Aging directly affects operational readiness of the plants and raises two significant safety issues. The first issue concerns the increased potential for common-mode failure. Multiple failures of a particular component due to aging could lead to unacceptable plant vulnerabilities to accidents. A second issue, that of a reduction in the margin of safety afforded by the defense-in-depth concept, would also be addressed in the Nuclear Plant Aging Research (NPAR) Program. This would contribute to the basic understanding of how much aging contributes to the risk of severe accidents. The NPAR Program will also add new insights into the resolution of other high priority generic issues and will assist the NRC in determining when aged equipment no longer meets regulatory requirements and will quantify the risk significance of aging. Such considerations are necessary for decisions regarding continuing safe operation of licensed plants. They are also needed for decisions regarding extensions of operating licenses for existing nuclear power plants and defining what additional changes to the regulatory requirements are needed for license extensions. The overall assessment of this activity is CATEGORY A (VITAL).

Usefulness - Phase I engineering research has been completed for selected components and system, including motor-operated valves, check valves, auxiliary feedwater pumps, emergency diesel generators, electric motors, chargers and inverters, batteries, and circuit breakers and relays in safety-related systems and reactor protection systems. Also, on-site assessments of electrical circuits have been performed and aged components have been removed from the Shippingport plant for future evaluation. This program has been endorsed and is coordinated with NRR and to a lesser extent AEOD and the Regions. The NPAR Program is also providing key information to enable the NRC to resolve technical safety issues and define its policy and regulatory position in two planned rulemaking activities covering license renewal and maintenance. The prognosis of developing timely answers to the aging and plant life extension questions is very good with the bulk of the research being completed in the period 1992-93 (assuming appropriation of planned funding). This activity is assessed as HIGHLY USEFUL.

Appropriateness - NRC needs an independent assessment of the effects of aging and the efficacy of mitigating methods such as surveillance, monitoring and maintenance procedures. The Commission has defined the need for understanding and mitigating the effects of aging in its 1987 POLICY AND PLANNING GUIDANCE, NUREG-0885, in its soon-to-be-published 5-Year Plan and in its Strategic Plan. A strong commitment was made to Congress for the implementation of an aging mitigation program by the testimony of both the Chairman and the EDO to the Subcommittee on Energy and Power on November 10, 1987. This activity is assessed as HIGHLY APPROPRIATE.

Resources - Cumulative costs through FY87 total $11 million. Costs for FY88 is $5.5 million. Costs proposed for FY89 are $8.5 million. Completion of the activity in 1993 is estimated to require an additional $39 million beyond the FY87 total.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: REACTOR EQUIPMENT QUALIFICATION
Assessment Panel: Arlotto (NRC), Aldrich (SAIC), Ybarrondo (SCIENTECH)
Branch Chief: Milton Vagins

### EQUIPMENT QUALIFICATION METHODS

Current research in Equipment Qualification (EQ) is not very active. The limited work that is being done is focussed on severe accident EQ on new equipment. EQ should more properly be included in Aging Research.

Safety Assurance - This activity weakly addresses question A-2, A-4, A-8 and C-1. The nature of this program has been to perform confirmatory research to confirm licensing decisions and to improve analytical tools needed to determine the acceptability of equipment performance under accident conditions. It is assessed as CATEGORY C (VIGILANT).

Usefulness - As currently configured, the research may produce only limited information which bears on resolution of safety assurance questions. The activity is assessed as USEFUL.

Appropriateness - This activity requires special facilities, it goes beyond design basis, and it provides independent information, but industry must also bear the burden in EQ. This activity is assessed as VERY APPROPRIATE.

Resources - Resource requirements include approximately $__million to date, $__million to complete, $ 0.8 million in FY88, and $0.6 million in FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: SEISMIC AND FIRE PROTECTION
Assessment Panel: Blond (SAIC), Mattson (SCIENTECH), Ybarrondo (SCIENTECH)
Branch Chief: Andy Murphy

### EARTH SCIENCES

The purpose of the Earth Sciences research activity is to provide the basic data required to understand the causes, frequency, and severity of earthquakes in the U.S. In the past, this activity provided the information needed for NRC's development of 10 CFR Part 100 and its implementation through Regulatory Guides and the Standard Review Plan. Significant work in this area has been going on for more than a decade. These programs have had major effects on nuclear power plants. The future program is intended to supplement the existing data and to answer additional questions concerning the seismological risk to nuclear facilities. In the future the activity will consist of geological, geophysical, and seismological studies operation of seismographic networks in the eastern and central U.S. , and installation of the National Seismographic Network in cooperation with the U.S.Geological Survey to replace the current seismographic networks. Several programs already in place will continue to produce better understanding of tectonic provinces, frequencies and effects of seismic events, and the seismic wave transmission characteristics of media through which earthquakes propagate.

Safety Assurance - This activity addresses questions C-1 and, to a lesser extent, A-5. The risk significance of this activity is high. The seismic contributor to risk typically occurring at 2 to 4 times the SSE. A high level of uncertainty is associated with predicting the occurrence of the earthquake and the vibratory ground motion associated with it. The general consensus is that there are significant safety margins in current methods of seismic design. However, there is great uncertainty about large earthquakes, knowledge is gained in every earthquake that occurs, and the current body of knowledge is insufficient to fully characterize the seismic risk at all existing sites. Future research in this activity should provide a better basis for such characterizations when additional seismic risk analyses are required in the future as part of the program to perform independent plant evaluations for external events. The Earth Sciences activity will advance the state of knowledge of seismic risk, but the extent and nature of NRC's future role in this area is uncertain. Overall, the activity is assessed as CATEGORY C (VIGILANT).

Usefulness - The future work under this activity has been well coordinated with NRR through weekly staff discussions. The future program is well coordinated with USGS, the Corps of Engineers, and foreign government efforts. The programs underway and envisioned for the future are highly likely to provide needed improvements in seismic requiren [illegible] necessary development and implementation of the seismic networks. This activity is assessed as HIGHLY USEFUL.

Appropriateness - The USGS is assuming Federal government responsibility for the new seismic networks, and NRC is in the process of phasing out its supportive role in that area. Utilities and EPRI have seismic monitoring programs at individual sites. Beyond the transition of the seismic network support to USGS, the NRC must continue to fund research in earthquake propagation and attenuation, soil failure and site response. In addition, the NRC must keep abreast of improving knowledge developed by the scientific community in this area and adjust its requirements and practices as necessary to reflect contemporary knowledge and residual uncertainties. This activity is assessed as APPROPRIATE.

Resources - Resource requirements include $50 million to date, $20 million to complete, $3.6 million for FY 88, and $4.1 million for FY89. This activity has received approximately 50-50 support from other federal and state agencies. $5 Million of the NRC effort from 1987 through 1992 is for replacing the seismic network and turning it over to the USGS. USGS is spending an equivalent amount.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: SEISMIC AND FIRE PROTECTION
Assessment Panel: Blond (SAIC), Mattson (SCIENTECH), Ybarrondo (SCIENTECH)
Branch Chief: Andy Murphy

### COMPONENT RESPONSE TO EARTHQUAKES

The purpose of the Component Response to Earthquakes research activity is to provide data on the seismic response and fragility of safety related buildings, piping, and equipment. The component failure (fragility) data that it provides serve as input to the related research activities on seismic analysis methods and design margin assessment. The activity is comprised of several analytical-experimental efforts - namely, determining how buildings transmit earthquake loads to safety systems and components, developing more realistic piping design criteria to provide better balance of safety between normal operating and accident conditions, and predicting how and at what earthquake magnitude the buildings , piping, and electrical and mechanical equipment fail to perform their safety functions. This last area is also based on earthquake data and data from seismic qualification tests conducted by licensees. The activity is only a few years old, and much of the data necessary for its completion remain to be gathered. The output of the program will be catalogs of data concerning the failure of safety components when vibrated at high amplitude; these data are then used with estimates of the vibration levels in nuclear plants to assess the magnitude of earthquake that the plant can withstand without failure of the components to perform their safety function .

Safety Assurance - This activity addresses questions A-2, A-9, C-2 and C-1. These questions relate to understanding the risk that earthquakes portend for reactors and then, if necessary, doing something to reduce that risk Most probabilistic safety assessments that address external hazards to nuclear power plants find that the seismic risk is very important, if not dominating, compared to the other risks. In these probabilistic assessments, there is uncertainty about the response of safety components to large earthquakes beyond their design basis; i.e., their fragility is uncertain because of the lack of data on component performance under severe vibration conditions beyond the seismic design basis. Such data are provided by this activity and are required as input to the seismic margin research activity, which is assessed as vital to safety assurance. Overall, this activity is assessed as CATEGORY A (VITAL).

Usefulness - The results of this research are needed to assess current seismic design criteria (based partially on judgment and conservative assumptions), for ongoing PRA activities, and for the ongoing seismic margins research activity. Its products are being used as they become available. Although this activity has been underway for only a few years, it is at a high level of productivity and is expected to conclude in about three more years. This activity is assessed as HIGHLY USEFUL.

Appropriateness - The interest in knowing the ultimate dynamic capability of safety components stems from concerns about the adequacy of the design basis for licensed plants, so it is appropriate for the gove[illegible] to be in the lead. NRC is the only agency in the government that has the responsibility fo[illegible]ntly con[illegible]ming the adequacy of the safety design basis. Japan and Taiwan hav[illegible] program[illegible] NRC. Although EPRI has a program in margin assessment, it has no p[illegible] gather c[illegible] fragility data, and such data are not provided by the less severe tests [illegible] qualify safety related equipment for the dynamic effects of des[illegible], the only way to get the data is for NRC to pay for it. Overall, this [illegible] APPROPRIATE.

Resources - Special skills [illegible] response and fragility data. Such skills are gained from experience in [illegible]ion of these types of tests. Resource requirements in[illegible] $12 million to dat[illegible]on to complete by FY92 , $ 3 million for FY88, and $ 3.7 m[illegible]9.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: SEISMIC AND FIRE PROTECTION
Assessment Panel: Blond (SAIC), Mattson (SCIENTECH), Ybarrondo (SCIENTECH)
Branch Chief: Andy Murphy

### VALIDATION OF SEISMIC ANALYSIS

The purpose of the Validation of Seismic Analysis research activity is to provide data from systems configurations typical of actual nuclear power plants to validate the computer models that are used to analyze the dynamic response of safety systems to earthquakes. Past and future research consists of dynamic tests of large models to understand systems effects, such as pipe and pipe support interactions and soil-structure interactions. Since the models are so large, the data are difficult and expensive to obtain, and multi-party funding is appropriate. Future projects include the excitation of a decommissioned nuclear power plant in Germany, shaking of a reactor coolant loop model on a table in Japan, and measurements obtained from a containment building in a seismically active area on Taiwan. The program is about one-half complete, and the remaining data are needed to give complete validation of existing methods relied on for licensing decisions.

Safety Assurance - This activity addresses safety assurance questions A-5, C-1, and C-2. Although the activity will provide additional assurance that the seismic capability of existing designs is adequate, which is a concern that falls under safety assurance question A-5, that is not the main intent of the activity. Rather, the principle concern of this activity is the residual risk associated with large earthquakes beyond the design basis. There are two ways to understand the residual seismic hazard to nuclear plants; one is to analyze the response of the plant to big earthquakes using codes of the type that this activity helps to validate; the other is to look at the margin to failure of the safety related components and decide if that margin is adequate. The latter approach is not as dependent on the code validation work performed in this activity. The former approach is the one used for the seismic portion of probabilistic safety assessments, so this activity is important to reducing the uncertainty of those analyses, at least as far as the state of the art is concerned today (see the activity on seismic design margin). Overall, because the results of this activity will help but not be crucial to a Category A question and be most useful for Category C questions, it is assessed as CATEGORY B (IMPORTANT).

Usefulness - There is excellent coordination of this research activity with the reactor licensing staff. The data remaining to be obtained are needed to complete the regulatory validation of both design codes and probabilistic risk assessment (PRA) techniques. The design codes and the PRAs are used on both current plants and on future designs. The data are becoming available when needed by the analysts working for NRC. Overall, the activity is assessed as HIGHLY USEFUL.

Appropriateness - The seismic analysis codes are being validated on a world wide scale. The Canadians, Japanese, French, and Germans have related research that is being coordinated with this activity. Also, there is a 1/4-scale seismic analysis verification test jointly sponsored by EPRI and Taipower that helps to provide the needed data. Because the analysis methods are used by designers, it is appropriate that they be involved in supporting the research. NRC must also be involved because of the need for independent verification of the adequacy of models and for confirmation of the analytical results. Because the activity is needed by NRC to independently validate analyses both within and beyond the design basis, and because the industry has a parallel program for its interests, the activity is assessed as HIGHLY APPROPRIATE.

Resources - Special skills are needed in the seismic analysis of complex structures. The resource requirements for this activity include $3 million to date, $4.5 million for completion by FY92, $1.5 million for FY88, and $1.3 million for FY89.

**SUMMARY OF ACTIVITY**

PROGRAM ELEMENT: SEISMIC AND FIRE PROTECTION
Assessment Panel: Blond (SAIC), Mattson (SCIENTECH), Ybarrondo (SCIENTECH)
Branch Chief: Andy Murphy

SEISMIC DESIGN MARGIN METHODS

The purpose of the Seismic Design Margin Methods research activity is to develop and apply novel approaches to the estimation and control of the residual risk to nuclear power plants from extreme earthquakes. The product of the activity will be improved guidance for assessing the inherent capabilities of nuclear power plants to withstand earthquakes above the design level and more effective means to identify any existing vulnerabilities of nuclear power plants to seismic events. The activity involves the Lawrence Livermore Laboratory and other consultants in the development of system walk-down techniques and the testing of those techniques in representative plants. The method depends upon input from another research activity concerning component response to earthquakes. Also included in this activity are lessons learned from probabilistic risk assessments of seismic events and earthquake experience data. The activity is only a few years old, and it has only a few years to go. It has been applied by NRC to one plant, and EPRI is now applying it to others. When the methods are proven by these trial applications, this research will end.

Safety Assurance - This activity addresses questions A-2, A-5, and C-1. The activity has high promise for identifying current, unacceptable seismic design weaknesses in operating plants, if it were to be applied to all plants, which is not now envisioned. The activity is also important because it can remove the need to analyze large seismic events in probabilistic risk assessments. It is expected that the results of this research will confirm that the margin to failure in an earthquake is typically very large, if equipment is properly anchored. Overall, this activity is assessed as CATEGORY A (VITAL).

Usefulness - The new methods produced by this activity are now becoming available. Their production is coincident with the development of methods for making individual plant evaluations of the vulnerability to severe accident initiators originating inside the plant. The research is useful for future reactor design and licensing. Seismic margin has been a controversial area for years; this activity is the most important original contribution to resolving that controversy. Overall, it is assessed as HIGHLY USEFUL.

Appropriateness - EPRI is cooperating with this research activity. EPRI is conducting independent applications of the new methods in several plants. It has been necessary for NRC to provide government support for methods development, peer reviews, and trial applications until there was acceptance of the methods by industry. This area involves the residual risk beyond the design basis required by NRC, so the government had to take the lead. Once the methods have been proven useful, then it will be appropriate for NRC to require that the methods be applied generally by the industry. Overall, the activity is assessed as HIGHLY APPROPRIATE for NRC funding, phasing into industry funding.

Resources - The skills of fragility and systems analysis specialists are needed for this activity. Resource requirements include $1.5 million to date, $1 million to complete by FY90, $0.8 million for FY88, and $0.9 million for FY89.

**SUMMARY OF ACTIVITY**

PROGRAM ELEMENT: CONTAINMENT STRUCTURAL INTEGRITY
Assessment Panel: Arlotto (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Andy Murphy

## STRUCTURAL TESTS

The purpose of this research is to permit reliable prediction of the capacities and failure modes of the variety of existing containment designs if they were to be loaded beyond their design bases. A key insight emerging from the research on accident analyses is that the mode and timing of containment failures are very important in determining accident consequences. Early failure, without other mitigating factors, can result in large radioactivity releases, while delayed failure of even several hours can significantly reduce the amount of radioactive material available for release. Hence, the ultimate concern of the containment performance issue is how well the containment, conservatively designed for a postulated loss-off-coolant accident (LOCA), can withstand the pressure and temperature associated with severe core damage accident. For scenarios in which containment integrity is maintained, consequences are small. In those scenarios in leading to containment failure, consequence predictions depend on both timing and type of failure. The manner by which it fails would influence the amount of airborne radioactive materials that could be released outside the containment. Knowledge of the time interval during which containment leak-tight capability is ensured is important because if the time interval between the release of radioactive material and containment failure is long, substantial fission product deposition will occur within the containment. Furthermore, the mode in which containment fails, e.g. gross failure versus leakage through failure of penetrations, could influence the amount of radioactive material inside the containment that would be released outside the containment.

Safety Assurance - This research is needed for the resolution of safety assurance questions A-3 (short term containment failure modes), and A-4 (best estimates of course and consequences). Potential failure modes and the timing of failure modes in accident sequences are crucial elements in assessing the risk associated with individual plants. Because of the relationship of the research to the resolution of questions A-3 and A-4 this activity is assessed as CATEGORY A (VITAL).

Usefulness - The results of the research will be used to develop more reliable estimates of failure modes for individual plants, Some initial applications have already been made, especially for steel containments - an area in which the experimental effort is virtually complete. Improved estimates of containment capacities, performed for the revision of NUREG-1150, were based in large measure on information developed from this research. Industry-sponsored efforts to develop improved estimates of the likely performance of the Peach Bottom containment rely heavily on past experiment son steel containment models. This activity is assessed as HIGHLY USEFUL.

Appropriateness - Industry-sponsored research and development on containment performance was influenced by the design basis accident concept and was focused on developing designs that would perform reliably under DBA conditions. No effort was thought warranted on attempts to examine performance beyond that level. When interest in this topic developed, it was accepted that NRC bore the prime responsibility for developing basic data while applications to individual plants remains an industry responsibility. The research program had been designed in this way and is assessed as HIGHLY APPROPRIATE.

Resources - Cumulative costs for this activity through FY87 are $18 million. Costs for FY88 are $2 million. Proposed costs for FY89 are $3.6 million. It is estimated that costs to completion of the activity, in 1991, will require $10 million beyond the FY87 total.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: HIGH-LEVEL WASTE
Assessment Panel: Costanzi (NRC), Aldrich (SAIC), Mattson (SCIENTECH)
Branch Chief: Frank Costanzi

### HLW MATERIALS AND ENGINEERING

The NRC High Level Waste (HLW) research activity has two overall purposes. They are: (a) the development of an understanding of the way a repository system works, to allow determining whether DOE's compliance demonstration is adequate, and (b) given this basic understanding of the phenomenology, determination of the attributes necessary to DOE's compliance demonstration for NRC reaching a finding of reasonable assurance. The research in this area is focused on determining the implementation criteria for the engineered barrier requirements in 10 CFR 60. The research activities are focused on identifying key phenomena and the degree of precision needed for tests and description of performance of waste packages and engineered systems in the physico-chemical repository environment. DOE is conducting the basic research on materials and the environment; the NRC is looking at the tests and experiments which will be needed in order to determine failure modes and to establish confidence that the findings can be extrapolated out to 1000 years. From the findings of this research into failure mechanisms will come an estimate of the source term associated with package failure.

Safety Assurance - This activity directly addresses question A-12. The research in this area will have a direct effect on how DOE designs and manufactures the waste package and the shaft seals. An early failure of the package could lead to a more serious challenge to the sites, especially during the first 300-1000 years when thermal effects are greatest and when analysis of the effects is most difficult. Even if the site is the primary barrier, defense-in-depth requires that the package be capable of limiting the source term. This activity is assessed as CATEGORY A (VITAL).

Usefulness - Lack of adequate funding during the nascent stages of the research, which can best be characterized as long-term, has precluded starting on needed research, such as modeling of intergranular stress corrosion cracking and compression of the waste package after a seismic event. The research must be completed on schedule to comply with NRC mission of licensing DOE package and site. On the plus side, international agreements with Japan, Switzerland, France, and others have amplified available resources. Research conducted to date, has provided system models for analyses instrumental to the decision to place more emphasis on the role of the package in the requirements of 10 CFR Part 60. Review of the work as published in peer journals has been positive. Frequent programmatic reviews are conducted at the division level of NMSS, with formal NMSS review of RES project proposals. Moreover, the Waste Management Review Group (WMRG) assures concordance between waste research and technical assistance. The results of research in this activity, like the results of all waste management research conducted by RES, are delivered routinely to the user office via research summaries issued by the Waste Management Branch, RES. The activity is assessed as HIGHLY USEFUL.

Appropriateness - The independence of the work from DOE research provides NRC with the knowledge necessary to adequately assess and license the DOE waste package submittal. The activity is assessed as HIGHLY APPROPRIATE.

Resources - Resource requirements include approximately $10 - 15 million cost to date, $10 million to complete, $ 1 million in FY88, and $1 million in FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: HIGH-LEVEL WASTE
Assessment Panel: Costanzi (NRC), Aldrich (SAIC), Mattson (SCIENTECH)
Branch Chief: Frank Costanzi

### HLW HYDROLOGY AND GEOCHEMISTRY

The NRC HLW research program has two overall purposes. They are: (a) the development of an understanding of the way a repository system works, to allow determining whether DOE's compliance demonstration is adequate, and (b) given this basic understanding of the phenomenology, determination of the attributes necessary to DOE's compliance demonstration for NRC reaching a finding of reasonable assurance. Hydrology and Geochemistry research is looking at how to characterize the ground water system, the chemistry of the site, response to earthquakes, hydrologic testing and measurement techniques, and the permeability of fractured earth (unsaturated tuff). In keeping with the NRC's regulatory role, the research is focused on how the data should be interpreted for assessing acceptability in terms of 10 CFR 60 requirements rather than providing a duplication of the basic research being conducted by DOE. Some of the research in this area continues to be generic in nature (e.g.,permeability testing is being conducted in basalt) since the results are independent of whether the tests are conducted in basalt or tuff.

Safety Assurance - The activity directly addresses question A-12. The NRC must understand the fundamental physical and chemical mechanisms of ground-water flow and radionuclide transport for the unique nature of a high-level waste repository in order to conduct a reliable license review. DOE is quickly moving forward with its site characterization plans; the results of this research will be used to structure DOE's site characterization. The activity is assessed as CATEGORY A (VITAL)

Usefulness - NMSS is using the results now in reviewing the DOE site characterization plans. The work is well-coordinated with NMSS via WMRG, reports and briefings are provided by RES to NMSS/WM staff, and there have been at least 10 papers published in technical periodicals. International agreements with Japan, Switzerland, France and others have amplified available resources. As currently funded, the research is sufficient to enable NRC to make licensing decisions consistent with the mandated schedule. The activity is assessed as HIGHLY USEFUL.

Appropriateness - DOE should be leading the work in this area, and it is not. DOE should be doing more basic research in hydrology and geochemistry with the NRC maintaining its independent abilities in order to properly review the DOE submittals. The activity is assessed as VERY APPROPRIATE.

Resources - Resource requirements include approximately $15 million in sunk cost, no more than $10 million to complete, $1 million in FY88 and $1 million in FY89. Special skills in geohydrology, geochemistry, and modeling are required.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: HIGH-LEVEL WASTE
Assessment Panel: Costanzi (NRC), Aldrich (SAIC), Mattson (SCIENTECH)
Branch Chief: Frank Costanzi

### HLW COMPLIANCE ASSESSMENT AND MODELING

In order to be able to effectively review the DOE demonstration of safety of the HLW repository against the requirements of 10 CFR 60, the NRC is integrating the measurements and tests from the other research program areas into physical models of components and systems. Models of overall repository performance are also being modified to reflect the improved understanding of repository subsystem interaction. These models, which include computer solutions for transport prepared by SNL and source term modeling at the FFRDC, have been based upon the 1984 Modeling Strategy document published by NMSS. Currently the SNL salt model is being modified to meet the specific requirements of the Yucca tuff site. SNL is being phased out of the work to avoid any conflict of interest with their DOE-sponsored work.

Safety Assurance - The activity directly responds to question A-12. NRC policy requires an independent assessment capability for HLW using self-generated models. Long lead times are required to develop and validate these models. The product of the work will be used as a basis for approving overall capability of the site and waste package combination. Analyses such as these must be performed to demonstrate compliance with EPA standards. The activity is assessed as CATEGORY A (VITAL)

Usefulness - The analysis methods made available by the research, and the validation of these methods, will be available in time for use in the licensing process. Coordination with NMSS through WMRG is good. International agreements with Japan, Switzerland, France and others have amplified available resources. There is one possible constraint of the research as currently funded: at a higher funding level, validation of the models could be bolstered by running more natural analog studies. The activity is assessed as HIGHLY USEFUL.

Appropriateness - Adherence to NRC policy requires modeling used for licensing to be conducted independently. DOE appears to be developing its own model, but the adequacy of this model will not be known until the site characterization is performed. The activity is assessed as HIGHLY APPROPRIATE.

Resources - Resource requirements include approximately $10 million to date, $15 million to complete, $1.4 million in FY88 and $1.4 million in FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: LOW-LEVEL WASTE
Assessment Panel: Costanzi (NRC), Aldrich (SAIC), Mattson (SCIENTECH)
Branch Chief: Frank Costanzi

### LLW MATERIALS AND ENGINEERING

The research in this activity is focused on the waste package and other engineered features of the disposal system. Included is an exploration of the alternatives to shallow land burial, solidification methods, containers and their survivability, and testing protocols for forms and containers. Questions regarding the function of the concrete barriers, proposed by some states, are being studied to determine what function the barriers provide, how long they will last, and the effects of their failure. NRC has the licensing authority, but the agreement states will probably issue the licenses. RES develops the technical criteria for licensing, and NMSS/state programs provide technical information to the states in regards to implementation.

Safety Assurance - The activity addresses question B-15. Compliance with federal statute demands the formulation of a justifiable technical basis for LLW disposal, development of which will require better data on waste forms and long term waste immobilization. Public perception of the risk from low-level waste is a factor for decisions. The states in which the LLW disposal sites will be located depend upon the NRC to establish technical criteria. The activity is assessed as CATEGORY B (IMPORTANT).

Usefulness - Although closure is still some 30 years off, facility design is already underway. The concern is that delaying the establishment of closure criteria could lead to licensing problems later which could have been resolved more economically during the design phase. In terms of coordination, the LLW program interacts with WMRG and has informal coordination with candidate states, Southern States Energy Board, DOE, and EPA. The product of the research currently being performed is delivered to users via Research Summaries issued by RES, Waste Management Branch. These summaries, which provide a more timely method of disseminating information than the normal reporting mechanisms, describe the problem being addressed, the progress made, and the regulatory significance of the findings. The activity is assessed as HIGHLY USEFUL. However, more resources are needed now in order to adequately develop regulatory criteria for closure of the LLW sites.

Appropriateness - DOE/NE programs address alternative designs for LLW, but their research is fundamental rather than regulatory. EPRI has some research in the cost and design of LLW alternatives which is coordinated with the NRC work, and there is also coordination with research in Japan and the U.K. The activity is assessed as HIGHLY APPROPRIATE for addressing the regulatory concerns with which NRC will be concerned.

Resources - Resource requirements include $6 million to date, $6 million to complete, $1.5 million in FY88, and $1.2 million in FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: LOW-LEVEL WASTE
Assessment Panel: Costanzi (NRC), Aldrich (SAIC), Mattson (SCIENTECH)
Branch Chief: Frank Costanzi

### LLW HYDROLOGY AND GEOCHEMISTRY

The main concern of this research activity is the determination of the disposal site source term associated with LLW. RES is developing a suite of models for performance assessment based on known behavior in current and old sites. Disposal site performance is determined by its hydrologic and geochemical characteristics. There are major uncertainties in this area, such as that associated with the effects of vegetation; while plants help in keeping the site dry, they also present problems with mobilization of nuclides. Data about a Canadian LLW site made available through AECL (Chalk River) is being used in this research; the AECL data are well characterized, there are good records, and RES has ready access to the data. Specific research is being conducted by UCLA/Univ. of Maryland (Beltsville demonstration), PNL (site models, geochemistry, mobilization in soils), BNL (source term), and MIT (stochastic hydrology).

Safety Assurance - This research addresses question B-15. As with HLW, LLW disposal is mandated by federal statute. This research will identify the capabilities and limitations of current hydrologic flow and contaminant transport models as applied to NRC's LLW licensing and regulatory program. This activity is assessed as CATEGORY B (IMPORTANT).

Usefulness - Both the states and NMSS are users of the information and there is coordination with NMSS via WMRG. Coordination with federal and state agencies is facilitated through the LLW technology coordinating committee. The activity is assessed as HIGHLY USEFUL.

Appropriateness - It is the responsibility of the NRC to license LLW disposal facilities. This responsibility presupposes a level of knowledge adequate to perform the licensing in a manner protective of public health and safety. Since the detailed knowledge to perform this licensing surpasses the level of effort already expended in outwardly similar-appearing EPA programs, it is appropriate for the NRC to perform this research. We also believe that EPRI should be encouraged to do more research in this area; they are already doing research on leaching of coal piles and contamination of ground water, but they are doing little to address hydrology and geochemistry with respect to radionuclides. Overall, the research being conducted by the NRC is considered HIGHLY APPROPRIATE because it is needed to evaluate licensee submittals.

Resources - Resource requirements include \$6 million to date, \$4 million to complete, \$0.7 million in FY88, and \$0.7 million in FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: LOW-LEVEL WASTE
Assessment Panel: Costanzi (NRC), Aldrich (SAIC), Mattson (SCIENTECH)
Branch Chief: Frank Costanzi

### LLW COMPLIANCE, ASSESSMENT, AND MODELING

The research in this activity is concerned with the modeling of the hydrology of the sites in order to be able to predict movement of radionuclides. Information from other program areas (hydrology and geochemistry) is utilized to determine the appropriate parameters to be used in predictive models of site performance. RES is developing performance assessment methods and validating the methods using the characteristics of existing LLW sites such as Chalk River.

Safety Assurance - The activity, which addresses question B-15. Compliance models provided by this research are needed by the candidate LLW disposal sites. The activity is assessed as CATEGORY B (IMPORTANT)

Usefulness - It is projected that specifications for the assessment models needed by the states will be available from the NRC in 3-5 years, consistent with schedule requirements. There is good coordination with NMSS via WMRG. The activity is assessed as HIGHLY USEFUL .

Appropriateness - Since there is no policy requiring an independent model, the research is correctly focussed on regulation in as much as it will give the agency the knowledge to specify the characteristics of adequate models. The activity is assessed as HIGHLY APPROPRIATE.

Resources - Resource requirements include $5 million to date, $5 million to complete, $0.7 million in FY88, and $0.8 million in FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: REACTOR CONTAINMENT SAFETY
Assessment Panel: Blond (SAIC), Mattson (SCIENTECH), Ybarrondo (SCIENTECH)
Branch Chief: Mel Silberberg

### CORE MELT PROGRESSION AND HYDROGEN GENERATION -

The Core Melt Progression and Hydrogen Generation Research Activity provides a data base and analytical models of the governing physical and chemical processes attendant to core melting in light water reactors (LWRs). The experimental research consists of in-pile integral tests, including examination of TMI-2 core debris, laboratory separate-effects experiments, and determination of basic metallurgical data. Also the research consists of the development and validation of mechanistic computer models for in-vessel core-melt progression and hydrogen generation, including the response of the reactor coolant system (RCS) prior to its breach by the core debris and the mode of vessel failure. This research provides the input on the melt mass, ejection rate, composition, and temperature needed to assess the core-melt threat to containment integrity. Five laboratories perform different aspects of this complex research.

Safety Assurance - This activity strongly addresses questions A-2, A-3, A-4, B-1, B-9 and C-2. Because there are many possible core melt scenarios in LWRs, and because these scenarios affect the amount and characteristics of the core debris, fission products, and hydrogen that escape from the RCS, much of the uncertainty in predicting the course and consequences of core melt accidents lies within the scope of this activity. Currently there are large quantitative uncertainties in the potential challenges to containment from core meltdowns. Understanding the state of the damaged core is important for managing an accident beyond the design basis in order to limit its consequences. Understanding the progression of the core melt through the time of failure of the RCS is important for managing actions that could be taken during a core melt down to prevent early containment failure. Overall, this activity is assessed as CATEGORY A (VITAL.)

Usefulness - The research has not yet resolved important differences of opinion among industry, laboratory, and government scientists on subjects vital to safety enhancement and the reduction of uncertainty, including hydrogen generation mode of vessel failure, characteristics of the ejected debris, etc. Two detailed mechanistic computer codes for predicting system response are available : MELPROG/TRAC for use in unrecovered accidents and risk assessment, and SCDAP/RELAP5 for use in accident management by core reflooding. At this time, neither code has been accepted for use by industry although the codes have been used extensively in the U.K., particularly in the Sizewell B inquiry, and in Japan and other countries. Neither have IDCOR and NUMARC been using these detailed codes in severe accident activities. There is some competition among the laboratories that may be nonproductive. There has been long-standing disagreement with IDCOR on the IDCOR models with an early cut off of hydrogen generation despite the abundance of experimental evidence to the contrary and rejection of the IDCOR model by the international scientific community. The Kouts Panel recommended concentration of the research on the late phases of core-melt progression as treated by the MELPROG/TRAC code, while others recommend INPO use of SCDAP/RELAP5 for early phases of core-melt progression and accident management. This activity is assessed as VERY USEFUL.

Appropriateness - Because core melting is beyond the design basis and not included in NRC licensing requirements, research in this area should be led by NRC. Given the significance of the research to hydrogen control, however, it is also appropriate to continue seeking cooperative funding from EPRI, INPO and NUMARC. This activity is assessed as VERY APPROPRIATE.

Resources - Cumulative costs for this activity through FY87 are $50 million. Costs for FY88 are $5.7 million. Proposed costs for FY89 are $5.7 million. It is estimated that costs to completion of the activity, in 1995, will require $50 million beyond the FY87 total.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: REACTOR CONTAINMENT SAFETY
Assessment Panel: Blond (SAIC), Mattson (SCIENTECH), Ybarrondo (SCIENTECH)
Branch Chief: Mel Silberberg

### CORE - CONCRETE INTERACTIONS -

The Core - Concrete Interactions research activity provides experimental data and modeling to understand an important element of the effect of a core melt down in a light water reactor with conventional containment. It concerns the physical and chemical processes that would occur if molten core materials were to come in contact with concrete in the containment structure. Included in the activity are the release of combustible and non-condensable gases, reduction of molten metals, interlayer heat and mass transfer in debris pools, and degradation of concrete containment structures. One laboratory provides both large-scale integral experiment and medium-scale aerosol release tests coordinated with an analytical program of code development and assessment (CORCON and VANESA); while another laboratory conducts small scale separate effects tests and model development. The activity began around 1975; the end product is the ability to analyze the core and concrete interactions adequately for severe accident decisions.

Safety Assurance - This activity strongly addresses questions A-3, A-4, B-9 and C-2. It involves a significant source of uncertainty about containment performance for core melt down accidents, namely, whether gases emitted by core concrete interactions could combust and cause early containment failure. This activity is necessary for timely resolution of VITAL safety questions concerning the potential for early containment failure in two types of pressure suppression containment, Mark I, Mark III, and ice condenser. The propensity for early dry well liner failure in the Mark I design is being given high priority for resolution by NRC because of the potential it holds for unacceptable risk at a number of operating plants. In addition, this activity is important for reducing the uncertainty of containment response and the nature and magnitude of radioactive materials released in a core melt down for all LWR containment types. This activity is assessed as CATEGORY A (VITAL.)

Usefulness - Research results will probably be used in the Individual Plant Examinations for evaluations of vessel melt-through conditions. Emergency planning, implementation of Severe Accident Policy, and design of future LWR's will be affected by the outcome of this research. The acceptability of risk for Mark I containments and associated backfits that might be needed are vitally dependent on early conclusions about core concrete interaction. The results for the Mark I containment are expected in 1988, and the activity is expected to be complete in 1992. This activity is assessed as HIGHLY USEFUL.

Appropriateness - There are users of this activity besides NRC, particularly other nations with operating LWR's. The BETA program in FRG is coordinated with the US research, as is source term research by EPRI. Industry would not fund this research because it is beyond the licensing basis. NRC must fund this research because it concerns vital questions about the adequacy of the licensing basis and risk acceptability. This activity is assessed as HIGHLY APPROPRIATE.

Resources - Special skills in thermal hydraulics, metallurgy, and chemistry are required. Resource requirements include $21 million to date, $10 million for completion, $1.7 million for FY88 and $1.8 million for FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: REACTOR CONTAINMENT SAFETY
Assessment Panel: Blond (SAIC), Mattson (SCIENTECH), Ybarrondo (SCIENTECH)
Branch Chief: Mel Silberberg

### DIRECT CONTAINMENT HEATING

The Direct Containment Heating research activity provides experimental data and computer modeling to understand the physical processes associated with the possible high pressure ejection of molten core materials from a light water reactor during a core meltdown accident. The activity investigates the effect of such processes on the reactor containment and accident source terms. The activity is relatively new since this potential mechanism for early containment failure was only recently recognized. The activity involves large scale (1/10th linear) tests using high temperature melt simulants and a few separate effects tests (small scale in air and water to date, larger scale later) and modeling of Reactor Coolant System (RCS) failure and core debris redistribution using the computer codes MELPROG and CONTAIN. Two laboratories are performing the work.

Safety Assurance - This activity is related to questions A-3, A-4, A-7, A-8, B-9 and C-2. The possibility that the RCS will fail before the vessel does is being investigated under the aegis of the activity "Natural Circulation Inside The RCS".. The answers this activity may provide are expected to significantly reduce uncertainties in risk assessment at relatively low cost over the next few years. The results of this research may lead to a guidance to reactor operators on how to avoid the high pressure ejection of molten core materials from the RCS during a core meltdown. There is high uncertainty among NRC contractors and industry scientists over whether materials so ejected would be entrained or distributed sufficiently to lead to excessive heating and pressurization of the containment atmosphere and over-stressing of the containment. Ex-vessel hydrogen generation and subsequent combustion increase the likelihood of containment failure. The research results are intended to resolve these uncertainties. However, any experimental data will likely be of reduced scale. The need for an analysis capability in this area parallels that in the core concrete interaction activity, which this activity lags by about five years in model development. Overall, this activity is assessed as CATEGORY B (IMPORTANT.)

Usefulness - . The portions of this activity pertaining to accident management that investigate the feasibility and desirability of reducing RCS pressure under core melt conditions are HIGHLY USEFUL because they may contribute to reducing risk and uncertainty. The portions that deal with modeling of behaviors of entrained particles of a molten core materials and hydrogen processes are long-range programs. Depressurization may not be found to be possible or useful, therefore knowledge of the high pressure melt ejection could be essential to address the DCH issue that has a potentially disastrous consequence. If depressurization proves feasible and desirable in the future, this activity should be stopped. Overall, this activity is assessed as VERY USEFUL.

Appropriateness - This activity addresses areas beyond the safety design basis for nuclear power plants, and it concerns the adequacy of the current licensing basis. Therefore, it is appropriate for NRC funding and not for industry funding. Because the activity is new and originated in the U.S., there is only limited coordination of international interests. The industry is not supportive of this activity in its severe accident programs. Overall, this activity is assessed as HIGHLY APPROPRIATE.

Resources - Severe accident analysts and unique facilities are required for this activity. Resource requirements include \$2.2 million to date, \$12 million to complete by 1995, \$1.2 million in FY88, and \$1.7 million for FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: REACTOR CONTAINMENT SAFETY
Assessment Panel: Blond (SAIC), Mattson (SCIENTECH), Ybarrondo (SCIENTECH)
Branch Chief: Mel Silberberg

### CODE MODELS, VALIDATION, AND ANALYSIS

The Code Models, Validation, and Analysis research activity provides computer modeling of the overall plant response to core melt accidents in light water reactors (LWR's). It consists of code development and analysis work at five laboratories involving four codes, STCP, SCDAP, MELPROG, and CONTAIN. A related code MELCOR is under development by the risk assessment group in the Office of research. The codes are arranged in two tiers, namely, faster running simple models and slower running detailed models. The development of BWR models has lagged the development of PWR models.

Safety Assurance - This research activity strongly addresses questions A-2, A-3, A-4, B-1, B-9 and C-2. The activity produces the analytical tools through which essentially all severe accident research results are applied by the NRC. The results of this activity can be used in the assessment of industry results in individual plant evaluations (IPE's) and probabilistic safety assessments and to resolution of vital safety questions involving Mark I and ice condenser containments. The risk reduction potential associated with applying these analysis tools is high because of the better understanding of core melt behavior that they provide. This activity is assessed as CATEGORY A (VITAL.)

Usefulness - This activity is assessed as VERY USEFUL because of the acceptance of the codes in the international arena even though there is a separate effort relative to industry codes. The results of the code development have been used in licensing. (Shoreham 25% power review and Seabrook reduced EPZ requirement.) The NRC codes are capable of confirming the validity of the Severe Accident Policy Statement, and that will provide independent assessment of the analyses that NRC intends to require of each plant through the IPE. Industry shows no sign of using the NRC codes for IPE's. Overall assessment of plant response is needed for accident management decision making, and industry is most likely to use MAAP and SCDAP for those purposes, while STCP and the mechanistic codes are likely to be used internationally.

Appropriateness - Since IPE's are to be required of licensees, this activity is assessed as VERY APPROPRIATE. Disagreement between industry and NRC on code models has precluded cost sharing for common codes and has led to separate efforts. Until definitive experimental evidence can be obtained, the separate efforts represent uncertainty in the state-of-the-art. The program has extensive foreign support in both code use and cooperative development.

Resources - This activity requires coordination of the skills of uniquely qualified analysts in the Laboratories. Resource requirements include $35 million to date, $46 million to complete by 1995, $3.9 million in FY88, and $6.6 million in FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: REACTOR CONTAINMENT SAFETY
Assessment Panel: Houston, Blond, Ybarrondo
Branch Chief: Mel Silberberg

### HYDROGEN TRANSPORT AND COMBUSTION

The Hydrogen Combustion Research activity provides an experimental and theoretical database to be used to quantify the threat to safety-related equipment and the containment structure posed by hydrogen combustion. It consists of experimental and theoretical tasks to improve the understanding of: (1) hydrogen transport; (2) diffusion flames, deflagration, accelerated flames and deflagration to detonation transition (DDT) and the detonation combustion modes; (3) the effect of combustion on iodine source term; and (4) the feasibility of selected hydrogen mitigation systems.

Safety Assurance - This research activity strongly addresses safety assurance questions A-3, A-4, A-5, A-8, B-7, B-10 and C-1. This activity produces the analytical tools for assessing the consequences of hydrogen combustion for both degraded core and more severe accidents. Information generated can be used to address the high priority Generic Safety Issue 121 on hydrogen control for large dry PWR containments and will provide the NRC with an additional capability to determine an acceptable accident mitigation capability for the PWR Ice Condenser containments. Overall this activity is assessed as CATEGORY B (IMPORTANT).

Usefulness - The data base developed from hydrogen combustion research will be used by a large group of people in as much as the consequences of combustion effect other areas such as direct containment heating, equipment survival, and containment integrity. In the past, confirmatory research was needed to provide the NRC with the capability to close out unresolved hydrogen control issues, such as flame acceleration and DDT for the PWR Ice Condenser plants. Analytical tools developed under this activity are available for use in rule implementation efforts such as assessing the adequacy of both interim and permanent hydrogen control systems. This activity is assessed as VERY USEFUL.

Appropriateness - This activity is assessed as VERY APPROPRIATE. It has generated an independent data base for the NRC to use in review of the hydrogen control systems selected by the utilities.

Research - Experimental facilities and code development, assessment and application are required for this activity. Resource requirements include $11 million to date, $3.8 million to complete by FY92, $0.7 million in FY88, and $0.7 million in FY89.

**SUMMARY OF ACTIVITY**

PROGRAM ELEMENT: REACTOR CONTAINMENT SAFETY
Assessment Panel: Houston (NRC), Blond (SAIC), Ybarrondo (SCIENTECH)
Branch Chief: Mel Silberberg

## STEAM EXPLOSIONS

Past research has been directed towards assessing the probability of direct alpha containment failure mode via steam-explosion-generated large-mass missile. Alpha containment failure mode is a process in which an in-vessel steam explosion resultant from the slumping of a large mass of core melt into lower-plenum water accelerates a slug of overlying material into the upper head, detaching the head and expelling it through the containment. This research consisted of: (1) experiments with tens of kg corium-thermite melts on the conditions under which energetic steam explosions occur and the energetics of such explosions, (2) modeling steam-explosion mechanisms, and (3) analysis of the alpha-containment failure mode process. The expert Steam Explosion Review Group (SERG) convened by NRC in 1984 concluded that the probability of the alpha containment failure mode was less than 0.01 per core melt, and thus did not constitute a significant risk.

Because of the conclusions of the SERG report and severe budget constraints, further steam explosion experiments have been stopped, contrary to the recommendations of both the SERG panel and the Kouts panel. Quite aside from the very particular alpha containment failure made, both explosive and non-explosive rapid steam generation from melt-coolant interactions with accompanying hydrogen generation and fission-product release are very significant in core melt progression and must be accounted for. Current NRC research in this area consists of the development and validation of the semi-mechanistic Integrated Fuel-Coolant Interaction (IFCI) model of both explosive and non-explosive melt-water interactions and hydrogen generation for incorporation into the MELPROG mechanistic in-vessel melt-progression code. IFCI can also be used on a stand alone basis. One laboratory is currently performing this research.

Safety Assurance - This activity, which is relevant to questions A-3, A-4, A-8, B-1, B-7, B-10, C-1 and C-2, is assessed as CATEGORY C (VIGILANT). All accident management actions when there is molten or liquified (eutectic) material in the core involve this activity. While no research specifically directed to accident management has been performed, nearly all the past and current experiments and models are directly applicable to accident management considerations. Some new work on the rates of quenching of both hot solid and molten debris and on the analysis of the coolability of large complex masses of partially molten debris (as at TMI-2) would be desirable for accident management use.

Usefulness - This activity is assessed as VERY USEFUL. The research in this activity and the research in this area by others have not yet produced a truly mechanistic model of explosive and non-explosive rapid steam generation for general use. There is also some continuing difference of opinion among the experts on the upper bound of the alpha containment-failure mode probability. The IFCI model will be available for general use, and it will provide a unique tool for assessing, quantitatively, the effects of explosive and non-explosive rapid steam generation as a part of reactor accident analysis.

Appropriateness - This activity is assessed as HIGHLY APPROPRIATE. Because core melt is beyond the design basis and is not included in NRC licensing requirements, it is appropriate that NRC should lead the research in this area. There is general awareness of and interest in steam explosions and the broader class of thermal explosions outside the NRC, in both the foreign and domestic communities. Close coordination with outside research and support of the NRC research are important, and this has been achieved. Cooperation on accident management research should be sought with INPO, NUMARC, and EPRI.

Resources - Resource requirements include about $5 million to date, $1.5 million to complete in 1992 , $185,000 for FY88, and $185,000 for FY89. Additional research to address specific core reflooding questions for accident management, including coolability limits, would require additional funding.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: REACTOR CONTAINMENT SAFETY
Assessment Panel: Houston (NRC), Blond (SAIC), Ybarrondo (SCIENTECH)
Branch Chief: Mel Silberberg

### FISSION PRODUCT BEHAVIOR AND CHEMICAL FORM -

This activity provides the capability to estimate source terms from the containment for postulated severe accident sequences. Specifically, the activity provides experimental data and modeling on fission product and aerosol behavior in the fuel, the reactor coolant system, and the containment. The experimental program consists of mostly out-of-reactor experiments and few in-reactor experiments. There are a total of five national and commercial laboratories involved in this activity.

Safety Assurance - This activity , which is vital to question B-9, B-10 and C-5, important to A-4 and C-2, and relevant to A-7, B-8, A-9 and C-1, is assessed as CATEGORY B (IMPORTANT). The quantities, timing, and chemical forms of fission products released from fuel dominate the subsequent transport behavior of these fission products in the reactor coolant system and containment. This will impact the degree of deposition of fission products at both locations and the final source term leaving the containment. Additionally, although containment loading issues such as direct containment heating and core-concrete interactions directly influence containment failure times, the consequences of these processes need to be estimated with computer codes developed in this activity, so this activity also contributes to safety questions involving Mark I and ice condenser containments. Research results from This activity will also reduce the uncertainty in severe accident risks. Fission product revaporization and late iodine release, are found to contribute large uncertainties in Draft NUREG-1150 risk estimates affecting severe accident source terms for late containment failure accidents. These fission products are modeled as being permanently removed from source term consideration but may revaporize or resuspend at a later time when the source term in the containment is small.

Usefulness - This activity is assessed as VERY USEFUL. The immediate objective of research in the in-vessel fission product release area is to provide information on the prototypicality of the less expensive out-of-pile experiments relative to the expensive in-reactor experiments. If out-of-reactor experiments produce similar results to those from in-reactor experiments and for the same reasons, large savings in program costs can be envisioned in future experimental programs. Research on containment fission product chemistry is providing experimental and analytical support to the revision of Standard Review Plan section 6.5.2. Finally, all research results from This activity will be used for emergency planning, equipment qualification, Safety Goal and Severe Accident Policy implementations and future reactor design and licensing.

Appropriateness - This activity is assessed as VERY APPROPRIATE. Research results from this activity are of interest to other organizations, such as EPRI, within the U.S., and other countries such as the United Kingdom, the Netherlands, Federal Republic of Germany, and Canada. These organizations and countries are partners of our Severe Fuel Damage Program where research in this activity is coordinated. National Science Foundation support should also be sought for this research.

Resources - Special in-reactor, out-of-reactor, and diagnostic facilities, and experts in the area of fission product chemistry, either experimental and theoretical, are required to perform the tasks in this activity. Resource requirements include $26 million to date, $7 million to complete by 1993, $ 1 million for FY88, and $1.3 million for FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: REACTOR CONTAINMENT SAFETY
Assessment Panel: Houston (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Mel Silberberg

### NATURAL CIRCULATION IN THE REACTOR COOLANT SYSTEM -

The Natural Circulation in the Reactor Coolant System (RCS) Research Activity provides analyses predicting the RCS thermal-hydraulic behavior from accident initiation to core melt and vessel failure. This activity, in concert with the core melt progression activity, will furnish the initial conditions to be used in other research activities including Direct Containment Heating, Core-Concrete Interactions, and Hydrogen Combustion. The activity is currently focused on the multi-dimensional natural circulation flows during a risk-dominant high-pressure station blackout accident. Issues being addressed are: the structural integrity of the RCS pressure boundary prior to vessel failure and the influence of circulatory flows on the melt progression processes. This activity involves the use of three state-of-the-art computer codes: COMMIX, MELPROG/TRAC, and SCDAP/RELAP5 at three different National Laboratories are being used to support the analyses.

Safety Assurance - This activity, which is important to questions A-3, A-4 and C-1 and relevant to questions A-8, B-7, B-9 and B-10, is assessed as CATEGORY B (IMPORTANT). It will provide answers to vital questions on accident management at relatively low cost over the next few years. Results will assess the likelihood of high-pressure melt ejection, and provide guidance to the operators on how to prevent and mitigate high-pressure melt ejection during a severe accident. There is general agreement between the preliminary analyses sponsored by NRC and by EPRI - namely, the RCS pressure boundary may fail either at the surge line which connects the pressurizer to a hot leg or at the hot leg connection to the vessel "before" the failure of the vessel lower head. As a result, the RCS may be depressurized to a low pressure before the molten core fails the vessel lower head and enters the containment. However, uncertainties exist regarding the size of the failure in the surge line or the hot leg, which will determine the rate of depressurization. Uncertainties also exist for the calculated temperature history of the surge line and other piping. Future research will be performed to improve our understanding and to bound the uncertainties.

Usefulness - This activity is assessed as VERY USEFUL, because of its significance to future reactor licensing. The activity may also provide guidance to the operators on how to prevent or mitigate high-pressure melt ejection to the containment.

Appropriateness - This activity is assessed as VERY APPROPRIATE. Although delving into areas beyond the design basis, the research will have significance for accident management. Consistent with the latter consideration, EPRI has contributed to the understanding of natural circulation in the RCS by providing useful data and code calculations.

Resources - Severe accident and thermal-hydraulics analysts are required for this activity. Resource requirements include $1.3 million to date, $2.3 million to complete, $0.4 million for FY88 and $0.7 million for FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: REACTOR ACCIDENT RISK ANALYSIS
Assessment Panel: Houston (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Joseph Murphy

### REVIEW OF PRA'S

The purpose of this research is to review PRA's submitted to NRR. While some of the work could be classified as technical assistance, RES is also trying to develop less costly ways to perform the reviews. Currently averaging $450K per review, the reviews are as costly to perform as is the original analysis. Guidelines being developed under this effort focus the review upon the boundary conditions and assumptions, with spot checks performed as required to confirm the accuracy of the calculations. Currently PRA reviews are performed by BNL - if effective, the guidelines developed in this activity could help in shifting some of the review work to other laboratories, as well as back to the NRC.

Safety Assurance - This activity is strongly responsive to safety assurance questions A-2 (unacceptable vulnerabilities), A-3 (short term containment failure modes), A-4 (course and consequence of severe accidents), A-5 (USI resolution), B-1 (additional knowledge about complex operating events), and B-6 (human factors, etc. in normal operations.) The results of this research will provide a greater knowledge of the risk levels resultant from a variety of initiators, and failure associated with human factors, severe accidents, and other vulnerabilities. A prerequisite for determining the risk level posed by a given plant is knowledge of the accuracy of the PRA inputs. Reviews can be effective in spotting major oversights in PRA's and are therefore a vital contributor to safety assurance. This activity is assessed as CATEGORY A (VITAL).

Usefulness - Because of the complexity of a PRA, it has been difficult for NRR to specify the requirements of a PRA review. The results of the research may produce information bearing on the resolution of the safety assurance questions, but because of the lack of clear specifications, the research is not as useful as it might otherwise be. This research is assessed as USEFUL.

Appropriateness - Clearly, it is the responsibility of the NRC to perform the review of the PRA's. This activity is assessed as HIGHLY APPROPRIATE.

Resources - Cumulative costs through FY87 total $0.4 million. Prior reviews, including some FY87 activity, were funded by NRR. Costs for FY88 are $0.9 million. Proposed costs for FY89 are $1.6 million. Completion of the activity is estimated to require an additional $1.8 million per year until all industry sponsored PRA's which are submitted have been revised.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: REACTOR ACCIDENT RISK ANALYSIS
Assessment Panel: Houston (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Joseph Murphy

### SEVERE ACCIDENT MANAGEMENT

In FY88, the purpose of this activity is to provide a chapter for Accident Management strategies for NUREG 1150. These strategies will provide the information to support operator decisions, during severe accident situations, which could reduce the probability of core melt This work has included studies of the NUREG-1150 plants, and other plants will be studied in the future. This research is consistent with the larger severe accident management research project ("Individual Plant Examinations" activity) being conducted in the Division of Reactor and Plant Systems. In FY89, and beyond, this task will examine audit PRAs are they are performed to evaluate potential accident management strategies.

Safety Assurance - This research is strongly responsive to safety assurance questions A-2, A-3, A-4, and C-2. It is also relevant to safety assurance questions A-8, B-1, and B-7. Strategies for dealing with vulnerabilities and accident sequences can help plant operators avoid sequences which could lead to core melt. Because the results of this research could directly contribute to the resolution of these questions, this activity is assessed as CATEGORY A (VITAL).

Usefulness - .This research should provide NRR with the necessary background of knowledge required to effectively audit the accident management strategies of the utilities. Without this knowledge the NRC will not have a basis against which to judge the utility strategies. Coordination with other accident management research being conducted within NRC could be improved. Because the results of this research could directly contribute to the resolution of these questions, this activity is assessed as VERY USEFUL.

Appropriateness - It is the responsibility of the utilities to develop accident management strategies. This research will provide knowledge needed to review the utilities' capabilities. This activity is assessed as APPROPRIATE.

Resources - Costs for FY88 (first year of activity) are $0.2 million. Proposed costs for FY89 are $0.4 million. Completion of the activity in 1993 is estimated to require an additional $1.5 million beyond the FY87 total.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: REACTOR ACCIDENT RISK ANALYSIS
Assessment Panel: Houston (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Joseph Murphy

### RISK MODEL DEVELOPMENT

The purpose of this research is to complete the development of the MELCOR and MACCS codes, which are used to determine severe accident source terms (MELCOR) and public consequences resulting from accidents (MACCS.)

MELCOR is on the verge of becoming an application code, at which point it will cease being a development effort and will become a maintenance effort. Prior to this, however, the code will need to undergo verification and validation. The BWR version of the code will be completed first,with the PWR version slated for completion in the following year. MELCOR will replace the older, costly, source code package. Current research includes updating physical models as information becomes available and trial use, as well as trying to install the code on a PC - it already runs on a VAX.

Similar work is being done on the code MACCS. The NRC intends to publish MACCS 1.5 this year, and the code will be ready for applications in another year.

Safety Assurance - This research has a strong relationship to safety assurance questions A-4, B-7, B-9, and C-2; and a weaker relationship to questions A-2, A-8, and B-5. These programs could be vital for safety assurance, but until the codes are compared with similar codes and validated against experimental programs this activity is ranked as being CATEGORY B (IMPORTANT).

Usefulness - .The present regulations do not consider severe accidents beyond the design basis. However, the Severe Accident Policy Statement requires that such analysis be performed. The activity is assessed as USEFUL.

Appropriateness - Clearly, it is the responsibility of NRC to review PRA and perform independent audits as necessary. This activity is assessed as HIGHLY APPROPRIATE.

Resources - Cumulative costs in FY87 total $1.1 million. Costs for FY88 are $1.6 million. Proposed costs for FY89 are $1.6 million. Completion of the activity in 1993 is estimated to require an additional $8.3 million beyond the FY87 total.

**SUMMARY OF ACTIVITY**

PROGRAM ELEMENT: REACTOR ACCIDENT RISK ANALYSIS
Assessment Panel: Houston (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Joseph Murphy

RISK UNCERTAINTY METHODOLOGY

The purpose of this research activity is threefold: (a) to develop statistical techniques to be used in processes involving expert elicitation, (b) to perform a backend analysis as part of a broader MELCOR application, and (c) perform the LaSalle (??) study of severe accident results.

Safety Assurance - This activity is responsive to safety assurance questions A-2, A-3, and A-4. The methodology provides a yardstick for risk measurement and takes some of the subjectivity out of PRA. The risk uncertainty methodology is assessed as CATEGORY C (VIGILANT) to safety assurance.

Usefulness - . The results of this research could be used by the PRA branch of NRR and by RES to assess source terms with state-of-the-art tools. This activity is assessed as USEFUL.

Appropriateness - This effort is underway to improve NRC capabilities for performing plant audits. It is assessed as being HIGHLY APPROPRIATE.

Resources - Cumulative costs through FY87 total $1.1 million. Costs for FY88 are $1.5 million. Proposed costs for FY89 are $1.2 million. Completion of the activity in 1993 is estimated to require an additional $5.6 million beyond the FY87 total.

**SUMMARY OF ACTIVITY**

PROGRAM ELEMENT: REACTOR ACCIDENT RISK ANALYSIS
Assessment Panel: Houston (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Joseph Murphy

## RISK REBASELINE ANALYSES

This research has two purposes: (a) to finish NUREG 1150, and (b) to extend NUREG 1150 to include external events within the 1150 results and extend front and back end analyses in order to be able to analyze B&W and C-E plants. The Commission sees this as a way to fulfill its obligation to ACRS to provide an independent audit of PRA's.

Safety Assurance - This research is responsive to safety assurance questions A-5, B-8 , and C-1. Completion of NUREG 1150 should identify potential gaps in regulation resultant from system interactions. This activity is assessed as CATEGORY B (IMPORTANT) to safety assurance.

Usefulness - The results of this research could be used by the EDO and Office Directors to prioritize risk issues in the PRA arena, and to provide the knowledge required to determine the appropriate research balance between accident mitigation activities and accident prevention activities for research. This activity is assessed as USEFUL.

Appropriateness - It is the responsibility of the NRC to gain such knowledge as may be required to carry out regulation of the nuclear industry, so this is an appropriate activity for NRC funding. This activity is assessed as VERY APPROPRIATE.

Resources - Cumulative costs through FY87 total $2.7 million. Costs for FY88 are $3.8 million. Proposed costs for FY89 are $2.2 million. Completion of the activity in 1993 is estimated to require an additional $11.4 million beyond the FY87 total although a routine sampling of plants may require additional expenditures thereafter.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: REACTOR ACCIDENT RISK ANALYSIS
Assessment Panel: Houston (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Joseph Murphy

### RISK BASED MANAGEMENT METHODOLOGY

The purposes of this research are: (a) to complete the development of SARA, (b) to load data into the management tool, and (c) to apply SARA to the prioritization of generic issues and multi plant action items. SARA provides the NRC with the ability to test PRA assumptions as variables. Using SARA, an analyst can explore the effect on overall plant risk of proposed plant modifications.

Safety Assurance - This research is responsive to safety assurance questions B-1 (additional knowledge of response to complex operating events), B-6 (human factors, reactor controls, and artificial intelligence applicability to operations), and C-1 (improved analytical tools). Overall, this activity is assessed as CATEGORY C (VIGILANT.)

Usefulness - .SARA may be used in the review of submittals in response to the IPE generic letter. This activity is assessed as USEFUL.

Appropriateness - SARA provides the NRC with the tools it will need for trending and tech. spec. optimization. This activity is assessed as APPROPRIATE.

Resources - Cumulative costs through FY87 total $2.2 million. Costs for FY88 are $1 million. Proposed costs for FY89 are $1.6 million. Completion of the activity is estimated to require an additional $2 million per year in the future to analyze new issues, prioritize new MPAs, and loan new PRA and IPE results into the data base.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: PLANT PERFORMANCE
Assessment Panel: Sheron (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Louis Shotkin

### MIST AND OTSG TESTING (B&W)

This research activity has two main purposes, the first of which is to provide experimental data and analysis to satisfy the requirement of the TMI task action plan item II.K.3.30, "Revised SBLOCA Method to Show Compliance with 10 CFR Part 50, Appendix K." The other purpose is to confirm licensing decisions made with respect to Babcock and Wilcox (B&W) power plants. The projects, which are sponsored under a mixture of joint and separate funding arrangements, have already produced data to resolve the thermal-hydraulic issues related to the TMI-2 SBLOCA of 1979 and were used to support requests by Florida Power Corporation and Sacramento Municipal Utility District for exemptions from the requirement to install high point vents for reactor coolant systems (as required under 10 CFR 50.44(3)(iii)).

TMI task action plan item II.K.3.30 requires that SBLOCA models be compared to applicable data. A program under joint NRC/industry sponsorship was established to provide this data. This program consists of integral and separate effects tests conducted in experimental facilities mimic the unique behavior of B&W plants. The key integral facility is the Multi-loop Integral System Test (MIST) facility. A scaled integral test facility known as the University of Maryland 2 x 4 loop is used to address MIST design anomalies and the effects of scale distortion. Other separate effects experiments are conducted to study the unique thermal-hydraulic behavior of the B&W Once-Through Steam Generator (OTSG) and the B&W hot leg U-bend.

Plant transients at Davis-Besse and Rancho Seco in 1985 demonstrated the complex behavior of B&W plants, underscoring the need for research which will result in a better understanding of the OTSG thermal-hydraulic behavior during steady state, transient, and accident conditions. SBLOCA data generated by this research will confirm licensing decisions regarding the perceived risk of SBLOCA at a B&W plant.

Safety Assurance - The research is most directly responsive to safety assurance question C-1 inasmuch as it provides information confirmatory of past licensing decisions. There is also a less direct relationship with questions B-1, B-6 and C-2. While the research provides additional knowledge concerning response to complex operating events (B-1), it has already provided the information needed for the issues it was designed to resolve. The links with improvements in operations (B-6) and probabilistic safety assessments (C-2) are indicative of spin-off applications. Overall, the activity is assessed as CATEGORY C (VIGILANT).

Usefulness - The research facilities used under the aegis of the activity are capable of replicating the behavior of the B&W plant. The results are expected to be useful in answering the relevant safety assurance questions. It is our understanding that the results obtained so far are adequate to resolve most of the issues on which the research is focused. Overall, the activity is assessed as VERY USEFUL.

Appropriateness - Confirmation of licensing decisions is clearly the responsibility of the NRC. The activity is assessed as HIGHLY APPROPRIATE.

Resources - Cumulative costs through FY87 total $14 million. Costs for FY88 are $2.3 million. Proposed costs for FY89 are $3.9 million. Completion of the activity in 1991 is estimated to require an additional $6 million beyond the FY87 total.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: PLANT PERFORMANCE
Assessment Panel: Sheron (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Louis Shotkin

### 2D/3D

The purpose of this research is two-fold: (1) to resolve licensing concerns for effectiveness of core cooling provided by PWR emergency core cooling systems (ECCS) during large and medium break LOCAs, and (2) to provide large-scale data for assessment of the scaling capabilities of computer codes to predict the accident response of PWRs during large and medium break LOCAs. The 2D/3D activity provides experiment data and computer code (TRAC) analyses in support of the ECCS rule revision, and an evaluation of code uncertainty in modeling ECC bypass around the downcomer, coolability of a partially damaged core, steam binding effect during reflood, multi-dimensional flow effect in the core, and effectiveness of upper plenum injection and vent valves.

In the past, 2D/3D provided full-scale test data on mixing of the high pressure injection fluid with the primary coolant fluid already present in the cold legs to help resolve the pressurized thermal shock (PTS) issue. 2D/3D also provided full-scale test data on counter-current flow between steam and water to help resolve whether a stable flow pattern exists in a reflux condenser mode of cooling during a small break.

Data from the continuing tests are anticipated to be used in revising 10 CFR 50 Appendix K rules. 2D/3D will also provide data which can be used to assess and improve the multi-dimensional capability of TRAC. Testing has been completed in both Japanese facilities belonging to 2D/3D. About half of the 30 planned German tests have been completed. FRG, JAERI and the NRC are currently negotiating to extend joint funding of 2D/3D for two more years beyond the September 30, 1988 expiration.

Safety Assurance - This activity most strongly addresses safety assurance question C-1 inasmuch as it is confirmatory in nature. There is also a less strong relationship to questions A-2, B-1, B-10 and C-4. Results beneficial to determining existing vulnerabilities (A-2) are anticipated to be in the nature of spin-offs however, rather than as a defined end product. A similar evaluation is made concerning the activities' contribution to additional knowledge of complex operation events (B-1), review and certification of standard plants (B-10), and prioritization of potential generic safety issues (C-4). ECCS bypass is no longer the vital issue that it was in the late 1970's -- thanks in large part to the success of research like 2D/3D, which has supplied data and computer code (TRAC., RELAP) analyses supportive of the ECCS rule revision. Overall, the activity is assessed as CATEGORY C (VIGILANT).

Usefulness - 2D/3D is likely to produce information useful in answering the indicated questions. It is well coordinated with NRR, AEOD and ACRS through meetings, telephone calls, weekly and monthly reports, quick-look and data reports. Periodic review by the T/H Regulatory Research Review Group is also conducted. This activity is assessed as VERY USEFUL.

Appropriateness - It is appropriate for the NRC to fund research confirmatory of licensing decisions, but because of the benefits to JAERI and FRG, this activity is jointly funded. The assessment is APPROPRIATE.

Resources - Cumulative costs through FY87 total $85 million. Costs for FY88 are $2.7 million. Costs proposed for FY89 are $1.7 million. Completion of the activity in 1990 is estimated to require an additional $5 million beyond the FY87 total.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: PLANT PERFORMANCE
Assessment Panel: Sheron (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Louis Shotkin

### ROSA-IV

The purpose of this research is to improve NRC understanding of the transient phenomena related to SBLOCAs and operational transients. ROSA-IV will also provide information for the development and assessment of innovative ECCS operating procedures and accident management procedures which will enable the reactor operator to properly respond to plant accidents and transients, and to safely recover the plants.

ROSA-IV is jointly funded by the NRC and JAERI. JAERI is responsible for the design, construction and operation of the two facilities comprising ROSA-IV; NRC is responsible for providing best-estimate codes (TRAC-PWR, RELAP5) and advanced two-phase flow instruments in return for access to all test results. About 28 of the 40 planned tests for the first phase have been completed. Negotiations are underway to extend the agreement (which expires January 31, 1988) through 1992 to allow completion of the 40 first Phase tests plus 20 more second Phase tests.

In the past, data from ROSA-IV have been used to facilitate benchmarking of the TRAC and RELAP5 codes.

Safety Assurance - The research is most strongly responsive to safety assurance question C-1, inasmuch as it is predominantly confirmatory in nature. There is also a less strongly defined relationship to questions A-2, A-4, B-1, B-6, B-10 and C-2. Relationship to existing vulnerabilities (A-2), course and consequences of severe accidents (A-4), operating events (B-1), human factors (B-6), certification of standard plants (B-10), and probabilistic safety assessments (C-2) is considered to be of a spin-off nature. Overall, the activity is assessed as CATEGORY C (VIGILANT).

Usefulness - The results of the research will be useful to improving the analytical tools TRAC and RELAP5, but there is no particular regulatory need on which the research is focused. The activity is well coordinated with NRR, AEOD and ACRS through meetings, telephone calls, weekly and monthly reports, quick-look and data reports. Periodic review by the T/H Regulatory Research Review Group (RRRG) is also conducted. Overall, the activity is assessed as VERY USEFUL.

Appropriateness - Improvement of the analytical tools used during regulation is clearly the responsibility of the NRC. The activity is assessed as HIGHLY APPROPRIATE.

Resources - Cumulative costs for ROSA-IV through FY87 total $4.5 million. Cost for FY88 is $0.8 million. Cost proposed for FY89 is $1.3 million. Completion of the activity in 1992 is estimated to require an additional $2 million beyond the FY87 total.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: PLANT PERFORMANCE
Assessment Panel: Sheron (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Louis Shotkin

### CONTINUING EXPERIMENTAL CAPABILITY (CEC)

The purpose of the CEC is to provide NRC with future thermal hydraulic experimental capability as needed. Because of the long lead times required for certain facility types, particularly large integral tests, planning and construction must anticipate future needs long before the experimental results are needed. Because all U. S. integral thermal hydraulic facilities are scheduled to be shut down by the end of FY1988, this program was initiated in FY 1986 to evaluate the needs and design basis for an improved scaling integral facility (CEC-ISIF). A potential need is also foreseen for integral system data to support advanced LWR's currently being studied by industry and DOE.

Safety Assurance, Appropriateness, Resources - Since there is no current funding for this activity, no assessments were made.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: PLANT PERFORMANCE
Assessment Panel: Sheron (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Louis Shotkin

### BASIC STUDIES

The purpose of this research is to obtain experiment data, and assessment of the data, to advance NRC knowledge of existing safety margins in operating plants. Included within the Basic Studies activity are three areas of research: (1) a test loop at the University of Maryland which will provide integral and separate effects data crucial to the MIST and OTSG testing of the Babcock & Wilcox design, (2) the assessment of condensation induced water hammer in operating nuclear power plants, and (3) research into boron mixing in the lower plenum of BWR's during ATW's transients, and thermal mixing for PTS considerations. Additionally, the evaluation of transient reactivity feed back implication in U.S. Reactors as delineated in the Chernobyl Accident Implications Report (NUREG-1251) has been initiated.

As discussed for the MIST and OTSG Testing activity, the data obtained from the thermal mixing experiments were used to support the PTS rule. Data from the boron mixing research has shown a higher degree of thermal mixing than indicated by GE data, leading to the NRC judgement that the existing abnormal transient operator guidelines for BWR operation are conservative. Consideration of this finding could allow BWR owners to relax the current guidelines for ATWS.

Safety Assurance - The B&W research being conducted at the University of Maryland is responsive to the same questions as already identified for MIST/OTSG: strongly responsive to C-1, less responsive to B-1, B-6, and C-2. Likewise, this particular piece of research is assessed as CATEGORY C (VIGILANT).

The water hammer research is responsive to C-1 in as much as it will provide the NRC with improved analytical tools in this area. Accordingly, it is assessed as CATEGORY C (VIGILANT).

The boron mixing research is most strongly related to resolution of safety assurance question C-1, but it also is only a little less responsive to A-2, A-4, and B-1. Certainly the findings to date indicate that the results could shed new light on complex transients for the BWR plant (A-2), and help define the course and consequence of likely severe accident scenarios (A-4). Additionally, the research will provide improvement of analytical tools for calculation of boron mixing. Overall, the activity is assessed as CATEGORY B (IMPORTANT) on the basis that even though it is predominantly responsive to C-1, the fairly strong relationship to the A and B questions merits a higher category of assessment.

Usefulness - The University of Maryland research will be useful in confirming past licensing decisions, most notably those pertaining to B&W plants, and is assessed VERY USEFUL.

The water hammer research will provide an additional tool in this area and may therefore produce information bearing on resolving C-1. It is assessed as USEFUL.

The boron mixing research is assessed as HIGHLY USEFUL because of the results it will provide to possible deregulation.

Overall, the activity is assessed as HIGHLY USEFUL on the strength of the boron mixing research.

Appropriateness - The University of Maryland work and the water hammer work are both confirmatory of regulations and are assessed as HIGHLY APPROPRIATE. The boron mixing research is also regulatory in nature, but in as much as the end result to date indicate a possible deregulation, it is assessed as VERY APPROPRIATE.

Resources Cost for FY88 is $1 million. Cost projected for FY89 is $2.4 million. No completion date, per se, has been identified since this is a continuing activity.

**SUMMARY OF ACTIVITY**

PROGRAM ELEMENT: PLANT PERFORMANCE
Assessment Panel: Sheron (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Louis Shotkin

THERMAL-HYDRAULIC CODES

The purpose of this research is two fold: (1) to refine and maintain the systems codes TRAC-PWR, RELAP 5 and TRAC-BWR and (2) to develop a methodology to determine the uncertainty of the code results for a given transient and a given plant design. These codes are used to (a) understand and evaluate the implications of transients in operating reactors, (b) evaluate emergency operating procedures, (c) audit licensee licensing submittals, including changes to technical specifications, (d) provide training to NRC staff in plant transient behavior, (e) assist in resolution of issues such as pressurized thermal shock, and (f) evaluate the front-end of risk dominant accident sequences. Current application of the Code Scalability, Applicability, and Uncertainty (CSAU) methodology will define, quantitatively, how well a given code handles a given transient and plant.

The thermal-hydraulic codes have been used to perform several hundred, documented, full-scale plant analyses of transients. These codes have provided the NRC with an independent technical capability to analyze transient and accident response. This activity will ensure the continued refinement of the codes concomitant with the general growth of knowledge in thermal-hydraulics and will further ensure the technical vigilance needed to maintain and apply the codes in a timely manner.

Revision of th acceptance criteria for ECCS performance given in 10 CFR 50 Appendix K LOCA will allow realistic calculation of LOCA phenomena. Validity of analysis results conducted under the provisions of the revised criteria will require that the uncertainty of the results remain under a specified level. The CSAU methodology is being developed to enable the calculation of the uncertainty.

Safety Assurance - This research is strongly responsive to safety assurance question C-1. The codes themselves are considered reasonably mature, but the CSAU research will improve the codes. The activity is, therefore, assessed as CATEGORY C (VIGILANT).

Usefulness - The research will provide information needed to improve the codes; it is assessed as HIGHLY USEFUL.

Appropriateness - Improving regulatory tools is clearly the responsibility of the NRC. The activity is assessed as HIGHLY APPROPRIATE.

Resources - Cumulative funding through FY87 totals $60 million. Costs for FY88 is $2.7 million. Costs proposed for FY89 is $5 million. Completion of the activity in 1990 is estimated to require an additional $7.7 million beyond the FY87 total.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: PLANT PERFORMANCE
Assessment Panel: Sheron (NRC), Aldrich (SAIC), Lond (SAIC)
Branch Chief: Louis Shotkin

### T/H TECHNICAL SUPPORT CENTER (TSC)

The purpose of this research is to ensure the continuing availability of a group of expert staff and appropriate operational safety assessment methods, for use on a priority basis, to assess the safety significance of operational issues as well as the benefits and hazards of alternate regulatory actions related to these issues. To maintain this expertise the NRC will undertake a comprehensive assessment and synthesis of existing thermal hydraulic research associated with safety issues or major areas of investigation, or, as appropriate, plans for research to enable issue closure, as well as an evaluation of appropriate regulatory actions.

Examples of completed tasks conducted under the aegis of TSC include an evaluation of B&W plant operational safety to support NRC's reassessment of B&W plant safety, and an analysis of the safety significance of instrument tube ruptures which penetrate the lower reactor vessel head. Examples of continuing support include an analysis of reactor vessel depressurization to mitigate direct containment heating, as needed for support ECCS rule revision. Future issues to be addressed by TSC cannot easily by defined, but will be associated with safety-significant events in operating reactors, including severe accident management evaluations and safety assessment of advanced LWR concepts.

<u>Safety Assurance</u> - This activity is most strongly responsive to question C-1. It is also relevant, but to a lesser degree, to questions A-2, A-4, B-1, and B-6. TSC is quintessential technical vigilance. The availability of a cadre of experts will improve NRC analytic capabilities and enable NRC to better characterize areas of potential concern in timely fashion. This activity is assessed as CATEGORY C (VIGILANT).

<u>Usefulness</u> - Because the work conducted under TSC by definition involves priority safety issues, these tasks will be provided with necessary resources and expert staff to assure that results are timely and that the work is closely coordinated with appropriate offices of the NRC. This activity is assessed as HIGHLY USEFUL.

<u>Appropriateness</u> - Because TSC tasks are principally directed at establishment of NRC positions or actions relative to important safety issues, they are HIGHLY APPROPRIATE for NRC funding.

<u>Resources</u> - Cumulative costs through FY87 total $2 million. Cost for FY88 is $0.9 million. Cost proposed for FY89 is $1.7 million. The activity is not anticipated to have a defined completion date, but an annual cost of $4 million beyond FY89 is expected.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: HUMAN PERFORMANCE
Assessment Panel: Sheron (NRC), Blond (SAIC), Ybarrondo (SCIENTECH)
Branch Chief: Frank Coffman

### HUMAN FACTORS RESEARCH

The purpose of this research is to explore methods to better understand the causes of human error and to identify methods for reducing human errors that present a risk to public health and safety. Past accomplishments of NRC and industry in response to the TMI-2 accident addressed nuclear power plant staffing and qualifications, control room design, emergency operating procedures, and display of safety parameters. Despite that effort, human error and inadequate management continue to be significant contributors in events which can have direct, immediate impacts on public and health and safety. This research program supports strong recommendations from the National Academy of Sciences (NAS) for continuing human factors research at the NRC (Revitalizing Nuclear Safety Research, 1986; Human Factors Research and Nuclear Safety, 1988) in the following research areas: Human performance and human reliability; Man-machine interface; Procedures; Organization and Management; and, Qualifications and training. The anticipated future products of this safety research will be the capability to identify, prioritize, and resolve human factors concerns in the operation, maintenance, and management of nuclear power plants.

Safety Assurance - This activity is strongly responsive to questions A-2 (determine what unacceptable vulnerabilities exist), B-6 (safety in normal operations and anticipated operational occurrences), C-1 (accident prevention through characterization of areas of potential concern), and C-2 (completeness and precision of probabilistic safety assessments), and is less strongly related to questions A-4 (improve accident management and emergency planning) and B-3 (evaluate and disseminate operating experience). Success of this program will result in a reduced incidence of human errors and management inadequacies that lead to events which can affect public health and safety. Human errors can not be totally eradicated, but this research should result in a reduction of risk through improved performance of personnel and management. This activity is assessed as CATEGORY B (IMPORTANT).

Usefulness - The Commission's Policy and Planning Guidance (1987) emphasizes the importance of human factors research. NRR and AEOD have reinforced that emphasis by identifying specific user needs in each of the five NAS recommended areas. The priority of this research is expected to be concluded successfully and to result in regulatory products that can be applied immediately by the NRC user offices. This activity is assessed as USEFUL.

Appropriateness - Resolution of human factors concerns related to safety should result in increased protection of public health and safety through improved regulation of industry in human factors areas related to performance of personnel and management. It will also benefit the nuclear industry in terms of increased plant availability, reduced cost of operation, etc. Since both the NRC and the nuclear industry are expected to benefit from this work, human factors research is categorized as APPROPRIATE.

Resources - Previous NRC human factors research ended in 1985. This is a new effort with costs of $1.6 million for FY88, and $1.8 million for FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: HUMAN PERFORMANCE
Assessment Panel: Sheron (NRC), Blond (SAIC), Ybarrondo (SCIENTECH)
Branch Chief: Frank Coffman

### HUMAN ERROR DATA COLLECTION AND ANALYSIS

The purposes of this research activity are to provide improved quantification methods, data, and procedures for: (1) conducting human reliability analysis segments of nuclear power plant (NPP) probabilistic risk assessments (PRAs), (2) utilizing results of these analyses to support resolution of generic safety issues, (3) identifying future human performance assessment research needs, and (4) supporting other NRC human factors initiatives. To date, methods and data emerging from this activity are being used inside and outside the NRC to quantify and estimate human performance at NPPs. In the future, the Commission has determined that reliability and risk assessments will be used as a technical basis for regulatory decision making in the areas of generic safety issues resolution, backfitting, implementation of safety goals, and severe accident management policies. Upwards of 65% of NPP safety-related events involve human error. Reviews of past PRAs suggest that large uncertainties exist in human error quantifications due, in part, to a paucity of rigorous methods and input data. The subject research responds to these needs. Future products, first, involve development and transfer to PRA practitioners of a variety of performance quantification methods which incorporate state-of-the-art technologies in the areas of consensus expert judgement, computer modeling, and field reporting. Second, they involve acquisition of human error probability data from nuclear settings, methods for applying field data from non-nuclear settings in analyzing performance of NPP personnel, and implementation of a data base management system as a central repository of human and hardware failure data to support NRC risk-related analyses and regulatory decision making,. Third, they involve development of procedures for fully integrating the human reliability analysis into the PRA process to reduce PRA uncertainties and to enhance the ability to assess the overall impact of human performance on NPP risk. Additional products in the areas of cognitive and behavioral modeling employing computer simulation techniques can be expected to significantly improve the NRC's ability to gain insights into NPP personnel errors of omission and commission under abnormal plant conditions and during beyond design basis events.

Safety Assurance - The activity is strongly responsive to questions A-1 (ensure that a utility maintains an adequate state of operational readiness), C-1 (accident prevention through characterization of areas of potential concern), C-2 (completeness and precision of probabilistic safety assessments), and C-4 (techniques to identify and prioritize potential generic safety issues), and is less strongly related to questions A-4 ( improve accident management and emergency planning), B-1 (knowledge of complex operating events and accidents), B-3 (evaluate and disseminate operating experience), and B-6 (assure safety in normal operations and anticipated operational occurrences). Overall, the activity is assessed as CATEGORY C (VIGILANT).

Usefulness - The data needed and the subset being obtained is defined in NUREG/CR-468. This activity is assessed as USEFUL.

Appropriateness - Almost every PRA done within the U.S. has used THERP which came from this work. Industry has a great deal to gain from such research. The activity is assessed as APPROPRIATE.

Resources - Resource requirements include $6 million through FY87, $__million to complete by FY__, $0.9 million in FY88, and $1.1 million for FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: RELIABILITY OF REACTOR SYSTEMS
Assessment Panel: Sheron (NRC), Blond (SAIC), Ybarrondo (SCIENTECH)
Branch Chief: Frank Coffman

### PERFORMANCE INDICATORS

The purpose of this research is to apply reliability engineering methods and human performance considerations to develop, evaluate, and interpret more objective and predictive indicators than are currently in use by the Commission. Past accomplishments include the development and use of a set of performance indicators to help recognize symptoms of poor or declining safety performance at operating plants. Currently, performance indicators are one of several inputs to NRC senior management decision making regarding the need to adjust plant-specific regulatory programs. In the future, improvement of the objective and predictive regulatory indicators for the large number of diverse operating plants requires continuing evaluation of the effectiveness of the current performance indicators as plants age and management systems change. Anticipated future products of this research are a continually improving set of performance indicators with which NRC can anticipate and react to problem areas on a plant specific and generic basis.

Safety Insurance - This activity is strongly responsive to questions A-1 (how should NRC monitor adequate operational readiness) and C-1 (accident prevention through characterization of areas of potential concern), and less responsive to questions A-2 (determine unacceptable vulnerabilities at plants), B-3 (evaluate and disseminate operating experience), and C-5 (improve regulatory structure). Improved indicators will lead to improved insight into the safety of operating and future plants. The activity is assessed as CATEGORY A (VITAL).

Usefulness - AEOD is taking steps to implement interim research results produced in 1987. Examples include improved indicators based on research on generic issue backlog, and unavailability of safety systems. The product of this research will be tied to PRA, organization, and management policies. NRC's Commission-approved plan for performance indicators (SECY-86-317) includes requirements for this improvement of both risk-based and programmatic indicators. The activity is assessed as HIGHLY USEFUL.

Appropriateness - Where indicators to be used by NRC are similar to these used by industry, steps are taken to avoid needless duplication. But experience teaches that this program is clearly an area involving vital regulatory concerns, even if industry was uninvolved, resulting in an assessment of HIGHLY APPROPRIATE.

Resources - Resource requirements include $2 million through FY87, $2 million to complete by FY__, $0.75 million in FY88, and $0.9 million for FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: RELIABILITY OF REACTOR SYSTEMS
Assessment Panel: Sheron (NRC), Blond (SAIC), Ybarrondo (SCIENTECH)
Branch Chief: Frank Coffman

### EXTERNAL EVENT SAFETY MARGINS

The purpose of this research activity is to respond to the Commission's Severe Accident Policy Statement which identified the need for a systematic examination of each existing plant for any plant-specific vulnerabilities to severe accidents (see Individual Plant Examination activity (IPE)). NRC and industry experience with plant-specific Probabilistic Risk Assessments (PRAs) has indicated that external hazards (earthquake, floods, etc) can be dominant contributors to severe accidents. Thus any systematic examination for plant-specific vulnerabilities to severe accidents would be incomplete without consideration of external hazards. The future needs of the NRC from this research are to define which and to what degree external hazards must be considered in the IPE. This activity will include efforts to review the results of submitted IPEs for External Events (IPEEE). Severe accidents are the major contributors of risk to the public from the operation of nuclear power plants and external events can be a major contributor of risk to severe accidents. No major generic vulnerabilities to severe accidents from external events are believed to exist. But, the anticipated future products of this research, the IPEEEs, will help to identify ways to further reduce risk and may identify major plant-specific vulnerabilities to external events.

Safety Assurance - This activity is strongly responsive to questions A-1 (how should NRC monitor adequate operational readiness), A-2 (determine unacceptable vulnerabilities at plants), A-3 (short-term containment failure modes and acceptable mitigation), and A-4 (improve accident management and emergency planning), and is less strongly related to A-5 (information and actions needed for USI's and GSI's), A-8 (severe accident prevention and mitigation for future plants), B-1 (knowledge of complex operating events and accidents), B-3 (evaluate and disseminate operating experience), B-5, B-6 (assure safety in normal operations and anticipated operational occurrences), B-7 (long-term containment failure modes), C-1 (accident prevention through characterization of areas of potential concern), and C-2 (improve completeness and precision of PRA's). The activity is assessed as CATEGORY A (VITAL).

Usefulness - The research is being carried out in direct response to a Commission Policy Statement. This research is timely and directly applicable to both determining what external events should be included in the IPEEE and guiding industry in their plant-specific IPEEEs. The activity is assessed as HIGHLY USEFUL.

Appropriateness - The IPEEE implementation is a regulatory research activity that is the responsibility of the NRC. But NRC is also working with industry in this matter through NUMARC for developing abbreviated methods to search for plant-specific vulnerabilities. This activity is assessed as HIGHLY APPROPRIATE.

Resources - Major funding for this activity started in FY 1988. Resource requirements include $0.4 million through FY87, $5-6 million to complete by FY92, $0.3 million in FY88, and $1.5 million in FY89.

**SUMMARY OF ACTIVITY**

PROGRAM ELEMENT: ACCIDENT MANAGEMENT
Assessment Panel: Sheron (NRC), Blond (SAIC), Ybarrondo (SCIENTECH)
Branch Chief: Frank Coffman

INDIVIDUAL PLANT EXAMINATIONS

The purpose of this research activity is to respond to the Commission's Severe Accident Policy Statement which identified the need for a systematic examination of each existing plant for any plant-specific vulnerabilities to severe accidents. Past accomplishments of this activity have been to technically illustrate the importance of Accident Management as a logical result of any examination for plant specific vulnerabilities since the cause and consequences of a severe accident can be greatly influenced by the operator's actions. Future needs of the NRC are to continue to evaluate proposed accident management strategies, especially those which do not involve significant changes in plant design, but rather procedures and training, because substantial safety benefits can be achieved quickly and cost effectively from the latter. Severe Accidents are the major contributors to of risk to the public from the operation of nuclear power plants. No major generic vulnerabilities to severe accidents are believed to exist. The anticipated future products of this research,the IPEs, will help to identify ways to further reduce risk and may identify major plant-specific vulnerabilities. Also, the associated implementation of accident management plans will bolster the defense in depth concept by extending planning and procedures for dealing with reactor accidents beyond the point that current emergency operating procedures typically cover.

Safety Assurance - This activity is strongly responsive to questions A-1 (how should NRC monitor adequate operational readiness), A-2 (determine unacceptable vulnerabilities at plants), A-3 (short-term containment failure modes and acceptable mitigation), and A-4 (improve accident management and emergency planning), and is less strongly related to A-5 (information and actions needed for USI's and GSI's), A-8 (severe accident prevention and mitigation for future plants), B-1 (knowledge of complex operating events and accidents), B-3 (evaluate and disseminate operating experience), B-5, B-6 (assure safety in normal operations and anticipated operational occurrences), B-7 (long-term containment failure modes), C-1 (accident prevention through characterization of areas of potential concern), and C-2 (improve completeness and precision of PRA's). The activity is assessed as CATEGORY A (VITAL).

Usefulness - The IPE implementation is in direct response to a Commission Policy Statement. The associated accident management research is timely and directly applicable to both guiding industry in their plant, specific accident management planning and in assisting NRC in evaluating industry accident management plans. This activity is assessed as HIGHLY USEFUL.

Appropriateness - The IPE implementation is a regulatory research activity that is the responsibility of the NRC but effective plant-specific implementation will require industry cooperation. NRC is working with industry in accident management implementation through NUMARC. This activity is assessed as HIGHLY APPROPRIATE.

Resources - Major funding for this activity started in FY 1988. Continuing accident management research and resources to review the large number of IPEs submitted over the next few years will require annual funding of about $2.5 million through at least FY 1992. Resource requirements include $1.2 million through FY87, $10-15 million to complete by FY92, $1.5 million in FY88, and $2.5 million for FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: RELIABILITY OF REACTOR SYSTEMS
Assessment Panel: Sheron (NRC), Blond (SAIC), Ybarrondo (SCIENTECH)
Branch Chief: Frank Coffman

### DEPENDENT FAILURE ANALYSIS

The purpose of this research activity is to provide methods for the assessment of the risk significance of common cause failures, requirements for the collection of the appropriate data, and the identification and development of defensive strategies to defeat common cause failures. Methods for assessing other dependent failures, such as design and construction errors, will also be considered. Many of the incidences that are reported to AEOD are the result of dependencies. Also, most of the significant events at plants are the direct result of dependencies among equipment. Past accomplishments include NUREG/CR-4780, "Procedures for Treating Common Cause Failures in Reliability and Safety Studies." Techniques for treating location dependencies have been developed and successfully applied in the Risk Methods Integration and Evaluation Program. NUREG/CR-4780 was developed jointly with EPRI. Future needs of the NRC in this area and anticipated future products are evolving at this time.

Safety Assurance - This research contributes to question A-2 (determine unacceptable vulnerabilities), B-1 (knowledge of complex operating events and accidents), B-3 (evaluate and disseminate operating experience), B-11 ( review of advanced reactors), C-1 (accident prevention through characterization of areas of potential concern), and C-2 (improve completeness and precision of PRA's). It is research designed to evaluate potential shortcomings of proposed and existing plants. The activity is assessed as CATEGORY C (VIGILANT).

Usefulness - This research answers issues that are applicable at the time the research is completed, is currently being applied at the NRC and its contractors, and will be concluded successfully. This activity is assessed as USEFUL.

Appropriateness - This project benefits from the participation in a cooperative project with the UKAEA on dependent failures. Without NRC support and collaboration in this area, important data on dependent failures would not be available. This activity is assessed as APPROPRIATE.

Resources - Resource requirements include $1.2 million through FY87, $2 million to complete by FY__, $0.2 million in FY88, and $0.3 million in FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: RELIABILITY OF REACTOR SYSTEMS
Assessment Panel: Sheron (NRC), Blond (SAIC), Ybarrondo (SCIENTECH)
Branch Chief: Frank Coffman

### PLANT AND SYSTEM RISK AND RELIABILITY

The purpose of this research activity is to provide tools, methods, procedures, and apply reliability techniques to address specific reliability issues related to the safety of nuclear power plants. Past accomplishments in this research area consist of the Integrated Reliability and Risk Analysis System (IRRAS) being used by NRC contractors as a tool to aid in the resolution of generic safety issues and in the development of PRA-based inspections of plants. Also, research results from the technical specification evaluation program are being used by NRR. Future needs in this research area consist of developing procedures for the evaluation of technical specifications, developing the IRRAS, developing a PRA models and results data base, and adapting reliability engineering methods to better focus resources on important issues and to help resolve issues and prevent problems. Future work will address methods, problems, and reliability issues as they are identified.

Safety Assurance - This research has relevance to questions A-2 (determine unacceptable vulnerabilities at plants), A-5 (information and actions needed for USI's and GSI's), B-3 (evaluate and disseminate operating experience), B-8 (medium priority generic safety issue resolution), C-1 ( accident prevention through characterization of areas of potential concern), C-2 (improve completeness and precision of PRA's), and C-4 (identify and prioritize potential generic safety issues). It is assessed as CATEGORY B (IMPORTANT).

Usefulness - This research provides a mechanism for research insights to be used in the regulatory process, is currently being applied at the NRC and its contractors, and will be concluded successfully. This activity is assessed as USEFUL.

Appropriateness - While industry has developed and is using the PRA techniques,NRC has taken the lead in advancing the state-of-the-art. This activity is assessed as APPROPRIATE.

Resources - Resource requirements include $3 million through FY87, $5 million to complete by FY__, $1.5 million in FY88, and $2.5 million for FY89.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: STANDARDIZED AND ADVANCED REACTORS
Assessment Panel: Morris (NRC), Blond (SAIC), Ybarrondo (SCIENTECH)
Branch Chief: Tom King

### REVIEW DOE ADVANCED REACTOR CONCEPTS

The purpose of this activity is to provide licensing guidance on three advanced reactor conceptual designs submitted by the US Department of Energy (DOE) - - one modular High Temperature Gas-cooled Reactor (HTGR) and two modular Liquid Metal Reactors (LMRs). In order to assure that the designs are licensable, DOE has requested that NRC review the designs at this early stage, and provide guidance on the designs from the standpoint of licensing requirements. The designers will then be able to factor the findings of the reviews into the final design prior to submitting a formal application for licensing.

This activity is being conducted as part of the staff's implementation of the Commission's Advanced Reactor Policy Statement, and the end result will be a safety evaluation report on each reactor concept under review.

Safety Assurance - This activity is strongly related to the resolution of question A-8 and less strongly related to questions A-9, B-11, and C-4. The activity does not have any direct or immediate impact on public health and safety and is not associated with existing facilities, but it will have an impact upon future licensing. The results of this activity will be instrumental in the formulation of licensing requirements for advanced reactors of designs significantly different than LWRs and as such will have a direct bearing on future national energy policy. Because of the tremendous leverage which these early results are likely to have, this activity is assessed as CATEGORY A (VITAL.)

Usefulness - This research is needed in order to be able to formulate the licensing guidance, including accident prevention and accident mitigation capabilities which future nuclear power plants will be expected to meet. Addressing licensing of the conceptual designs at this stage will yield requirements which are timely in that they will be able to influence reactor design at an early stage. Overall, this activity is assessed as HIGHLY USEFUL.

Appropriateness - It is the responsibility of the NRC to develop the requirements for licensing nuclear reactors and to ensure compliance with these requirements. The activity is assessed as HIGHLY APPROPRIATE.

Resources - Cumulative costs through FY87 total $2.2 million. Costs for FY88 are $1 million. Cost proposed for FY89 are $1 million. Completion of the activity in 1991 is estimated to require and additional $4 million.beyond the FY87 total. FINS included in this activity are A3827 (BNL) and A9477 (ORNL).

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: SEVERE ACCIDENT PROGRAM IMPLEMENTATION
Assessment Panel: Morris (NRC), Blond (SAIC), Ybarrondo (SCIENTECH)
Branch Chief: Tom King

### SEVERE ACCIDENT POLICY IMPLEMENTATION

The purpose of this research activity is to develop requirements which will ensure the implementation of the Commission's Severe Accident Policy Statement in future Light Water Reactors (LWRs). Accordingly, this activity funds the development of rulemaking and supporting Reg. Guides. Results will include requirements for future applicants to submit a PRA, to evaluate a range of severe accidents and to comply with appropriate acceptance criteria to be defined.

Safety Assurance - This activity is strongly responsive to questions A-8, A-9, B-9 and B-10, and is less strongly related to question B-11. The activity will have a direct impact on the licensing of the ABWR and APWR designs currently under review by NRR. Because of the impact which the results from this research will have upon future reactors, it could effect national energy policy. Although this activity is important in that regard, safety could be assured by resolving the issues on an ad-hoc basis. This activity is assessed as CATEGORY A (VITAL).

Usefulness - The results of the research are needed for the resolution of issues related to the adequacy of severe accident prevention and mitigation of future LWR designs and will produce the licensing requirements for severe accidents in time to support the ABWR and APWR licensing reviews. Resolution of complex issues through rulemaking will avoid the need to adjudicate them during certification hearings. This activity is therefore assessed as HIGHLY USEFUL.

Appropriateness - It is the responsibility of the NRC to establish and enforce requirements for licensing nuclear reactors. The activity is assessed as HIGHLY APPROPRIATE.

Resources - There are no cumulative costs since the activity is starting in FY88. Costs for FY88 are $0.2 million in FY88. Costs proposed for FY89 are $0.2 million. Completion of the activity by FY90 is estimated to require a total commitment of $0.65 million over the three fiscal years. Only one FIN (B5706) is involved in this activity.

## ELIGIBILITY OF RES FUNDING FOR RADIATION PROTECTION AND HEALTH EFFECTS

Acceptance of a proposed Radiation Protection and Health Effects research project is dependent upon meeting one or more of the following criteria developed for use within the Radiation Protection and Health Effects Branch:

A. Data to be obtained must be needed by the Advisory and Consensus Standards organizations whose recommendations form the basis for NRC regulations and guidance.

B. Data to be obtained must be needed by the NRC staff for the development of standards on topics not included in Advisory or Consensus Standards organization recommendations.

C. The project must provide data which close gaps in technology that have been compensated for through the adoption of conservative assumptions in the standards-development process.

D. Data to be obtained must contribute to rational policy making in the NRC regulatory program.

E. Information obtained must contribute to the data base underlying the development of NRC positions or the monitoring of licensee performance.

F. Information obtained must assist the NRC staff in the resolution of practical problems in the Standards-Development, Licensing and Inspection programs.

G. The project must contribute to improvement in measurements required by the NRC for radiation protection and/or for demonstrating compliance.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: RADIATION PROTECTION AND HEALTH EFFECTS
Assessment Panel: Morris (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Robert Alexander

### REDUCE UNCERTAINTY IN HEALTH RISK ESTIMATES

The purpose of this research is to determine the appropriate relationship between radiation exposure and individual health risk. The improved or new health risk estimates resulting from this research will be used as the basis for revisions to NRC regulations and regulatory guides on radiation protection including 10 CFR 20 and its supporting regulatory guides. Also PRA risk coefficients and the related analysis of accident risks will be improved which will impact the implementation and formulation of safety goals.

Specific continuing research projects comprising this activity include:

- Continued NRC support of the National Council on Radiation Protection (NCRP), the International Commission on Radiological Protection (ICRP), and the Committee on Interagency Radiation Research and Policy (CIRRPC). Recommendations from these bodies have been, and continue to be, crucial to the continued improvement of radiation protection standards such as 10 CFR Part 20 (FIN Nos. D1580, A9140, G1030).

- A major long term interagency research program on cellular and molecular effects of radiation to reduce the large uncertainties in estimates of low doses health effects. Greater precision in these health effects estimates would improve PRAs, emergency response planning, siting review and implementation of the Commission's safety goals. (Feasibility study to begin in FY 88.)

Major research projects which respond to immediate needs include:

- A study of the health effects of industrial exposure to thorium and the long- term pattern of deposition of inhaled thorium and its daughter products in human tissue, conducted to reduce the uncertainty of estimated health risks for workers at sites where thorium is processed. (FIN A2050)

- A study to determine the adequacy of current neutron dose limits. NRC adoption of a controversial ICRP recommendation would lower the neutron dose limit by a factor of 2; animal studies conducted in this study will form a basis for agency decision in this matter. (To be initiated in FY 89).

- A study to reduce the uncertainties in radionuclide transfer functions for the transport of radioactive materials through the placenta to the embryo/fetus. These improvements will be used in the proposed revision of 10 CFR 20. (FIN B2923)

- Improvement of the health effects models for reactor accidents documented in NUREG/CR-4214. NUREG/CR 4214 is the technical basis for health effects estimates contained in NUREG-1150; improvements in these estimates will subsequently yield better estimates for the health risks posed by nuclear power. (FIN A1415).

Safety Assurance - (See NOTE preceding this page.) The diversity of research conducted within this activity requires examination of the individual projects in order to arrive at an assessment. While it is felt that the work on placental radionuclide transfer functions is responsive to question A-10 inasmuch as it is not known whether current exposure limits are adequate, the remainder of the research is deemed responsive to C-6. Depending upon the results of the research, fundamental changes in the standards for pregnant women may be indicated to ensure the health and safety of the embryo/fetus. Other research projects in this activity will result in improvements of the existing standards rather than sweeping revisions. based on these considerations the placental research is assessed as CATEGORY A (VITAL), while the balance of the activity is assessed as CATEGORY C (VIGILANT).

Usefulness - All of the research projects in this activity will produce information needed to resolve the relevant question. Each project is correctly focused on reducing the uncertainties in health risk estimates; the knowledge gained from the research will improve NRC capability to estahlish standards for the protection of the public from the effects of radioactive materials. The research appears to be on a schedule consistent with supporting timely decisions. Overall, the activity is assessed as HIGHLY USEFUL.

Appropriateness - It is a responsibility of the government to ensure the protection of the public from unnecessary risks associated with the uses of nuclear materials. Of the various governmental agencies, it is the NRC which has been charged with the dominant role in fulfilling this responsibility. Inasmuch as the results of this research will improve the capability to ensure this protection, it follows that this activity is assessed as HIGHLY APPROPRIATE.

Resources - Cumulative funding through FY87 was $3.4 million. Funding for FY88 is $0.7 million. Funding proposed for FY89 is $1.5 million. Completion of work scheduled through 1990 is estimated to require $3.7 million beyond the FY87 total. Support for work scheduled in FY 91 through FY 93 is estimated at $4.6 million.

## SUMMARY OF ACTIVITY

PROGRAM ELEMENT: RADIATION PROTECTION AND HEALTH EFFECTS
Assessment Panel: Morris (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Robert Alexander

### HEALTH PHYSICS TECHNOLOGY IMPROVEMENT

The purpose of this research is to improve the precision of extremity dosimetry, bioassay, and air sampling techniques so that the precision of these measurements is on a level comparable to that already achievable with whole body dosimetry. The reason for wanting to achieve such an improvement is to correct an inconsistency in NRC requirements in which performance criteria have been established only for whole-body dosimetry.

Specific continuing research projects comprising this activity include:

- Development of performance standards, testing procedures and accreditation programs for extremity dosimetry, bioassay, air sampling and instrumentation. Objective is to improve licensee performance on radiation protection measurements required by NRC regulation.

Major research projects which respond to immediate needs include:

- Development of emergency chemical and radiological bioassay procedure to be used in the evaluation of accidental human exposure to UF6 and to materials containing Am-241, Pu, Cm and Po-210. Review of an accident involving UF6 indicated that such a procedure is required to ensure prompt corrective action (FIN A3289).

- Several SBIR projects testing new measurement techniques, such as fibre optic applications to internal dosimetry measurements, for applicability.

- Ongoing technical assistance on an as-needed basis for interpretation of bioassay results, alternative radiation protection guidance and other items as identified by NRC staff. (FIN B0475)

Safety Assurance - (See NOTE preceding the activity "Reduce Uncertainty in Health Risk Estimates".) The research of this activity is responsive to question C-6. overall, this activity is assessed as CATEGORY C (VIGILANT).

Usefulness - All of the research projects in this activity will produce information needed to resolve the relevant safety assurance question. The projects are focused on improving capabilities for extremity dosimetry, bioassay and air sampling techniques. Knowledge gained from the research will improve NRC capability to regulate radiation exposure. The research appears to be on a schedule consistent with supporting timely decisions . Overall, the activity is assessed as HIGHLY USEFUL.

Appropriateness - It is a responsibility of the government to ensure the protection of the public from unnecessary risks associated with the uses of nuclear materials. Of the various governmental agencies, it is the NRC which has been charged with the dominant role in fulfilling this responsibility. Inasmuch as the results of this research will improve the capability to ensure this protection, it follows that this activity is assessed as HIGHLY APPROPRIATE.

Resources - Cumulative funding through FY87 was $0.4 million. Funding for FY88 is $0.2 million. Funding proposed for FY89 is $0.6 million. Completion of work scheduled through 1990 is estimated to require $1.4 million beyond the FY87 total. Suppon for work scheduled in FY91 through FY93 is estimated at $1.8 million.

**SUMMARY OF ACTIVITY**

PROGRAM ELEMENT: RADIATION PROTECTION AND HEALTH EFFECTS
Assessment Panel: Morris (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Robert Alexander

**DOSE REDUCTION AND STANDARDS DEVELOPMENT**

There are two purposes to this research activity: (a) to develop new methods of monitoring licensee performance indicators in the area of radiation protection, and (b) to modify current radiation protection standards and guidance in accordance with the recommendations of advisory bodies. Both purposes are reflective of an agency commitment to continually evaluate and improve those capabilities required to fulfill the mission of ensuring public health and safety.

Specific continuing research projects comprising this activity include:

- Computer programming and processing support for operation of the Commission's Radiation Exposure Information Reporting System (REIRS). REIRS data enable NRC to statistically evaluate effectiveness of NRC/licensee radiation protection and ALARA efforts. (FIN B0835)

- Development of an international data base on cost effective dose reduction techniques and critical analysis of U.S. plant performance on dose reduction. This work maintains NRC vigilance in the area of dose reduction (FIN A3259).

Major research projects which respond to immediate needs include:

- A study of the biological hazards presented by "hot" particles of beta-gamma emitters attached to the skin. Existing methods of dose estimation are not applicable; this effort provides confirmatory research to evaluate an approach suggested by NCRP. (Initiated in FY 88)

- Development of regulatory guides applicable to implementation of the revised 10 CFR Part 20 Radiation Standards. Adoption of the ICRP-26/30 dose limitation system and ICRP-30 dosimetry requirements necessitates issuance of new guidance to licensees. (FIN B8207)

- A study to determine if workers exposed to uranium in NRC-licensed activities are subject to greater risk than currently thought. This research addresses urinary tract ailments reported by workers at Nuclear Fuel Services. (FIN D2017).

- An investigation of planned releases of radioactive effluents to determine if the releases, though within the limits prescribed by 10 CFR Parts 20 and 50 at the time of release, reconcentrate through deposition in sludge or chemical absorption by biota (to be initiated in FY89).

Safety Assurance - (See NOTE preceding the activity "Reduce Uncertainty in Health Risk Estimates".) The research of this activity is responsive to questions C-6 and C-7. Overall, this activity is assessed as CATEGORY C (VIGILANT).

Usefulness - All of the research projects in this activity will produce information needed to address questions regarding radiation protection standards and ALARA. Knowledge gained from the research will improve NRC capability to regulate radiation exposure. The research appears to be on a schedule consistent with supporting timely decisions. Overall, the activity is assessed as HIGHLY USEFUL.

Appropriateness - While it is appropriate for the NRC, as an agency of the government, to support research applicable to ensuring regulatory capability, it is the responsibility of the regulated industries to perform the fundamental research required to prove effectiveness of new methodologies proposed for use by licensees. This is borne out by the greater volume of INPO and nuclear industry research being conducted in the area of dose reduction. Overall, this activity is accessed as VERY APPROPRIATE.

Resources - Cumulative funding through FY87 was $1.5 million. Funding for FY88 is $0.8 million. Funding proposed for FY89 is $1.2 million. Completion of work scheduled through 1990 is estimated to require $3.2 million beyond the FY87 total. Support for work scheduled in FY91 through FY93 is estimated at $3.7 million.

**SUMMARY OF ACTIVITY**

PROGRAM ELEMENT: FUEL CYCLE MATERIALS, TRANSPORTATION AND SAFEGUARDS RESEARCH AND STANDARDS DEVELOPMENT
Assessment Panel: Morris (NRC), Aldrich (SAIC), Blond (SAIC)
Branch Chief: Robert Alexander

FUEL CYCLE, TRANSPORTATION, SAFEGUARDS, AND MATERIALS SAFETY

The purpose of this activity is to develop new rules for radiation protection and safeguards as needed to respond to user staff requests of Commission directives. Currently the work is limited to support of rulemaking in two areas: (a) transportation and (b) materials safety. There is no active research in the areas of fuel cycle or safeguards.

Research in support of transportation regulation is a small effort ($75K for FY89) to assess the capabilities and appropriateness of continued use of Department of Transportation "specification packages." These containers, whose use is allowed under existing regulations, are being evaluated to determine their capabilities with respect to current package performance standards.

Research in support of material safety is being conducted in response to a Commission directive calling for the development of criteria through which a small level of radioactivity or quantity of radioactive material can be classified as Below Regulatory Concern (BRC). BRC levels are those levels of exposure which pose so little health risk that government intervention is limited or unwarranted. The Commission has directed the development of BRC levels applicable to radioactive waste and is exploring the potential for generic BRC criteria. The scope of activity extends to BRC applicable to LLW materials used in medical practice, pharmaceuticals, and universities, and generated at nuclear power plants, decommissioning, consumer products and recycling of materials and equipment. Both Congress and the EPA have expressed concern over the estimated costs of LLW disposal under the current undifferentiated system. Under BRC, individual petitioners for BRC status will pay for the research to put together a data base upon which the BRC levels will be developed.

Safety Assurance - Although individuals could be exposed to only very low doses, large numbers of people may be involved in some of the licensed practices. The safety implications may be significant for the population as a whole. The research is relevant to the resolution of safety assurance question B-14,B-15 and B-16. RES will process the petitions for BRC status, defining the appropriate BRC levels for different types of waste. Since the research is focused only upon B-15, it is assessed as CATEGORY B (IMPORTANT).

Usefulness - The activity is completely focused upon the definition of generic BRC levels. The impact will be to set appropriate levels of radiological contamination such that the residual risks are small and the costs of reducing them further are not justified on a cost-benefit basis. In this regard, rulemaking on LLW disposal, decommissioning, consumer products and recycling of materials and equipment will be based on the generic BRC levels. This activity is assessed as HIGHLY USEFUL.

Appropriateness - Establishing limits for acceptable radiation exposure is properly the responsibility of the NRC, and this research is required to establish the limits. This activity is assessed as HIGHLY APPROPRIATE.

Resources - Cumulative funding through FY87 was $0.5 million. Funding for FY88 is $0.4 million. Funding proposed for FY89 is $0.4 million. Completion of identified work in 1990 is estimated to require about $0.1 million beyond the FY87 total; however, based on planned follow-on activities and past experiences with regard to rulemaking support, budget levels of approximately $1 million/year are being requested.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

TO: JAMES MCKNIGHT ARM/DCB

PLEASE PUT THE ATTACHED COPY OF SCIE-91-88, A CONTRACTORS REPORT, IN THE PUBLIC DOCUMENT ROOM. I AM WRITING A NUREG REPORT WHICH REFERENCES THIS DOCUMENT.

J.W. PITTMAN DRA/EES
2-3746