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Task A-17

SYSTEMS INTERACTIONS IN NUCLEAR POWER PLANTS

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Applicability:	Light Water Reactors	
Projected Completion Dates:	Phase I - April 1980 (Phase I Report Issued for Public Comment) - August 1980 - Phase I Complete Phase II - May 15, 1981 (Tentative)	2

1. DESCRIPTION OF PROBLEM

The design of a nuclear power plant is accomplished by groups of engineers and scientists organized into engineering disciplines such as civil, electrical, mechanical, structural, chemical, hydraulic, and nuclear, and into scientific disciplines such as geology, seismology, and meteorology. The reviews performed by the designers include interdisciplinary reviews to assure the functional compatibility of the plant structures, systems, and components. Safety reviews and accident analyses provide further assurance that system functional requirements will be met. These reviews include failure mode analyses to assure that the single failure criterion is met.

The NRC review and evaluation of safety systems is accomplished in accordance with the Standard Review Plan (SRP) which assigns primary and secondary review responsibilities to organizational units arranged by plant systems such as containment systems, reactor systems, etc., or by disciplines such as mechanical engineering, materials engineering, and structural engineering. Each element of the SRP is assigned to an organizational unit for primary responsibility and, where appropriate, to other units for secondary responsibilities.

Thus, the design and analyses by the plant designers, and the subsequent review and evaluation by the NRC staff, take into consideration the interdisciplinary areas of concern and account for systems interaction to a large extent. Furthermore, many of our regulatory criteria are aimed at controlling the risks from systems interactions. Examples include the single failure criterion and separation criteria.

Nevertheless, there is some question regarding the interaction of various plant systems, both as to the supporting roles such systems play and as to the effect one system can have on other systems, particularly with regard to whether actions or consequences could adversely affect the presumed redundancy and independence of safety systems.

The problem to be resolved by this task is to identify where the present design, analysis and review procedures may not acceptably account for potentially adverse systems interaction and to recommend the regulatory action that should be taken to rectify deficiencies in the procedures. 2

2. PLAN FOR PROBLEM RESOLUTION

The plan for resolution of this task is to develop a method for conducting a disciplined and systematic review of nuclear power plant systems, for both process function couplings of systems and space couplings, to identify the potential sources and types of systems interactions that are determined to be potentially adverse. A matrix of systems and interactions will be synthesized generically for a nuclear power plant and verified for a selected facility. This matrix will be displayed as plant logic and system models, for example, somewhat analogous to techniques that have already been developed for similar kinds of studies and analyses. The 2

Standard Review Plan will then be measured against this synthesized matrix to determine the completeness of the review procedure. From this comparison, any necessary revisions to the review procedures, including necessary revisions to Standard Review Plan, Regulatory Guides, etc., will be developed and recommended for implementation.

The plan is to be accomplished in two phases. Phase I will include the development of a systematic review method for systems interaction and the application of that process to a finite category of interactions. Phase I will include an assessment of the Standard Review Plan to evaluate how well the plan addresses the potential systems interaction identified through the application of the process. At the conclusion of Phase I, the NRC staff will issue a NUREG Report that will identify the proposed requirements and safety evaluation for the category of interactions that will be investigated in Phase I. 2

Phase II, because of its dependence on the outcome of Phase I and other related programs being scoped at the time of this revision, cannot as yet be detailed. Phase II will likely expand the review methods developed in Phase I and apply the methods to other categories of systems interactions. Phase II may also include the investigation of other methods or technologies for identifying potential systems interaction.

The major elements of this Task are described in the following paragraphs:

(a) Sandia Laboratories will, through the accomplishment of the work described in Section 5 of this Task Action Plan, develop a systematic review process for systems interactions. Sandia Laboratories will verify and demonstrate the review process for an exemplary facility and will assess the Standard Review Plan against the systematic review process. All of this will be accomplished during Phase I of the Task.

(b) NRR will review and evaluate the work performed by Sandia Laboratories and will provide assistance in specialized technical areas to supplement the technical capabilities of the group at Sandia Laboratories. NRR will also, in conjunction with the Office of Standards Development, provide overall technical direction to Sandia Laboratories in the execution of plan. NRR will also provide the evaluation needed to form the technical basis for NRR management decisions regarding the acceptability of the task efforts by Sandia Laboratories.

(c) The Office of Standards Development will administer and manage the contract with Sandia Laboratories through its assigned Project Manager. OSD will also provide technical review, evaluation and direction of the work performed by Sandia Laboratories in conjunction with the technical overview by NRR.

(d) The Probabilistic Analysis Staff of the Office of Nuclear Regulatory Research will act as consultant to NRR, and

(e) The Career Management Branch of the Office of Inspection and Enforcement will provide guidance and instruction on plant operations to Sandia Laboratories in the development of plant and system logic models. 2

3. BASIS FOR CONTINUED PLANT OPERATION AND LICENSING PENDING COMPLETION OF TASK

As discussed in Section 1, this task addresses the development of a systematic process to review plant systems to determine their impact on other plant systems. The purpose of the task is to identify where the present design, analysis and review procedures may not acceptably account for potentially adverse systems interaction and to recommend the regulatory action that should be taken to rectify deficiencies. It is anticipated that this task will confirm that current licensing requirements and procedures acceptably control the potential for adverse systems interactions, even though some modifications for improvement in the review procedures and licensing requirements may be made.

Current licensing requirements are founded on the principle of defense-in-depth. Adherence to this principle results in requirements such as physical separation and independence of redundant safety systems, and protection against events such as high energy line ruptures, missiles, high winds, flooding, seismic events, fires, operator errors, and sabotage. These design provisions supplemented by the current review procedures of the Standard Review Plan (NUREG-75/087) which require interdisciplinary reviews and which account, to a large extent, for review of potential systems interactions, provide for an adequately safe situation with respect to such interactions. The quality assurance program which is followed during the design, construction, and operational phases for each plant is expected to provide added assurance against the potential for adverse systems interactions.

Plant licensing can continue pending ultimate resolution of this task because current licensing requirements provide an acceptable level of assurance against potentially adverse systems interactions. Previous licensing procedures that were followed for those plants now operating also provide assurance against potentially adverse systems interactions, although perhaps to a lesser degree than current procedures. Experience to date has demonstrated that operating plants have been designed to provide reasonable assurance that adverse systems interactions will not occur. Certain events such as fires and high-energy line breaks outside containment have been identified as hazards to safety-related equipment which also could cause adverse systems interactions. Corrective measures have been or are being taken on each plant to assure an acceptable level of protection against these hazards. These corrective measures will also reduce the potential for adverse system interactions.

In summary, the staff considers that present plant design and review procedures which have been developed and refined from these procedures followed for plants now in operation, provide reasonable assurance that

unacceptable adverse systems interactions will not occur. The results of this task are expected to confirm this view, although some modifications to improve review procedures and licensing requirements may be recommended. Accordingly, we conclude that while this task is being performed, continued operation and plant licensing can proceed with reasonable assurance of protection to the health and safety of the public.

4. NRR TECHNICAL ORGANIZATIONS INVOLVED

The conduct of this task is the responsibility of NRR. The Office of Standards Development is also participating in the task by administering the contract with Sandia and participating in the technical review of the Sandia work products. NRR participation includes overall management of the Task by a Task Manager and technical review of the Sandia work products. NRR personnel will also prepare the report providing the staff's conclusions based on the Sandia work.

The participation of NRR branches in Phase I of this task has fluctuated considerably. Shortages of personnel have been experienced at different times as Phase I proceeded, especially in systems-oriented branches following the Three Mile Island Unit 2 accident in March 1979. 2

Although this caused the staff to alter its procedure and timing for reviewing Sandia work products, it did not result in contractor schedule delays nor is it believed to have altered the completeness or quality of Sandia's Phase I work.

NRR and OSD manpower estimates by fiscal year are provided below in professional man-years:

	FY 80		FY 81	
	NRR	OSD	NRR	OSD
Phase I	3.0	0.25	0	0
Phase II	*	*	*	*

5. TECHNICAL ASSISTANCE

This task will be accomplished by assistance from Sandia Laboratories working under a contract that will be administered by the Office of Standards Development. The contract will cover a two-phase effort expended over an estimated time of 30 months. The first phase will include Task 1 through Task 13 as described in Attachment 1. The first phase is estimated to be completed in 24 months at a cost of $560,000. The second phase is estimated to be accomplished in 8 months at a potential cost of about $250,000. This estimate for Phase II is very preliminary. Actual requirements will not be available until the Phase II effort is better scoped. 2

*Will be determined after Phase II is scoped.

6. INTERACTIONS WITH OUTSIDE ORGANIZATIONS

This task will be coordinated with the Subcommittee on Plant Arrangements of the Advisory Committee on Reactor Safeguards as the task progresses. Several meetings have been held with the ACRS. The next meeting is planned with the Plant Arrangements Subcommittee in February 1980. Meetings are anticipated with NSSS vendors, A/Es, and utilities to assess the extent to which these organizations conduct reviews and analyses for systems interaction, and to keep these organizations informed of our developments. It is not intended to conduct a formal review process through these organizations, however. It is intended to develop a free exchange of information so that the task can take advantage of existing methods of review. 2

7. ASSISTANCE REQUIREMENTS FROM OTHER NRC OFFICES

The Office of Standards Development shall manage the contract effort and shall also provide technical input to the task effort to (a) supplement the contract effort, (b) direct and evaluate the contract effort, and (c) interface with the technical and management efforts by NRR. It is estimated that this effort by OSD will total 10.0 man-months during Phase I of the task. The Phase II effort has been estimated as about 6.0 man-months but will be dependent on the results of Phase I. 2

The Office of Inspection and Enforcement will provide guidance and instruction to Sandia Laboratories in the area of plant operations. It is estimated that this effort will be about 2 man-months.

The Probabilistic Analysis Staff, Office of Nuclear Regulatory Research, will act as consultant in the detailed development and execution of this task action plan. It is estimated that this total assistance from RES will be about 3 man-months of effort. It is anticipated that this group can provide valuable insights into the task because of its involvement with the Reactor Safety Study (WASH-1400). Additionally, this group would be requested to review and critique the results of this task action plan.

8. POTENTIAL PROBLEMS

A problem with the availability of NRR personnel and its impact as of the date of Revision 2 to this Plan is discussed above in Section 4. 2

Another problem area is that systems interaction cuts across all disciplines and technical branch review areas and cuts across all groups and divisions. Consequently, to effectively perform a review for systems interaction, it may be necessary to either define more clearly and more extensively the primary and secondary review responsibilities in the SRP or to organize a new element to perform the review, or both. Consideration will be given during execution of this task to the resolution of this problem.

A third problem area is related to estimating the scope and extent of effort required to complete Phase II. It is expected that the information generated during Phase I will provide a valid basis for a reassessment of the balance of effort to complete the task. In addition, several related NRC initiatives are being scoped as part of the TMI Action Plan (NUREG-0660) development. The scope of Phase II of Task A-17 will have to be coordinated with these related efforts. 2

ATTACHMENT 1

SANDIA LABORATORIES TASKS

The following is a brief description of the tasks that will be accomplished by Sandia Laboratories under a contract to the Nuclear Regulatory Commission and administered by the Office of Standards Development.

Task 1. Define Program Scope

The scope of the program will vary slightly depending on the undesired event which is being treated. The program assumes that systems interactions of concern are those which significantly decrease the likelihood of successful reactor shutdown, residual heat removal, and containment of radioactive products. The major emphasis will focus on interactions that might occur during normal operations and anticipated transients.

Task 2. Develop Interaction Description

This task would be accomplished by reviewing Licensee Event Reports, interviewing NRC staff members, reviewing relevant literature and drawing from the experience of the study participants. In this area, particularly, it is hoped that heavy NRC participation will take place. The methodology will be applicable to a wide range of systems interactions.

Task 3. Select Exemplary Facility

Sandia Laboratories is performing the systems analysis task of the Reactor Safety Study Methodology Application Program. In this program four plants, representative of the nuclear industry, are being studied and modeled in detail. It is envisioned that one of these could be used as the exemplary facility. Such a choice would allow a much smaller manpower requirement to verify and demonstrate the methodology than would otherwise be required.

Task 4. Review Standard Review Plan

This task will be carried on concurrently with the preceding tasks. It will include reviewing the Standard Review Plan to assure an understanding of current NRC procedures on the part of the study team.

Task 5. Develop Plant Logic Models

The system identification techniques used to identify the important combinations of systems would be expected to be based on generic LWR plant functional and accident sequence models. These models would be developed in this task. They are expected to be similar in physical structure to the event tree models in WASH-1400. However, for this application they would reflect generic plant functions common to all LWRs and would cover the range of conditions for which systems interactions could result in failure to shutdown the reactor, remove decay heat, and contain radioactive products.

Task 6. Develop System Models

The interaction identification algorithms used to identify potential interactions is expected to be based on models of the important systems which themselves will be derived from generic models of LWR plant systems. These generic models will be developed in the program. The generic models will be fault trees reflecting combinations of events which lead to system unavailability. In concept, they will be similar to the generic sabotage fault trees now under development for NRC.

Task 7. Develop System Identification Techniques

The techniques developed in this task will become detailed steps in the methodology. The purpose of the techniques will be to identify the important combination of systems. The first of the techniques will include comparing the applicant's plant functions and systems against the generic plant logic model. The usage of generic models in this case is very similar to the usage of the sabotage generic fault tree models. A sensitivity evaluation will be run to identify which combinations of systems for which, if their unavailabilities were not independent but tightly coupled (i.e., significant interactions exist), public safety could be significantly affected. The purposes of this task are to develop the actual techniques to be used, and to define the generic models and associated criteria in such a way that the techniques can be practically applied in the licensing environment.

Task 8. Develop Interaction Identification Algorithm

The algorithm developed in this task will be based on the generic fault trees. The design of the plant systems found to be important will be compared with generic fault trees reflecting unavailabilities of that type of system in general. From this will be derived system unavailability fault trees reflecting the applicant's design. Each event contributing to the unavailability of each of these important systems will be characterized to reflect such things as: component type, location, technology, manufacturer, maintenance procedures, and environmental susceptibilities. The fault trees of important systems would be compared to identify commonalities such as similar locations, environmental susceptibilities, etc. A simplified and "canned" version of the SETS code is envisioned for use in making this comparison. The purpose of this program task is to develop the necessary algorithms and package them in a manner that they can be practically used in the licensing environment.

Task 9. Develop Interaction Important Measures

The purpose of this task is to develop the methods of measuring the importance of commonalities or potential interactions identified using the interaction identification algorithm. Two methods will be explored. One will be the development of procedures to perform probabilistic evaluation of the interactions directly. The second will be to develop generic criteria based on a generic probabilistic evaluation. This second approach would allow the methodology to be applied qualitatively. In either case, the final measure would reflect the likelihood of the interaction taking place, the effect of the interaction on the plant systems, and the importance of the systems to safety.

Task 10. Verify and Demonstrate Review Procedure

The practicality of the review procedure in identifying and evaluating systems interactions is important. The purpose of this task is to measure that practicality by using the models, procedures, techniques, algorithms and measures on a plant representative of current technology. Appropriate Licensee Event Reports will be used to assess the applicability and completeness of the methodology relative to adverse system interactions.

Task 11. Assess Standard Review Plan

This task will include an assessment of the Standard Review Plan to determine the completeness of the plan regarding identification and evaluation of systems interactions that could potentially affect public safety.

Task 12. Prepare Phase I Report

This task will document all work done in Phase I of the program.

Task 13. Define Phase II Program

The nature of the Phase II program is dependent upon the outcome of Phase I and the desired level of implementation of the methodology by NRC. For example, where generic qualitative criteria can be developed reflecting the results of probabilistics evaluations, this criteria can be delineated and transferred to NRC easily. Where it is found that plant-specific characteristics will affect the criteria, then the algorithms and techniques will have to be defined in instruction and user manuals and the codes, if any, will need to be packaged in a convenient-to-use form.