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# SEISMIC SAFETY MARGINS RESEARCH PROGRAM

PROGRESS REPORT NO. 13

March 31, 1982

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T. Y. Chuang
L. E. Cover
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Prepared for

U. S. Nuclear Regulatory Commission

by

Lawrence Livermore National Laboratory

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by
Lawrence Livermore National Laboratory
Livermore, CA 94550
operated by University of California
for the U. S. Department of Energy

ABSTRACT

The Seismic Safety Margins Research Program (SSMRP) is an NRC-funded, multiyear program conducted by Lawrence Livermore National Laboratory (LLNL). Its goal is to develop a complete, fully coupled analysis procedure (including methods and computer codes) for estimating the risk of an earthquake-caused radioactive release from a commercial nuclear power plant. The analysis procedure is based on a state-of-the-art evaluation of the current seismic analysis and design process and explicitly includes the uncertainties inherent in such a process. The results will be used to improve seismic licensing requirements for nuclear power plants.

This document is a progress report* on the Seismic Safety Margins Research Program covering the period October 1, 1981, through March 31, 1982. The report gives a general description of the program, together with financial summaries and individual project details. Each project is summarized to show accomplishments, schedules, milestones and completion dates, budget and expenditures, and any concerns that may affect the project.

*Progress Report number 13 of the SSMRP is the ninth to be issued as a NUREG report. The first six in this series are available from Lawrence Livermore National Laboratory under the numbers ME79-206 through ME79-211. Progress Report number 13 continues the reporting of Phase II of SSMRP.

CONTENTS

SEISMIC SAFETY MARGINS RESEARCH PROGRAM
FIN A0126, A0362, A0363, and A0390

GENERAL DESCRIPTION

**Personnel**

NRC Program Manager: D. J. Guzy
Contractor: Lawrence Livermore National Laboratory (LLNL)
LLNL Program Manager: M. P. Bohn

**Program Dates**

Starting date: February 1978
Ending date: September 1984

**Justification**

NRR User Request No. 76-5, dated June 16, 1977

**Introduction**

The Seismic Safety Margins Research Program (SSMRP) is a NRC-funded, multiyear program conducted by Lawrence Livermore National Laboratory (LLNL). Its goal is to develop a complete, fully coupled analysis procedure (including methods and computer codes) for estimating the risk of an earthquake-caused radioactive release from a commercial nuclear power plant. The analysis procedure is based on a state-of-the-art evaluation of the current seismic analysis and design process and explicitly includes the uncertainties inherent in such a process. The results will be used to improve seismic licensing requirements for nuclear power plants.

The SSMRP was begun in 1978 when it became evident that an accurate seismic risk analysis must simultaneously consider all the interrelated factors that affect the final probability of radioactive release. In the traditional design procedure, by contrast, each factor is usually analyzed separately. These closely coupled factors are:

- The likelihood and magnitude of an earthquake.
- The transfer of earthquake energy from a fault source to a power plant, a phenomenon that varies greatly with the magnitude of an earthquake.
- Interaction between the soil underlying the power plant and the structural response, a phenomenon that depends on the soil composition under the plant and the location of the fault source relative to the plant.
- Coupled responses of a power plant's buildings and the massive reactor vessels, piping systems, and emergency safety systems within.
- Numerous accident scenarios, which vary according to types of failures assumed and the success or failure of the engineered safety features intended to mitigate the consequences of an accident.

A nuclear power plant is designed to ensure the survival of all buildings and emergency safety systems in a worst-case ("safe shutdown") earthquake. The assumptions underlying this design process are deterministic. In practice, however, they are clouded by uncertainty. It is not possible, for example, to predict accurately the worst earthquake that will occur at a given site. Soil properties, mechanical properties of buildings, and damping in buildings and internal structures also vary significantly.

To model and analyze the coupled phenomena that contribute to the total risk of radioactive release, it is therefore necessary to consider all significant sources of uncertainty and all significant interactions. Total risk is then obtained by considering the entire spectrum of possible earthquakes and integrating their calculated consequences. In the SSMRP this approach to risk analysis is embodied in the seismic methodology chain, comprising five steps: determining seismic input characteristics for a site, calculating the effects of soil-structure interactions, calculating major structure response, calculating subsystem response, and calculating probability of failure.

The seismic input consists of the earthquake hazard in the vicinity of a nuclear power station, defined by an estimate of the seismic hazard function (i.e., the relationship between the probability of occurrence and a measure of the size of an earthquake) and a description of the free-field motion. The soil-structure interaction link in the chain transforms the free-field ground motion into basemat or in-structure response, accounting for the interaction of the soil with the massive, stiff structures present at a nuclear power plant. Determination of the major structure response follows the soil-structure interaction step, where "major structure" commonly denotes a building, but may also include very large components. The final step in the traditional seismic analysis and design process is predicting subsystem structural response. An additional step in the SSMRP is the prediction of failure and subsequent risk of radioactive release.

**Objectives**

The objectives of the SSMRP are to:

1. Estimate the degree of conservatism of the present Standard Review Plan (SRP) seismic safety requirements.
2. Develop improved requirements and methods for safety assessment.

**Approach**

The approach toward achieving the program objectives is to develop probabilistic methodology that realistically estimates the behavior of nuclear power plants during an earthquake. This methodology will be tested against experimental data wherever possible. The work of the program is being performed in two phases:

1. In Phase I, completed in January 1981, the methodology was developed. Models for seismic input, soil-structure interaction, dynamic response of structures and subsystems, and fragility were developed and combined using a probabilistic computational procedure. The methodology was implemented in three computer programs: HAZARD, which assesses the seismic hazard at a given site, SMACS, which computes in-structure and subsystem seismic responses, and SEISIM, which calculates structural, component, and system failure probabilities. Sensitivity studies to gain engineering insight into seismic safety requirements were started. The results will help determine priorities for the Phase II effort.
2. In Phase II, any necessary additional models and probabilistic procedures will be developed. Sensitivity studies started in Phase I will be completed. The probability of failure of systems, components, and structures, and the probability of radioactive releases from a range of earthquake levels will be used to define needed improvements in the methodology. Necessary validation will be carried out, and the validated methodology will be used to refine estimates of conservatism and define the seismic contribution to reactor risk. The validated methodology will be used to recommend changes in the SRP seismic safety requirements, if needed, to obtain improved deterministic requirements.

For Phase II, which will progress beyond FY 82, we have identified five major goals:

**A. Sensitivity Studies**

Having assembled the preliminary versions of the codes HAZARD, SMACS, and SEISIM, and the preliminary fragility data base, we are ready to determine initially the relative importance of the various aspects of the seismic problem, using sensitivity studies.

The results will (1) give us confidence in the tools we developed, (2) help direct refinements in the tools and data developed, (3) allow us to compare our predictions with previous risk studies, and (4) identify future areas of research.

**B. Complete Zion Risk Assessment**

Having run sensitivity studies and improved our codes and data (to the minimum extent required), we can now complete the evaluation of the seismic risk at Zion. This evaluation will include uncertainty bands. The risk number will be based on our having completed all the necessary models (identified to date), fault trees, fragilities, and so on, although many of them will be preliminary.

C. **Develop Simplified Models**

Given our experience with sensitivity studies and the risk calculations, we can simplify the risk calculations to provide a procedure that can be used in a timely fashion to perform a routine probabilistic seismic risk assessment or to evaluate or benchmark risk assessments performed by other means.

D. **Validation**

Having calculated risk numbers, we must devote considerable effort to "verifying" them to the extent possible. Clearly the overall risk cannot be "verified," but we can perform studies, such as comparing with other codes and comparing with data at the structural or system level.

E. **BWR Risk Analysis**

Application of our tools, codes, and methods to a BWR to (1) provide comparative risk numbers, (2) demonstrate applicability of our simplified methodology to BWRs, and (3) provide a benchmark against which other probabilistic risk assessments can be compared.

**Work Scope**

The SSMRP consists of eight projects as indicated under "Cost and Development Schedule." The eight projects cover the major program goals described above. The work scope for each project in FY 82 is described in this document in a format that follows the SSMRP Standard Work Order document (NRC form 189).

## SUMMARY OF ACCOMPLISHMENTS

This report presents the progress and accomplishments in the SSMRP for the two-quarter period October 1, 1981, through March 31, 1982. During this period, the program underwent an extensive in-house review by the NRC that focused on the long-range plans for the program and the potential uses of the results generated in the program. In addition, the organization of the program was changed so that the individual projects making up the SSMRP are now defined along the lines of goals and products. Thus, the individual projects are now:

| | |
|---|---|
| Project I | General Program Management |
| Project II | San Onofre Nuclear Generating Station Auxiliary Feedwater System Analysis |
| Project III | Sensitivity Studies |
| Project IV | Completion of Zion Risk Assessment |
| Project V | Development of Simplified Models |
| Project VI | Validation of SSMRP Methodology |
| Project VII | Technology Transfer |
| Project VIII | BWR Risk Analysis |

All future reporting, including schedule, cost, and accomplishments, will be along the lines of these projects. This organization will make costs and progress towards these identifiable goals more transparent.

A second major change has been identification of a need to develop, in as timely a fashion as possible, a much-simplified version of the SSMRP methodology that will be suitable for use in performing or benchmarking routine seismic probabilistic risk assessments of nuclear power plants. Thus, we now have a specific project and budget for development of simplified models (Project V).

The third major change in the program has been in Project II, San Onofre Nuclear Generating Station (SONGS) Auxiliary Feedwater System Analysis. This project was begun in May 1981 to provide technical assistance to the NRC Office of Nuclear Reactor Regulation in their review of the SONGS plant. Work on this project was terminated in February 1982 at the request of NRC-NRR when unavoidable schedule conflicts in the delivery of input from Southern California Edison prevented completion of the project in a timely fashion. Before termination, a number of building response comparisons and model evaluations had been performed and sent for use by NRR. Because of the scheduling complications, it was determined that the remaining work would be only marginally cost-effective. During the months of February and March 1982, the SONGS analysis was put into a "wrap-up" mode, in which all pertinent data were assembled into a retrievable format, and a final report prepared to document all work completed. All activity and costing on the SONGS project will be completed following delivery of the final report in early May.

Scope activities and accomplishments in the remaining six projects are highlighted below.

**Project III. Sensitivity Studies**

Work on the sensitivity studies has been in progress since the beginning of the fiscal year. Our objective is to determine a preliminary ranking of components and safety systems with regard to their importance in contributing to final release category probabilities. These rankings and importance measures are based on the responses, fragilities, and accident sequences developed in Phase I of the SSMRP. The sensitivity studies are being used to determine the adequacy of the level of modeling used in Phase I, and to determine which (if any) areas of input require further attention, either analytically, experimentally, or through seeking additional data.

To this end, two importance-measure algorithms, the Vesely-Fussel measure and the Birnbaum measure, were programmed into the SEISIM code. After checking out these algorithms, an initial evaluation of importance ranking was made (based on 98 of the 148 accident sequences). The preliminary results showed that electrical components associated with the Emergency Safety Features electrical buses were most important. Next in importance were the power-operated relief valves and the reactor protection system. The most important safety system identified was the Auxiliary Feedwater System. A final set of importance-measure calculations will be made next quarter, using the entire set of 148 accident sequences, and a set of input uncertainties will be chosen to include random uncertainties only. (Uncertainties due to modeling will contribute to confidence bounds on the final results.)

One very important aspect of the Birnbaum importance measure is that it can be used to determine which components (or safety systems) should be upgraded to decrease, in the most cost-effective manner, the risk of radioactive release. Thus, it can be used to give the "biggest bang for the buck" in determining additional testing or quality assurance procedure changes or retrofitting options.

**Project IV. Completion of Zion Risk Assessment**

The objective of this project is to complete the seismic risk assessment for the Zion nuclear power plant that began in Phase I. By contrast, calculations performed in Phase I were demonstrations of the methodology, aimed at indicating any additional effort or scope required. Completion of the Zion seismic risk assessment involves three main additions to the Phase I calculations:

1. Completing the generation of all 148 accident sequences and their corresponding minimal cut sets.
2. Developing and implementing a cost-effective procedure for separating random-versus-modeling uncertainties and using the modeling uncertainties to compute confidence bounds on the final probabilistic risk results.
3. Completion of all needed piping models.

In the past two quarters, generation of all 148 accident sequences and cut sets was 90 percent complete. Solving the remaining fault trees required use of a new fault tree code (FTAP) instituted on a prime virtual memory computer. This code was modified to incorporate culling of the cut sets based on a dual probabilistic culling criterion. The use of probabilistic culling is a significant improvement over the manual techniques used in the Phase I calculations.

The task to develop and implement confidence bounds is proceeding on schedule. After initial investigation, eight possible avenues of approach were identified, leading to results of varying accuracy. A review panel consisting of Dr. C. A. Cornell (MIT), Dr. R. Wolff (UC, Berkeley) and Dr. Jon Collins (Acta, Inc.) was convened to help us in our review. As a result of this review, three alternatives were selected for further evaluation through pilot calculations to estimate computer cost. Final selection and implementation of the chosen method of computing confidence bounds will be performed next quarter.

All piping models selected for Zion were completed this last quarter. Four additional piping models for the Auxiliary Feedwater System were generated, completing the modeling for the Auxiliary Feedwater System. Since this system was found to be the most important safety system in the sensitivity studies of the Phase I results, it was felt that the piping modeling for this system should be completed back to and including pertinent parts of the main steam system.

The remainder of the year will be spent in ascertaining the effect of the local soil column geometry under Zion, completing all the accident sequence cut set determinations, rerunning the SMACS structural response calculations to separate random and modeling uncertainties, and, finally, computing the probabilities of failure and radioactive release with associated confidence bounds.

**Project V, Development of Simplified Models**

The scope and specific tasks for this project were defined in February 1982, and preliminary activities began in March. Our objective is to develop a simplified version of the SSMRP methodology that could be used to perform a seismic risk assessment for a cost of roughly $600,000 and in a time span of six to nine months. The methodology will be developed initially for a PWR, then extended to a BWR in Project VIII. The methodology will employ a standardized set of fault trees and accident sequences, design models, and calculational results, and calibrated uncertainties will be determined from our more detailed calculations.

The seismic input (time-histories and hazard curve) will be determined in a standardized procedure, resulting from a task to complete the seismic zonation of the central and eastern United States. This task, originally planned as part of the SSMRP, was transferred to the Earth Sciences Branch of the NRC Division of Health, Siting and Waste Management so that a closer coordination between NRC geosciences personnel could be maintained. This task, titled Seismic Hazard Characterization of the Eastern United States, will be reported under FIN A0392.

**Project VI, Validation of SSMRP Methodology**

This project gathers all the tasks devoted to benchmarking and validating the SSMRP methodology. Current tasks include reviewing and validating the fragility database used in Phase I, assessing structural damping values, and assessing the methods of generating the synthetic earthquake time histories by an alternative method based on Auto-regressive Moving Average (ARMA) models.

As part of the review of the Phase I fragility database, the Fragilities Panel was reconvened for a two-day meeting in February 1982. Besides reviewing our fragilities, the panel spent a significant part of the meeting helping us to determine the most appropriate means of separating random and modeling uncertainties for the fragility curves, as required for the final Zion risk calculations. In addition to the Fragilities Panel review, an ongoing search for additional data and for expert opinions has been under way. This work was undertaken by identifying people who have special knowledge of one or more of the generic fragility categories and by bringing each person to LLNL to review those categories and make recommendations for modification if appropriate. This activity will continue as new sources of information are identified.

The assessment of structural damping values was completed, and a report is in preparation. Work on the ARMA models began in January and is on schedule.

**Project VII, Technology Transfer**

The Technology Transfer project has the responsibility for timely dissemination of the codes, databases, and methodology developed in the SSMRP. This work will include both code configuration control and user's conferences in the future.

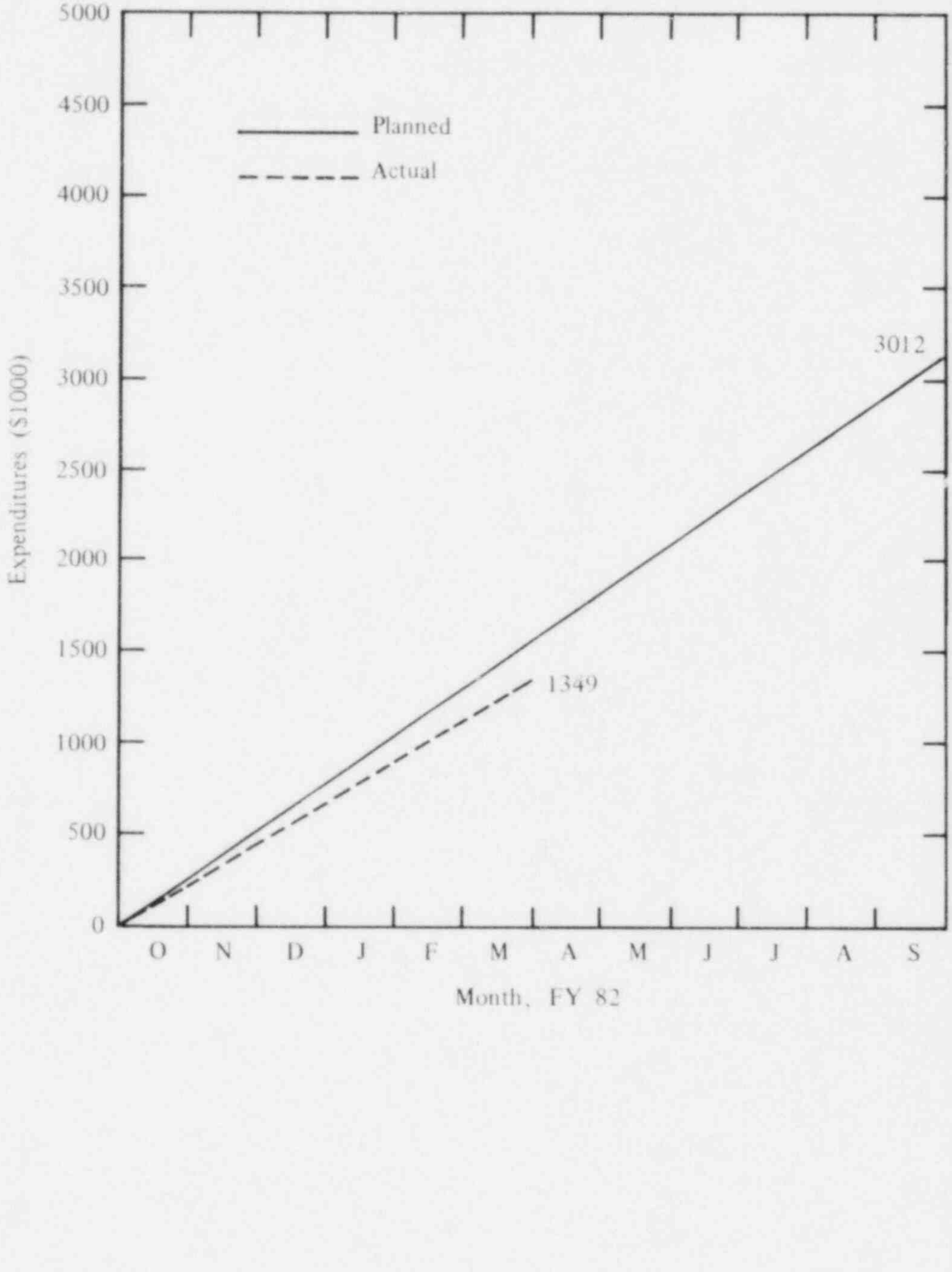
The main task in the past two quarters has been preparing a user's version of the SMACS structural response code. The code and its associated graphics package was installed on the Lawrence Berkeley Laboratory 7600 computer system. This version of SMACS is thus available to the public over standard telephone (MODEM) hookup. The same version of SMACS will compute the statistics of all building responses, including soil-structure interaction with any circular surface foundation overlying an arbitrary half-space model of the soil. Initial installation of this code was completed in February, and a draft of the user's manual will be released in early April.

**Project VIII, BWR Risk Analysis**

The scope of this project is to apply the simplified methodology developed for the PWR to a BWR, performing any required additional benchmarking in the process. This work will essentially follow the completion of the Development of Simplified Models project and will be performed primarily in FY 83.

Other than scope planning, there was no activity in this project in the past two quarters. In the remainder of FY 82, efforts will be devoted to obtaining existing fault and event trees for a BWR and modifying them to include seismic-induced failures. This work can be performed as soon as final negotiations with the owner/operator of the BWR under consideration are completed.

Expenditures for FY 82, Grand Totals (FIN A0126, A0362, A0363, and A0390)



## PROJECT I
## GENERAL PROGRAM MANAGEMENT
## FIN A0126

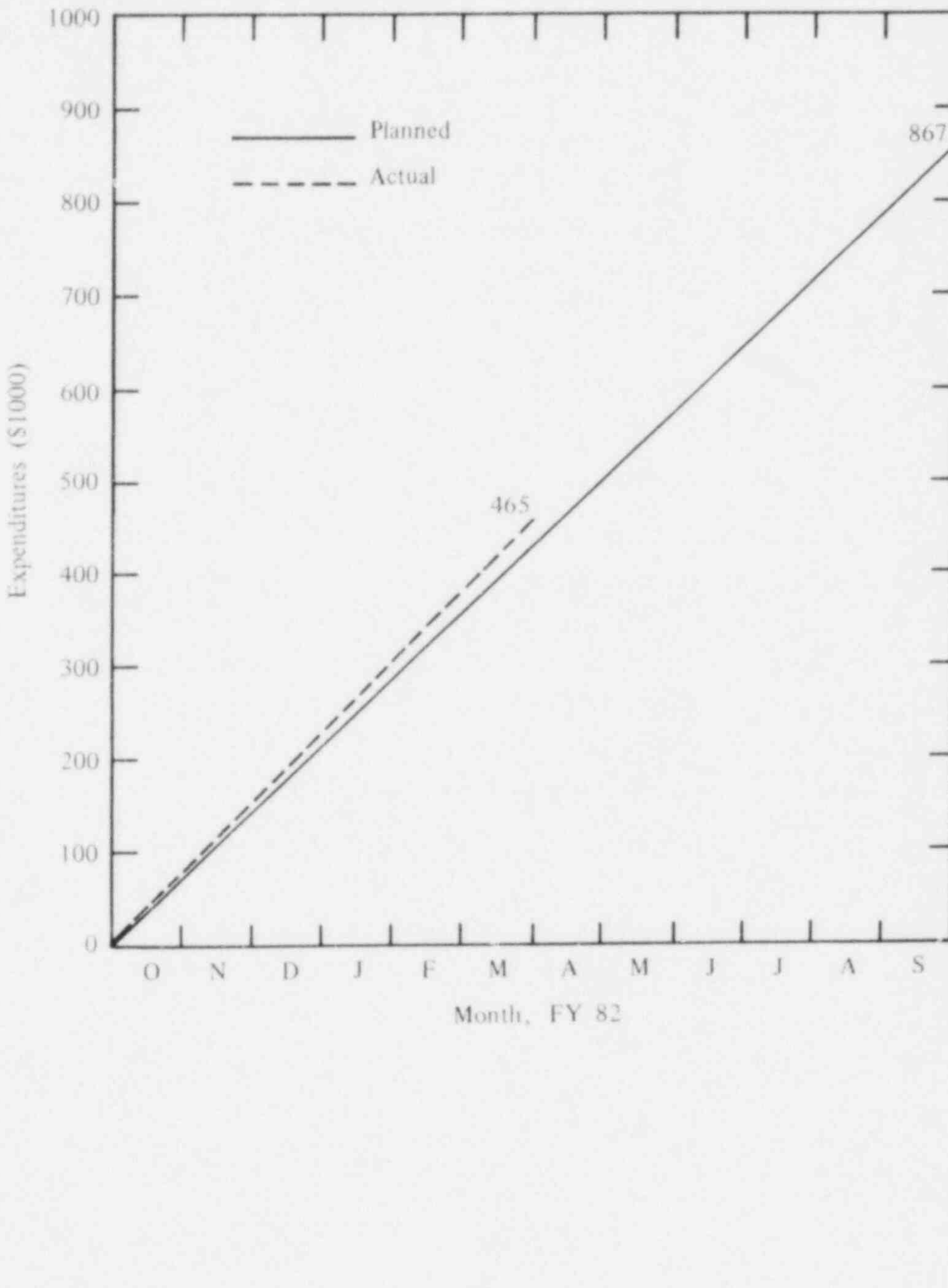
**Personnel**

NRC Program Manager: D. J. Guzy
Contractor: Lawrence Livermore National Laboratory (LLNL)
LLNL Program Manager: M. P. Bohn

**Reponsibilities**

1. Program coordination.
2. General consultants.
3. Technical documentation for all projects.
4. Applications to NRC concerns.
5. Program/projects travel cost.
6. Support of LLNL resident engineer at the HDR facility.

Expenditures for FY 82, General Program Management (FIN A0126)



## PROJECT I, GENERAL PROGRAM MANAGEMENT

### A. Accomplishments

Documentation of the SSMRP Phase I is nearing completion. Volume 4 of the Phase I final report (NUREG/CR-2015, Vols. 1-10) was completed and distributed. This report covers the Soil-Structure Interaction aspects of the Phase I calculations. All work on Volume 3 (Seismic Input) and Volume 8 (Systems Analysis) was completed, and these reports are in the final production stages. Volume 7 (Fragilities) is 80 percent written. The final report on the SONGS project is 90 percent complete.

An important activity in the Fall of 1981 was the presentations made at the 9th Water Reactor Safety Research Information Meeting. A full afternoon session was devoted to the SSMRP, with presentations by M. P. Bohn (Overview of the SSMRP), T. Y. Chuang (The SONGS Analysis), J. J. Johnson (Soil-Structure Interaction and Building Response), S. N. Shukla (SMACS Sensitivity Studies), and J. E. Wells (Probabilistic Risk and Failure Calculations).

Finally, a report was written describing the SSMRP on a "Scientific American" level of detail. It will be published in the April 1982 issue of the LLNL Energy and Technology Review, and should give nontechnical people an accessible description of the seismic risk question and the approach and progress made in the SSMRP to shed light on the issues involved.

PROJECT II
SAN ONOFRE NUCLEAR GENERATING STATION
AUXILIARY FEEDWATER SYSTEM ANALYSIS
FIN A0362

**Personnel**

NRC Program Manager: D. J. Guzy
NRC Project Manager: R. M. Kenneally
Contractor: Lawrence Livermore National Laboratory
LLNL Project Manager: T. Y. Chuang

**Objectives**

The objectives of Project II are to:

1. Identify the weak links in the auxiliary feedwater system (AFWS) of the San Onofre Nuclear Generating Station (SONGS) Unit 1.
2. Compare the probabilities of failure of the AFWS for Zion Unit 1 and SONGS Unit 1.
3. Compare the seismic responses of structures and piping systems of AFWS due to different input spectra and design values.

**Task Description**

Task II.1 – Development of Models for Response Computation

Task II.1 develops the models for soil, structures, soil-structure interaction and AFWS piping systems. Existing models furnished by SCE will be carefully studied to evaluate the efficiency of using them. If we find that using existing models is too inefficient–for instance, because of differences in computer programs–new models will be developed. For the portion in which SCE does not have existing models, new models will be developed. The task has four subtasks, described below.

Task II.1.1 – Develop Soil Model

Obtain and evaluate soil data for SONGS Unit 1. Estimate equivalent linear soil properties for system analysis.

Task II.1.2 – Develop Structural Models

Obtain, evaluate, and rerun the structure models furnished by SCE. Prepare the structure models for SMACS analysis. Benchmark the structure models against the models developed by SCE/Bechtel. Perform fixed-based eigenvalue analysis for model comparison.

Task II.1.3 – Develop Soil-Structure Interaction (SSI) Models

Generate the impedances and scattering matrices for soil conditions in system analysis. Prepare the SSI models for SMACS analysis.

Task II.1.4 – Develop Models of the AFWS Piping System

Obtain the piping system models for the AFWS from SCE. Evaluate and rerun these models. Create new models if necessary; for example, the portion of the AFWS was not recently modified (SCE may not have existing models for this portion). Identify the support points in the structures of these models.

Task II.2 – Comparison of the Seismic Responses of Structures and Piping Systems of AFWS with the Design Results

Task II.2 compares the seismic responses of structures and piping systems of AFWS due to different input spectra and the design results furnished by SCE. The input spectra are:

1. Original design (Housner) spectra for SONGS Unit 1 scaled up to 0.67 g ZPA (Zero Period Acceleration).
2. The design spectra for SONGS Units 2 and 3.
3. Spectra midway between the above two.

Generate a set of time histories for each spectrum. SMACS will perform the soil-structure interaction analysis, structure (housing AFWS) analysis, and AFWS piping analysis. Compute the seismic responses of structure and piping systems. Compare these results with the design results furnished by SCE. This task has four subtasks, described below.

Task II.2.1 – Develop Seismic Input Time Histories

Generate a set of time histories for each input spectrum. The response spectra of the time history will envelop their input spectra. The input spectra are specified under Task II.2 above.

Task II.2.2 – Compute Seismic Responses of Structures Due to Different Input Spectra

Compute the seismic responses of structures for each input spectrum as described above. Also compute the seismic motion of the AFWS piping support points. This seismic motion will be the input motion for the AFWS piping system.

Task II.2.3 – Compute Seismic Responses of the AFWS Piping Systems

Compute the seismic responses of the AFWS piping systems for each input spectrum.

Task II.2.4 – Compare the Seismic Responses of Structures and Piping Systems with the Design Results

Compare the results computed in tasks II.2.2 and II.2.3 with the design results furnished by SCE. This comparison will estimate the conservatism in the design analysis, which was based on the 0.67 g Housner spectra.

Task II.3 – Development of SONGS Site Specific Seismic Hazard Curves, Spectra, and Time Histories

In this task, we develop the seismic input required for both the systems analysis (SEISIM) and structural analysis (SMACS). SEISIM requires, as one of its inputs, the annual exceedence probability of any level of peak ground acceleration at the SONGS site. SMACS requires as input sets of time histories that are correlated with the hazard curve used in SEISIM. To develop this required input, we must first develop an Earthquake Occurrence Model that gives the locations of the earthquake relative to the SONGS site and rate of occurrence of various magnitude earthquakes. Along with the earthquake occurrence model, we also need a ground motion model that predicts the ground motion at the SONGS site from an earthquake of magnitude M located a distance R from the site. The earthquake occurrence model and ground models are used as inputs into our hazard analysis programs to generate the required input for SEISIM and SMACS. Thus three subtasks are defined:

Task II.3.1 – Develop the Earthquake Occurrence Model for the SONGS Site

Develop a range of earthquake occurrence models using both the extensive geologic and seismological investigation carried out by SCE and LLNL judgment. The SCE investigations will provide the basic zonation. Conduct also a brief literature review to develop a range of alternative models. Estimate rates of occurrence using both our data and SCE's data. Estimate largest earthquakes, using several approaches based on fault length, strain rate, and so on.

Task II.3.2 – Develop the Ground Motion Model for the SONGS Site

Ground motion models must be developed to account for the saturation of the magnitude scale based on such parameters as seismic moment, stress drop, and surface wave magnitude. In addition to source modeling, statistical analysis will be performed to establish reasonable bounds for correction factors to apply to generic ground motion models to account for focusing of seismic energy from nearby earthquakes. Our models will represent an extension of a project we have with RES and analysis of near source ground motion. In addition to our model, other ground motion models will be used.

Task II.3.3 – Develop Hazard Curves and Time Histories for the SONGS Site

Employ the computer programs developed in Phase II of SSMRP to develop the seismic hazard and spectra at the SONGS site, using the earthquake occurrence and ground motion models developed. Sensitivity studies will be carried out to determine which faults contribute most to the SEISMIC hazard. This information will be used to improve our model and reduce the uncertainty in our estimates. Time histories will be generated from the spectra developed from the improved model using SIMQ.

Task II.4 – AFWS Fault Tree Development

Task II.4 generates the fault tree for the AFWS of SONGS Unit 1. This task will also modify the AFWS fault tree of Zion Unit 1 to be comparable to SONGS Unit 1. The fault tree of the Zion-1 AFWS has been trimmed down considerably because the size of the SEISIM code is limited, since the system analysis includes other systems such as residual heat removal and safety injection. Because the AFWS is the only system considered in the analysis, therefore, the level of the details of fault tree could be brought up. This task has two subtasks:

Task II.4.1 – Develop Fault Tree of AFWS

Generate a fault tree for the AFWS, including water supply, electric power buses, AFW-pump discharge to steam generators, and the steam supply to the AFW-pump turbine. The fault tree will be analyzed to minimize cut sets, generate human and maintenance failure data, and generate fragility related basic event listings.

Task II.4.2 – Modify the Fault Tree of the AFWS of Zion Unit 1

Modify the AFWS fault tree for Zion Unit 1 to be comparable to SONGS Unit 1. Develop the fault tree of steam supply to the AFW-pump turbine. Analyze the modified fault tree for the input to SEISIM.

Task II.5 – Fragility Data Development and Fault Tree Coordination

Task II.5 develops the fragility curves of the structures and the beta-factors of the specific pipe sizes for SONGS Unit 1 AFWS. The fragility data for electrical and mechanical components of the Phase I of the SSMRP (which are generic in nature) will be used to the maximum extent. The fault tree will be coordinated with the responses of the electrical and mechanical components and the piping systems of AFWS. This task has four subtasks:

Task II.5.1 – Develop the Fragility Curves for the Structures Housing the AFWS

Using loads computed in the structures as part of Task II.2.2, examine the load paths, critical wall shear loads, and collapse mechanisms to determine the most likely modes of failure and corresponding fragility curves. These curves will include inelastic energy absorption through consideration of ductility factors. The building design specifications will also be examined for any potential local failures that might affect critical AFWS components.

Task II.5.2 – Develop the Beta Factor for the Piping Systems of AFWS

Piping fragility is determined by first scaling the computed response appropriately, then using a single master fragility curve. These scale factors (the "beta" factors) must be determined for all pipe sizes. A large number have already been derived for those pipes in the Zion plant. However, some additional factors will have to be developed for pipe sizes in SONGS that were not needed in the Zion analysis.

Task II.5.3 — Coordinate the Electrical and Mechanical Components of AFWS with Fault Tree and Structure Responses

Determine the location of the components (or groups of components) for each basic event identified on the fault trees developed in Task II.4.1 from either P & ID drawings or plant inspection, then prepare a table correlating all these components with their locations and fragility categories. Identify the minimum set of responses sufficient to provide the necessary SEISIM input for all the basic events and correlate these responses with the components on the fault trees.

Task II.5.4 — Coordinate the Responses and Fault Tree of the AFWS

Coordinate the seismic responses and fault tree of the AFWS. The beta factor technique developed in the Phase II of SSMRP will be used to normalize the responses, that is, resultant moments of pipes. Only those valves or pipe elements identified in the fault tree of AFWS will be analyzed.

Task II.6 — Identification of Weak Links of AFWS

Task II.6 computes the probabilities of failure of the AFWS of SONGS Unit 1. Responses of structures and AFWS piping systems will be computed by the SMACS computer program. Probabilities of failure of the AFWS will be computed by the SEISIM computer program. The weak links of the AFWS will be identified. There are two subtasks:

Task II.6.1 — Compute the Seismic Responses of Structures and AFWS

Compute the responses of structures and AFWS piping systems over a range of earthquake time histories developed in Task II.3.3. Coordinate these responses with the basic events of the fault tree of AFWS. Use SMACS to generate the response corresponding to its basic event as an input to SEISIM.

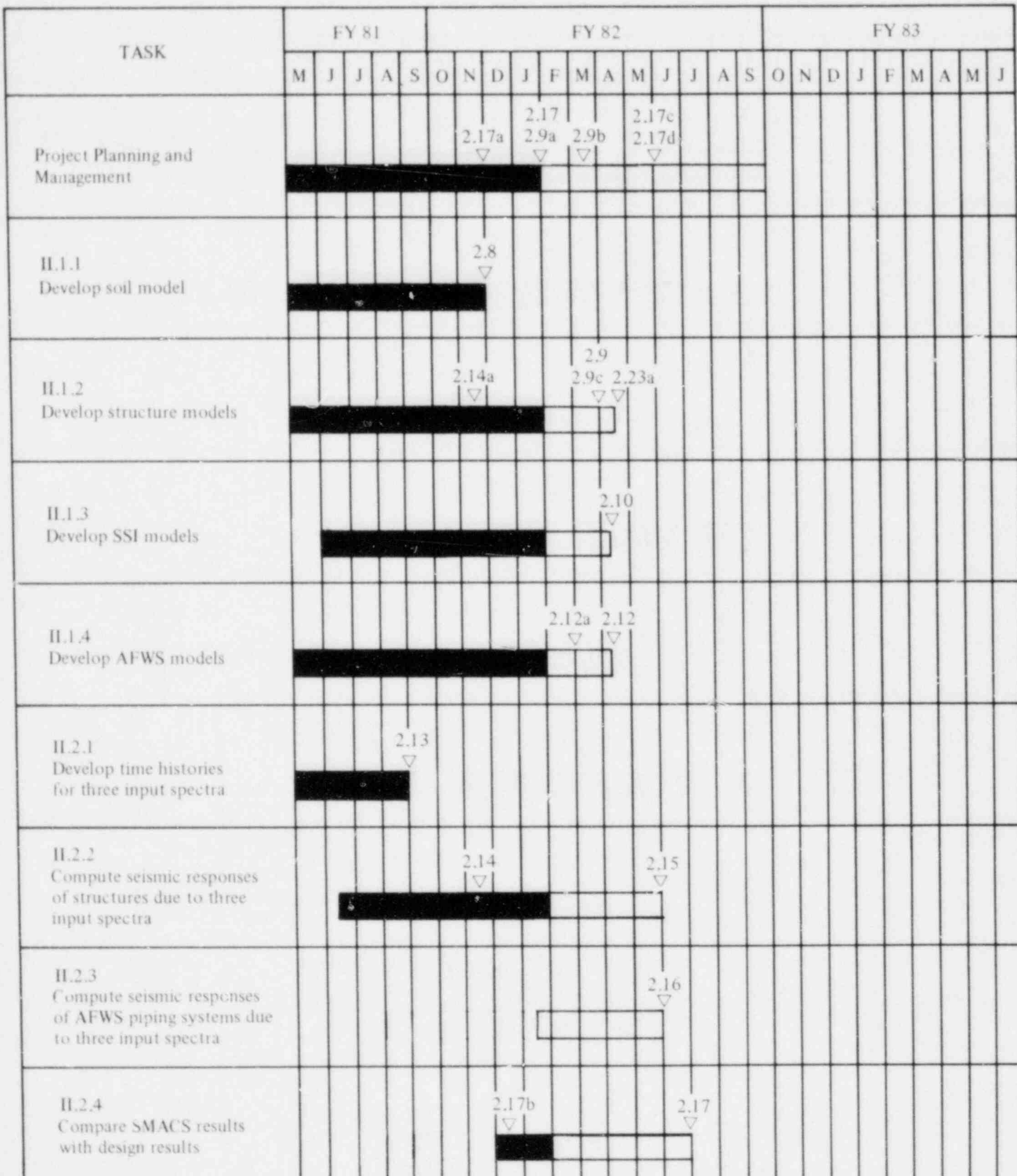
Task II.6.2 — Compute the Probabilities of Failure of AFWS and Identify the Weak Links

Incorporate the hazard curves, responses, fragility data, and fault tree into the SEISIM code. Compute the probabilities of failure of the AFWS. Produce the initial dominance ranking and generate additional dominance measures. Rank the risk contributors to the failure of the AFWS to identify the weak links of the AFWS of SONGS Unit 1.

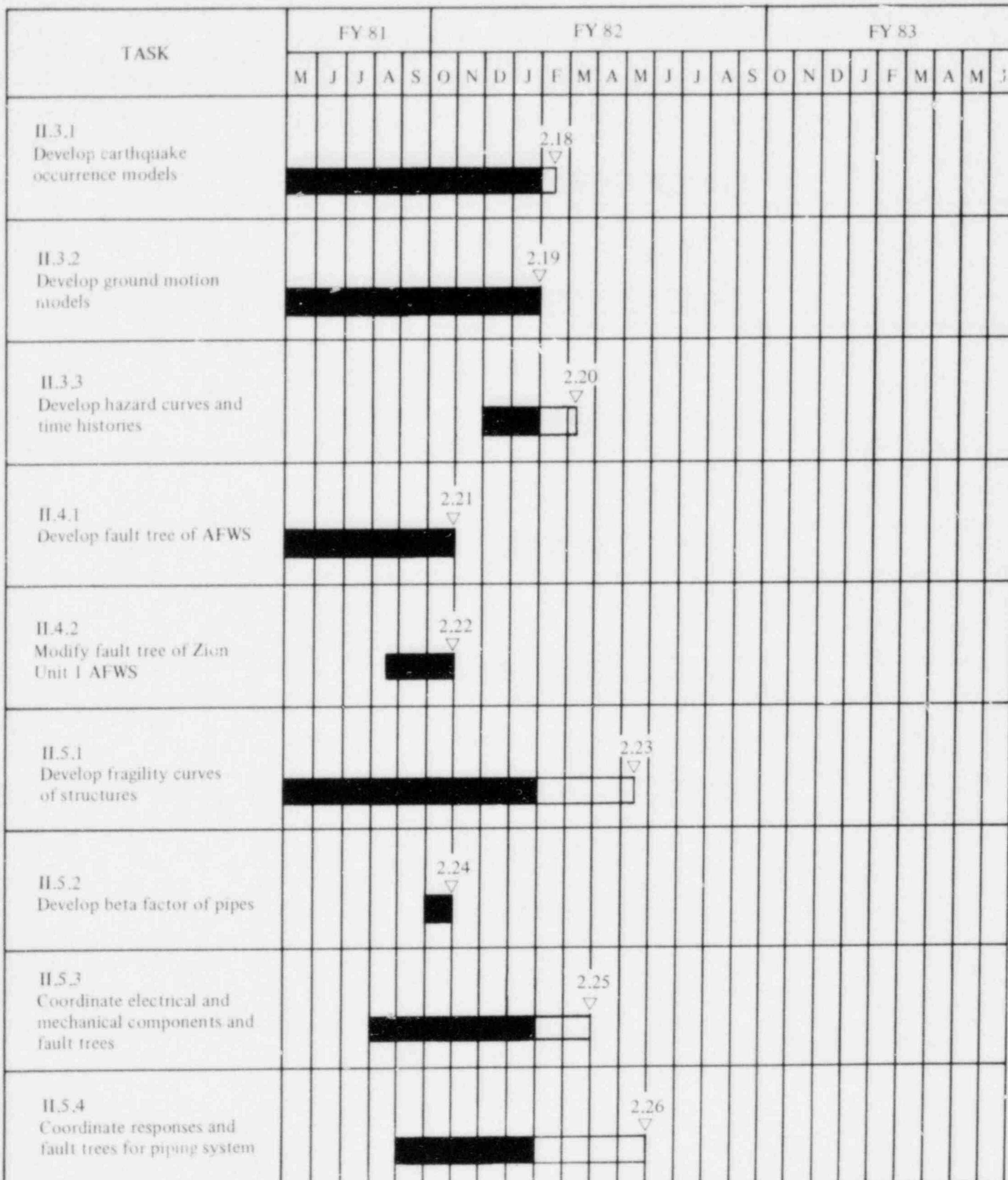
Task II.7 — Compare the Probabilities of Failure of the AFWS Between SONGS 1 and Zion 1

Compute the probabilities of failure of the AFWS of Zion Unit 1. Produce the initial dominance ranking, and generate additional dominance measures. Rank the risk contributors to the failure of the AFWS to identify the weak links of the AFWS of Zion Unit 1. Compare these results to the results for SONGS Unit 1.

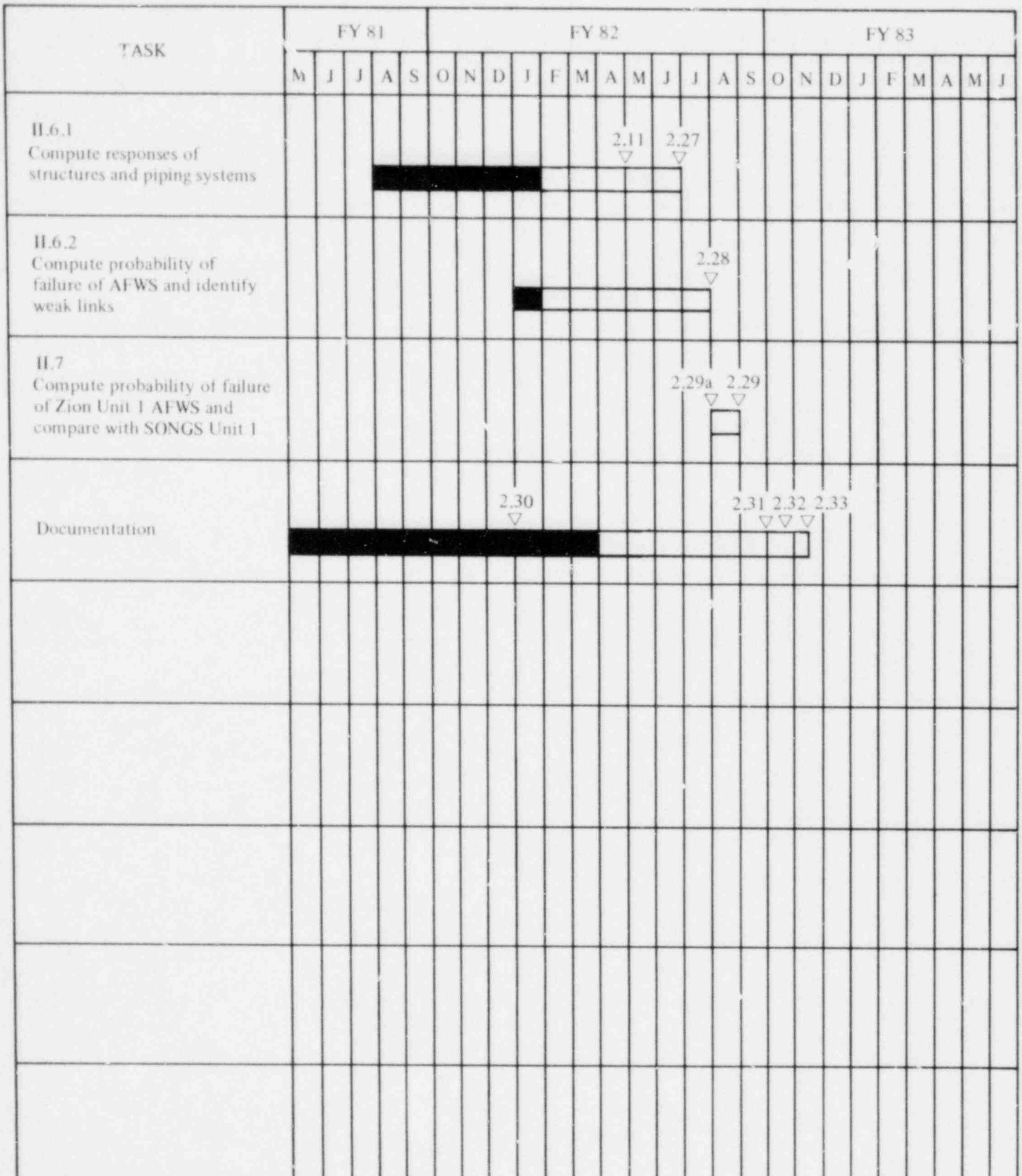
Project II Schedule



Project II Schedule
(continued)



Project II Schedule
(continued)



Project II Milestone Dates

| | Milestone | Original Target Date | Revised Target Date | Completed Date |
|---|---|---|---|---|
| 2.1 | Kickoff meeting | 11-21-80 | | 11-21-80 |
| 2.2 | SONGS site visit | 11-24-80 | | 11-25-80 |
| 2.3 | NRC-LLNL meeting | 12-18-80 | | 12-18-80 |
| 2.4 | Work plan completed | 1-15-81 | | 1-22-81 |
| 2.5 | Work plan revised | 2-6-81 | | 2-6-81 |
| 2.6 | Work plan finalized | 2-24-81 | | 2-24-81 |
| 2.6a | Work plan approved by NRC | | | 5-1-81 |
| 2.7 | All necessary data and models obtained from SCE | 7-3-81 | 1-29-82 | |
| 2.8 | Soil model developed | 7-3-81 | 12-1-81 | 12-1-81 |
| 2.9 | All structure models developed | 10-23-81 | 4-5-82 | |
| 2.9a | Modification of turbine and fuel storage building obtained from SCE | 1-29-82 | | |
| 2.9b | SCE/Bechtel fixed-base results of all structures obtained from SCE | 3-19-82 | | |
| 2.9c | All LLNL structure models (fixed base) compared with SCE/Bechtel | 4-5-82 | | |
| 2.10 | All SSI models developed | 10-23-81 | 4-5-82 | |
| 2.11 | SMACS test runs completed | 12-4-81 | 5-1-82 | |
| 2.12 | AFWS piping models developed | 10-23-81 | 4-5-82 | |
| 2.12a | AFWS piping supports location in the structure models identified | 3-1-82 | | |
| 2.13 | Time histories for the three NRC-specified input spectra developed | 7-3-81 | 7-15-81 | 8-31-81 |
| 2.14 | Reactor building responses due to the NRC-specified spectra computed | 8-14-81 | 11-24-81 | 11-24-81 |

Project II Milestone Dates
(continued)

| | Milestone | Original Target Date | Revised Target Date | Completed Date |
|---|---|---|---|---|
| 2.14a | Reactor building model compared with SCE/Bechtel | 11-15-81 | | 11-15-81 |
| 2.15 | All structure responses due to the NRC specified spectra computed | 1-8-82 | 6-1-82 | |
| 2.16 | AFWS piping responses due to the NRC specified spectra computed | 1-8-82 | 6-1-82 | |
| 2.17 | Design results and SMACS results compared | 2-5-82 | 7-1-82 | |
| 2.17a | Design results of reactor building obtained from SCE | 11-30-81 | | |
| 2.17b | Design results and SMACS results of reactor building compared | 12-15-81 | | 12-15-81 |
| 2.17c | Design results of all structures obtained from SCE | 6-1-82 | | |
| 2.17d | Design results of AFWS piping obtained | 6-1-82 | | |
| 2.18 | Earthquake occurrence model developed | 9-18-81 | 2-15-82 | |
| 2.19 | Ground motion model developed | 9-4-81 | 2-1-82 | |
| 2.20 | Hazard curves and time histories developed | 11-20-81 | 3-5-82 | |
| 2.21 | Fault tree of AFWS developed | 9-18-81 | 10-31-81 | 10-31-81 |
| 2.22 | Fault tree of Zion Unit 1 AFWS modified | 6-12-81 | 10-31-81 | 10-31-81 |
| 2.23 | Fragility curves for structures developed | 11-6-81 | 5-15-82 | |
| 2.23a | Preliminary stress analysis of structures for input to fragilities completed | 4-15-82 | | |
| 2.24 | Beta-factor for AFWS piping system developed | 10-16-81 | 10-31-81 | 10-31-81 |
| 2.25 | AFWS components, fault tree, and structure coordinated | 1-15-82 | 3-31-82 | |
| 2.26 | Responses and fault tree of piping coordinated | 12-18-81 | 6-1-82 | |

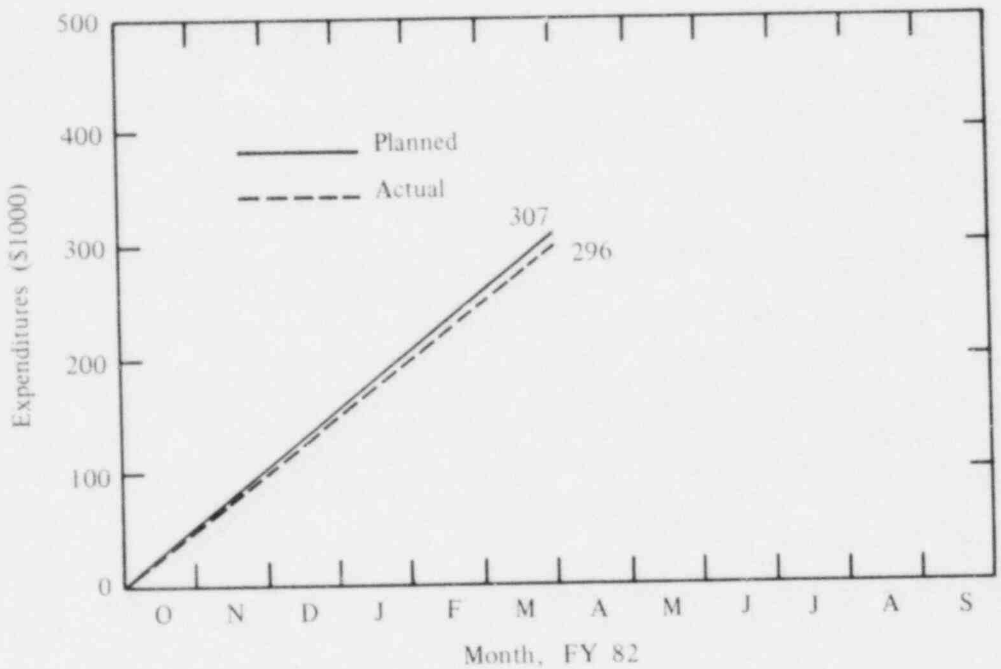
Project II Milestone Dates
(continued)

| | Milestone | Original Target Date | Revised Target Date | Completed Date |
|---|---|---|---|---|
| 2.27 | Seismic responses of structures and AFWS piping systems due to the time histories generated by Task II.3.3 computed | 2-15-82 | 7-1-82 | |
| 2.28 | Probabilities of failure of SONGS-1 AFWS computed | 3-19-82 | 8-1-82 | |
| 2.29 | Probabilities of failure of Zion-1 compared with SONGS-1 result | 4-16-82 | 9-1-82 | |
| 2.29a | Probabilities of failure of Zion-1 | 8-1-82 | | |
| 2.30 | Documentation of AFWS fault trees development | 12-31-81 | | 12-15-81 |
| 2.31 | Draft report of the SONGS-1 AFWS project transmitted to NRC | 10-1-82 | | |
| 2.32 | NRC comments on the draft report of SONGS-1 AFWS project received | 10-15-82 | | |
| 2.33 | Camera-ready copy of the final report of SONGS-1 AFWS project transmitted to NRC | 11-15-82 | | |

**Subcontractors**

1. Professor J. E. Luco, University of California, San Diego
2. Structural Mechanics Associates (SMA)
3. EG&G Inc.
4. Science Applications Inc. (SAI)

Expenditures for FY 82, Project II, San Onofre Nuclear Generating Station
Auxiliary Feedwater System Analysis (FIN A0362)



Project II, FY 82 Cost Breakdown

| | Task | Amounts ($1000) | |
|---|---|---|---|
| | | FY 82 Budget | YTD Spent |
| | Project Planning and Management | 35 | 28 |
| II.1.1 | Develop soil model | 2 | 2 |
| II.1.2 | Develop structure models | 8 | 31 |
| II.1.3 | Develop SSI models | 38 | 35 |
| II.1.4 | Develop AFWS models | 32 | 31 |
| II.2.1 | Develop time histories | 0 | 0 |
| II.2.2 | Compute structure responses | 9 | 8 |
| II.2.3 | Compute AFWS piping responses | 10 | 0 |
| II.2.4 | Compare SMACS results with design results | 5 | 4 |
| II.3.1 | Develop earthquake occurrence models | 9 | 7 |
| II.3.2 | Develop ground motion models | 9 | 8 |
| II.3.3 | Develop hazard curves and time histories | 44 | 29 |
| II.4.1 | Develop fault tree of AFWS | 16 | 16 |
| II.4.2 | Modify fault tree of Zion Unit 1 AFWS | 9 | 9 |
| II.5.1 | Develop fragility curves of structures | 56 | 17 |
| II.5.2 | Develop beta factor of pipes | 11 | 6 |
| II.5.3 | Coordinate electrical and mechanical components and fault trees | 15 | 6 |
| II.5.4 | Coordinate responses and fault trees for piping systems | 54 | 14 |
| II.6.1 | Compute responses of structures and piping systems | 62 | 21 |
| II.6.2 | Compute probabilities of failure of AFWS and identify weak links | 23 | 4 |

Project II, FY 82 Cost Breakdown
(continued)

| Task | | Amounts ($1000) | |
|---|---|---|---|
| | | FY 82 Budget | YTD Spent |
| II.7 | Compare probabilities of failure between SONGS-1 and Zion-1 | 44 | 0 |
| | Documentation | 30 | 20 |
| | Totals | 489 | 296 |

## PROJECT II, SAN ONOFRE NUCLEAR GENERATING STATION AUXILIARY FEEDWATER SYSTEM ANALYSIS

### A. Accomplishments

Work on this project continued only until January 31, 1982, when LLNL was directed by the NRC to stop the analysis effort. The accomplishments for each subtask up to this time are as follows:

**Project Planning and Management** — Additional information for SONGS-1 was received during this quarter. It included the data for piping, fixed-base analysis, and design response spectra of the reactor building at several selected points, together with other miscellaneous data. A team of LLNL personnel met with SCE and Bechtel on December 21, 1981. The subject of this meeting was Piping Information and Piping Response Comparison. We concluded that the most efficient way to gather piping information was to visit the SONGS Unit 1. We also discussed the piping response comparisons. The following response quantities should be compared:

| | |
|---|---|
| Piping components: | resultant moments |
| Active valves: | resultant accelerations |
| Piping supports: | forces and/or moments |
| Equipment nozzles: | nozzle loads (forces and moments) |

On January 20, 1982, we attended the presentation on "SONGS Unit 1 Masonry Wall Evaluation" by Computech Engineering Services at the NRC in Washington, DC.

**Task II.1.1, Soil Model Development** — Development of equivalent linear soil properties for use in the response comparison and seismic risk analysis was completed.

**Task II.1.2, Structure Model Development** — Structure model development proceeds in several steps: examination of the structural drawings and coding the model, debugging the model, eigenvalue extraction of the fixed-base structure, preliminary stress analysis for fragility assessment, independent review and benchmark of model with SCE results, and specification of all fragility, system, and subsystem requirements for response output from the SMACS analysis. SONGS-1 structure model development proceeded as follows:

- Sphere enclosure building, containment sphere, and reactor building — Each structure was being modeled separately in accordance with the input requirements of SMACS. Effort during the reporting period was devoted to benchmarking the reactor building model with SCE/Bechtel results. The modeling details of the SCE/Bechtel reactor building were matched as closely as possible to permit a valid model comparison. The resulting fixed-base frequencies were compared, and significant frequencies were found to be within 15% of each other. Remaining differences in modal analysis results were attributed to differences in modeling approach. A refined model of the containment sphere was developed to define more accurately the stress distribution near the sand/shell transition area. Both static and dynamic analyses were conducted to verify the adequacy of the new model. The reactor building and the containment sphere models were used in Task II.2.2.

- Turbine building — This building includes five separate structures on five interconnected foundations, plus the fuel storage building foundation. Three of the five were of detailed interest: the turbine pedestal, north turbine extension, and west feedwater platform. Models of the turbine pedestal, north turbine extension, and west feedwater platform were completed through the eigenvalue extraction stage during the quarter. The latter two models reflect design modifications provided by SCE/Bechtel. These design modifications are preliminary in the sense that the feasibility of field implementation remained to be evaluated. The south turbine extension model was revised to reflect the major equipment load data provided by SCE/Bechtel.

- Fuel storage building — An initial modal extraction analysis using the model of the modified fuel storage building was completed. However, at the request of SCE/Bechtel, the building model was redefined to its unmodified configuration, that is, before Bechtel's proposed design changes. A modal analysis of the revised model was not completed.

- Control-administration building — The eigenvalue extraction was completed during the reporting period, and a preliminary comparison of fixed base frequencies with Bechtel's results was made.

Details of the development of all structural models will be included in the project's final report.

**Task II.1.3, SSI Model Development** — This task is proceeding as follows:

- Reactor building/containment sphere — The final impedance and scattering matrices for the partial spherical foundation of the containment sphere/reactor building were completed for the 0.67-g acceleration level. These final results reflect a finer soil discretization and frequency interval than shown in our preliminary results. The preliminary values were smoothed to better match expected soil variations. The results were used in Task II.2.2.

- Other buildings — Sensitivity studies of the spatial discretization of the foundation impedance models for the turbine pedestal and several column footings were completed. Foundation models of anchor blocks Nos. 1 and 2 for the turbine building and for the fuel storage building were constructed, and similar sensitivity studies were conducted. A modified version of the computer program (SSIN), received from Prof. H. L. Wong, is capable of solving the SSI response problem for structures supported on multiple foundations. This version is presently being implemented at LLNL. Work was stopped on detailed modeling of the turbine building foundations pending receipt of foundation modifications from SCE/Bechtel.

**Task II.2.1, Time History Development** — This task has been completed.

**Task II.2.2, Computation of Seismic Responses of Structures Due to Different Input Spectra** — Using the dynamic characteristics of the reactor building and containment sphere defined in Task II.1.2 and the impedance and scattering matrices developed in Task II.1.3 for the partial spherical foundation, response analyses were performed for three definitions of the free-field ground motion at the SONGS site. In each case, thirty sets of time history records defined the input motion. The time histories were targeted to the SONGS Unit 1 seismic reevaluation response spectra, the SONGS Units 2 and 3 design response spectra, and the average of these two.

**Task II.2.4, Comparison of the Seismic Responses of Structures and Piping Systems with the Design Results** — Using the time history response from Task II.2.2, mean in-structure response spectra were calculated at seven points in the reactor building and compared with SCE/Bechtel design spectra. Median values of stress components at two locations on the containment sphere were also compared with SCE/Bechtel design calculations. Compared to our SMACS analysis (based on input time histories derived from spectra targeted to the SONGS-1 seismic reevaluation spectrum), the SCE/Bechtel design results envelop those of SMACS over the entire frequency range. As a general trend, the SCE/Bechtel results also envelop the SMACS results that used both the SONGS Units 2 and 3 design spectra and the average spectra as seismic input. The exception occurs at lower frequencies where the resonant frequency of our coupled soil-structure system occurs in conjunction with a much higher spectral amplification in the Units 2 and 3 design spectra.

**Task II.3.1, Earthquake Occurrence Model Development** — Considerable progress has been made on this task. Our consultant has completed a report on the assessment of active faults and maximum earthquakes of the Southern California-Northern Baja region adjoining the SONGS site. A study of the seismic activity rates using the historical earthquake history developed by us indicates that we will have to rely primarily on activity rates determined from estimates of the geological slip rate for the various faults. With our consultant, we have developed these required slip rates. We developed appropriate zones for our hazard assessment model.

**Task II.3.2, Ground Motion Model Development** – We have explored in some detail the effect of various schemes of weighting the near-field data to obtain improved estimates of the ground motion in the near-field. We have found that various scaling schemes lead to significant differences in the ground motion estimates–particularly for larger magnitude earthquakes. Since it is difficult to choose one model over another (each has positive and negative features), we will use several models in our hazard analysis.

**Task II.3.3, Development of Hazard Curves and Time Histories** – We have started the preliminary work on the task of incorporating the zonation and the activity rates developed in Task II.3.1 into our computer model. Also included in this task is the effort in obtaining the earthquake history sorted by zones for Task II.3.1. Some effort has been made to check out the computer program HAZARD MC developed in Phase I that was to be used to develop the spectra for the SONGS site.

**Task II.4.1, Fault Tree Development of AFWS** – The fault trees for the AFWS (including water supply, electric power buses, AFW pump discharge to steam generators, and the steam supply to AFW-pump turbine of the SONGS Unit 1) that were completed last quarter were analyzed. A draft report describing the fault trees has been completed.

**Task II.4.2, Fault Tree Modification of Zion Unit 1 AFWS** – The modified AFWS fault tree for Zion Unit 1 was analyzed. The draft report discussed in Task II.4.1 describes how the fault tree was modified so that it would be comparable to that of SONGS Unit 1.

**Task II.5.1, Structure Fragility Curve Development** – Preliminary evaluation of capacities for most of the structural elements in the structures housing the auxiliary feedwater system was completed. The structure fragility curves would be completed after the preliminary stress analysis identified in Task II.1.2 became available.

**Task II.5.2, Development of Beta Factors of Pipes** – Piping load scale factors (beta factors) were developed during this period for a wide range of parameters as needed for the SONGS Unit 1 auxiliary feedwater system. Tables of factors for stainless steel pipe and carbon steel pipe for the following are now available:

- Butt welds
- Elbows
- Reinforced and unreinforced branches
- Nominal diameters 0.5 through 24.0 in.
- Pipe schedules 10, 40, 60, 80, 120, 160
- Temperatures 100, 300, 500°F

**Task II.5.3, Coordination of Electrical and Mechanical Components and Fault Trees** – The fault trees for the SONGS Unit 1 auxiliary feedwater system were received and reviewed. Coordination of the basic events with the appropriate component fragility and location (to relate proper structural response) was begun.

**Task II.5.4, Coordination of Piping Responses and Fault Trees** – The specification of components for seismic response computation has been completed for eight of the nine auxiliary feedwater pump discharge piping models.

**Task II.6.1, Computation of the Seismic Responses of Structures and AFWS** – Preliminary setup work was initiated for the SMACS analysis.

B. **Next Quarter**

The final wrap-up and documentation of results obtained will be completed.

C. **Concerns**

1. **Technical**

   None.

2. **Schedule**

   None.

3. **Cost**

None.

D. **Meetings Attended**

December 21, 1981 – Piping response comparison and piping information discussion, Los Angeles, California, attended by T. Y. Chuang and L. C. Shieh.

January 20, 1982 – SONGS Unit 1 Masonry Wall Evaluation, Washington, DC, attended by T. Y. Chuang.

E. **Reports Released**

None.

PROJECT III
SENSITIVITY STUDIES
FIN A0126

**Personnel**

NRC Program Manager: D. J. Guzy
NRC Project Manager: D. J. Guzy
Contractor: Lawrence Livermore National Laboratory
LLNL Project Manager: J. E. Wells

**Objective**

To determine initially the relative contributors to seismic risk at the Zion site, using the building and component mechanical responses and the fragility database developed previously. These studies will identify any additional models or model refinements required and provide a preliminary indication of which components, safety systems, and accident sequences tend to contribute most to seismic risk at Zion. The results will play an important role, identifying areas to which significant validation effort should be devoted in the remainder of the SSMRP program.

**Task Description**

Sensitivity studies will be performed in each area of the calculational chain for seismic risk assessment. Specific tasks are described below.

Task III.1 – Ground Motion Model Sensitivity Studies

The objectives of this task are twofold. One is to develop alternative ground motion models to bound the potential systematic difference between eastern United States and western United States ground motion models. Distributions and bounds for the key parameters of ground motion models will be developed. The other objective is to develop confidence bounds. We will assess the impact these variations have on the definition of the seismic hazard in terms of the joint probability of a and $f_c$, and use these results with expert opinion to obtain a first approximation for confidence bounds on the seismic hazard. This task will require extensive regression analysis and earthquake modeling studies.

Task III.2 – Influence of Ground Motion Earthquake Occurrence Models on Time Histories

In Phase I we assumed that changes in the earthquake occurrence model or ground motion model would only primarily alter the probability of getting a given PGA range and only have a minor effect on the set of time histories used for the given PGA range. This assumption needs to be verified, or corrections should be made to the Phase I results. The objective of the task is to determine if it is necessary to generate new time histories when major changes are made in either the ground motion or the earthquake occurrence model or in both models. We hope to verify that the same time histories can be used and the influence of the changes in the model accounted for by only changing the hazard curve (probability of getting a given peak ground acceleration and corner frequency).

Task III.3 – SMACS/SSI Sensitivity Study

The objective of the sensitivity studies is to investigate the adequacy of the assumptions of the Phase I model and their effect on structural response and probability of radioactive release. Three key items require additional consideration:

1. Flexible basemat for the Zion Auxiliary-Fuel-Turbine (AFT) Building – model the AFT foundation as a series of interconnected rigid blocks to approximate more closely the physical situation.
2. Structure-to-structure interaction – include structure-to-structure interaction in computing structural response for seismic risk assessment of Zion Unit 1.
3. Effect of local nonlinear behavior (soil-structure separation) – its effect on structural response will be assessed.

In addition, special consideration will be given to the ability of soil shear modulus and damping to represent random and modeling uncertainty distinctly as we wish to do in Phase II.

Task III.4 – Sensitivity Study on Piping Support Behavior and Damping

The objective of this task is to study the effect of piping response due to damping (which only affects the dynamic responses of piping systems) and to support-stiffness. Two Zion-1 piping models will be used:

1. Auxiliary feedwater piping inside containment.
2. Residual heat removal and safety injection piping in the auxiliary building.

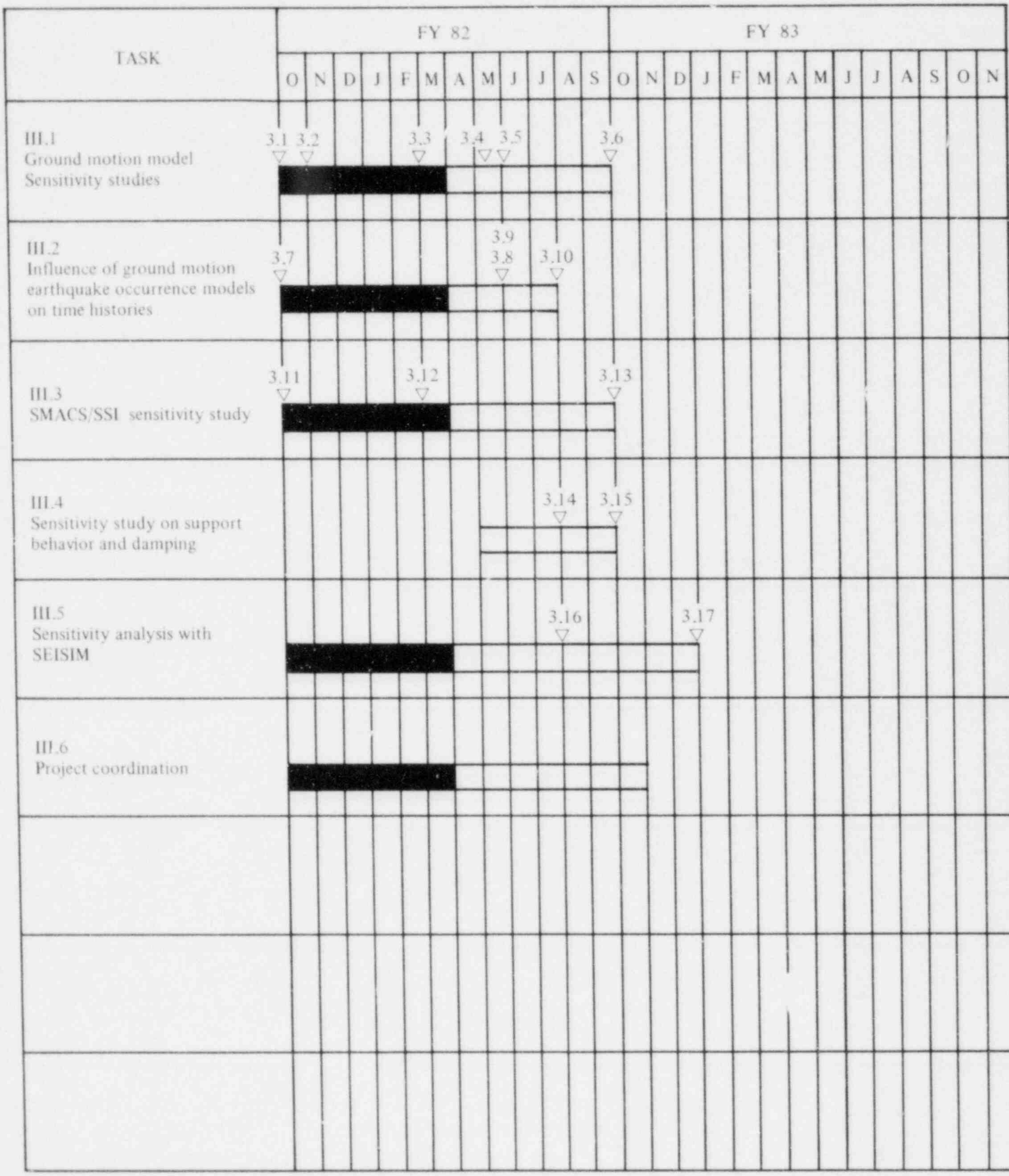
Task III.5 – Sensitivity Analyses with SEISIM

This task has two parts: importance ranking and sensitivity measurement. In the importance ranking portion, components, systems, accident sequences, and input parameters will be ranked on the basis of their importance to release probability. In the sensitivity measurement portion, the sensitivity of various output characteristics to changes or variations in significant input parameters is studied. These sensitivity measures will help the NRC develop an appropriate allocation of research resources.

Task III.6 – Project Coordination

Provide guidance on technical, administrative, and costs for the project. Interface with the other SSMRP projects.

Project III Schedule



Project III Milestone Dates

| | Milestone | Original Target Date | Revised Target Date | Completed Date |
|---|---|---|---|---|
| 3.1 | Initiate the extension of the data set developed in Task 2.1 of Phase I to include spectral data and selection of possible ground motion models to be investigated | 10-1-81 | | 10-11-81 |
| 3.2 | Initiate the development of ranges for earthquake parameters needed for model studies and start preliminary model studies | 11-1-81 | | 11-1-81 |
| 3.3 | Complete data set and model selection and start necessary regression analysis | 3-1-82 | | 3-1-82 |
| 3.4 | Complete choice of distributions and start final earthquake model studies | 2-1-82 | 5-15-82 | |
| 3.5 | Start combined assessment of both earthquake modeling study results and regression analysis results on hazard curves | 6-1-82 | | |
| 3.6 | Completion of results | 9-30-82 | | |
| 3.7 | Start selection of ground motion model/earthquake occurrence models to be studied | 10-1-81 | | 10-1-81 |
| 3.8 | Complete selection of models and start development of spectra and time histories for selected models | 12-1-81 | 5-15-82 | |
| 3.9 | Start preliminary assessment of influence on time histories and selection of sets to be sent to SMACS for evaluation | 4-1-82 | 5-15-82 | |
| 3.10 | Sets of time histories sent to SMACS for final evaluation | 6-1-82 | 8-1-82 | |
| 3.11 | Initiate flexible foundation study | 10-1-81 | | 10-1-81 |
| 3.12 | Initiate evaluation of structure-to-structure interaction, local nonlinear analysis assessment for Zion | 2-28-82 | | 2-1-82 |

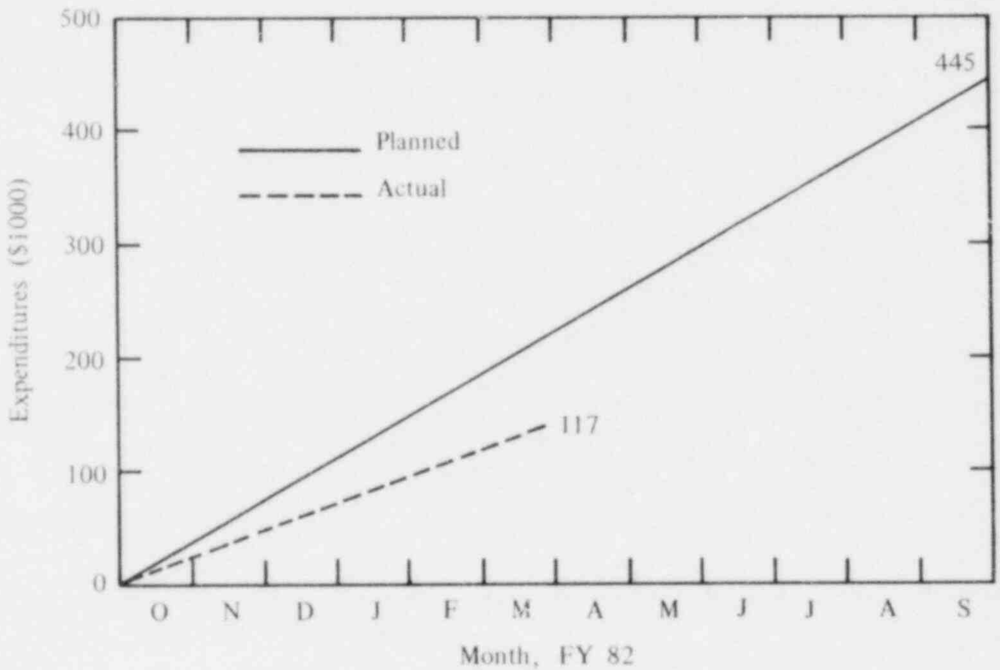
Project III Milestone Dates
(continued)

| | Milestone | Original Target Date | Revised Target Date | Completed Date |
|---|---|---|---|---|
| 3.13 | Complete flexible foundation and structure-to-structure interaction assessment for Zion | 6-30-82 | 9-30-82 | |
| 3.14 | Piping sensitivity study completed | 8-1-82 | | |
| 3.15 | Draft report on piping sensitivity study transmitted to NRC | 10-1-82 | | |
| 3.16 | Sensitivity studies using Phase I data complete | 6-30-82 | 7-30-82 | |
| 3.17 | Draft report on SEISIM sensitivity analyses transmitted to NRC | 1-1-83 | | |

**Subcontractors**

Structural Mechanics Associates (SMA)

Expenditures for FY 82, Project III, Sensitivity Studies (FIN A0126)



Project III, FY 82 Cost Breakdown

| Task | | Amounts ($1000) | |
|---|---|---|---|
| | | FY 82 Budget | YTD Spent |
| III.1 | Ground motion model sensitivity studies | 85 | 27 |
| III.2 | Influence of ground motion earthquake occurrence models on time histories | 20 | 8.2 |
| III.3 | SMACS/SSI sensitivity study | 90 | 32.4 |
| III.4 | Sensitivity study on piping support behavior and damping | 90 | 3.7 |
| III.5 | Sensitivity analysis with SEISIM | 110 | 23 |
| III.6 | Project coordination | 50 | 23 |
| | Totals | 445 | 117.3 |

## PROJECT III. SENSITIVITY STUDIES

### A. Accomplishments

**Task III.1, Ground Motion Model Sensitivity Studies** — We have obtained all of the currently available data for U.S. earthquakes and have installed the data on our computer system. Some data for Mammoth Lake and aftershocks of the Imperial Valley earthquake are still being processed. This will be completed during the next quarter. We are in the process of examining alternate ways of analyzing the data to yield better ground motion models. Of particular interest is how to improve scaling of ground motion models with magnitude and how the variation in Q influences the ground motion so that we can scale western U.S. data to the eastern U.S. The task has been delayed because of the resignation of Dr. Anthony Shakal. However, we have recently added Dr. Jean Savy to our staff, and he will be working on this task.

**Task III.2, Influence of Ground Motion Earthquake Occurrence Models on Time Histories** — The selection of ground motion model/earthquake occurrence models was started during this reporting period.

**Task III.3, SMACS/SSI Sensitivity Study** — Three areas of sensitivity studies were initiated during the reporting period–the effect of local nonlinear behavior (basemat uplift) on structural response and soil toe pressures, the effect of structure-to-structure interaction on structure and subsystem response, and the effect of flexible basemat assumptions on the response of the AFT comp'ex. Basemat uplift can influence two aspects of the seismic risk analysis: structure behavior, such as frequency shifts, and increased structure displacements and increased soil toe pressures. The latter item is important for estimating fina' risk numbers for Zion. Basemat uplift was investigated first through a literature review, then through formulation of the governing equations for the Zion containment building. Predicting when basemat uplift begins is straightforward from our linear analysis. However, predicting the amount of basemat uplift and the increase in toe pressure is much more difficult when only linear analysis is performed. We hope that calibration factors from published studies may be used to estimate it. Work preparatory to performing the structure-to-structure interaction sensitivity study was completed. The impedances and scattering matrices were assembled from existing data into the computer files necessary for SSIN or SMACS execution. Evaluation of the effect of a flexible basemat for the Zion AFT complex will be performed analytically. Implementation of a version of CLASSI that treats multiple foundations was initiated during this period.

**Task III.4, Sensitivity Study on Piping Support Behavior and Damping** — No activity during the reporting period.

**Task III.5, Sensitivity Analysis with SEISIM** — During the reporting period, a list of sensitivity analyses to be completed was generated. Modifications in SEISIM re‚aired to perform these analyses has been done. Preparation of input for these analyses has been started.

### B. Next Quarter

**Task III.1** — Installation of the Mammoth Lake and Imperial Valley earthquake data on our computer system will be completed next quarter. We will then start the combined assessment of both earthquake modeling study results and regression analysis results on hazard curves.

**Task III.2** — During the next quarter we will complete selection of models and start development of spectra and time histories for selected models. We will also start a preliminary assessment of influence on time histories.

**Task III.3** — Next quarter we will continue work on the flexible foundation and structure-to-structure interaction assessment for Zion. This work will be completed by the end of FY 82.

**Task III.4** — Work will begin on the piping sensitivity study during the next quarter. During the next quarter we will complete the analysis to study the effect of damping on piping response. We will initiate the study to analyze the effect of support stiffness on piping response.

**Task III.5** — During the next quarter we will begin our computer runs. The analysis will be completed during FY 82.

C. Concerns

1. **Technical**

None.

2. **Schedule**

Task III.2 – This task is behind schedule due to a change in staffing at LLNL. To complete this task in a timely fashion, we are seeking out a subcontractor to provide assistance in carrying out the scope of work.

Task III.3 – Completion of this project has been delayed. It will still, however, be completed during this fiscal year.

3. **Cost**

None.

## PROJECT IV
## COMPLETION OF ZION RISK ASSESSMENT
## FIN A0126

**Personnel**

NRC Program Manager: D. J. Guzy
NRC Project Manager: D. J. Guzy
Contractor: Lawrence Livermore National Laboratory
LLNL Project Manager: L. C. Shieh

**Objective**

To complete the analysis, begun in Phase I, of the Zion nuclear power plant. The results of the sensitivity studies performed as part of Project III will be used to guide any model refinements required. A major part of the completion of the Zion risk assessment is to develop a means of propagating random and modeling uncertainties separately through the entire seismic analysis chain, and thus end up with confidence bounds on the predicted probabilities of radioactive release.

**Task Description**

Task IV.1 – Confidence Intervals Development in SEISIM

Develop and implement techniques to construct statistical confidence intervals on the release histogram that simultaneously limit the probabilities in all release categories with a specified confidence. These intervals, which indicate the uncertainty due to sampling error in response and fragility, can then be extended to include seismic occurrence data, random failure data, and input variables used in deriving response quantities.

Task IV.2 – Complete SEISIM Computational Procedure

The following improvements will be incorporated into SEISIM:

1. Hunter's bound on the probability of accident sequences (it is already used for bounding system failure probabilities) to get more accurate bounds.
2. More efficient computation of sensitivity of event probabilities to changes of component strength and response parameters, including correlation.
3. Incorporation of probability of acceleration-dependent containment isolation valve failure.
4. Statistical ranking of importance measures for all earthquake levels in case ranks change at different levels.
5. Preparation of SEISIM for outside distribution.
6. Simplification of input and data management.

Task IV.3 – Modeling vs. Random Uncertainty for Fragilities

To be able to put uncertainty bounds on the final radioactive risk probabilities, it is necessary to separate the variance in each fragility curve into components due to random uncertainty (which cannot be further reduced by additional testing or analysis) and due to modeling, or systematic, uncertainty (which can be further reduced by testing or analysis). This has already been done for each independent mode in the expert opinion survey results; however, a valid statistical method must be devised to combine these independent modes into a single effective fragility curve with meaningful bounds. This will complete a task begun in FY 81.

Task IV.4 – Probabilistically Cull Fault Trees

All fault trees developed for Zion in Phase I will be probabilistically culled to ensure that all significant cut sets will be used in the final SEISIM risk evaluation.

Task IV.5 – Develop Additional Zion Piping Models

Develop the information necessary to determine the dynamic responses of the auxiliary steam supply to the auxiliary feedwater pump (AFWP) turbine of Zion Unit 1. This system's piping models, together with the models developed in Phase I and FY 81, will constitute all the models required for the comparison with the auxiliary feedwater system of SONGS Unit 1. This task includes generation of dynamic models, identification of the support location (in the structure) of safety systems, and coordination of the fault trees with calculated responses for the auxiliary steam supply to the AFWP turbine.

Task IV.6 – SMACS Software Development

The objectives of this task are to develop and maintain the computer program SMACS by (1) implementing features necessary to permit sensitivity studies to be performed, (2) improving the efficiency of SMACS, and (3) developing machine independent versions of SMACS to the extent possible.

Task IV.7 – Fragility Phase I Final Report

The purpose for this task is to complete the Phase I Final Report for the Fragility project.

Task IV.8 – Analysis of Local Site Conditions

Local site amplification has a potentially significant effect on structural response and is a major source of modeling uncertainty. In fact, Phase I did not include the effect of local site conditions on the seismic hazard curve or on the free-field acceleration time histories. The objectives of this task are to:

- Investigate the effects of local site conditions with respect to recorded ground motions.
- Examine the results of alternative calculational procedures to bound the effect.
- Develop earthquake time histories reflecting local site effects for SMACS sensitivity studies.
- Evaluate the effect of local site conditions on the Zion seismic hazard curve for inclusion in the final Zion analysis.

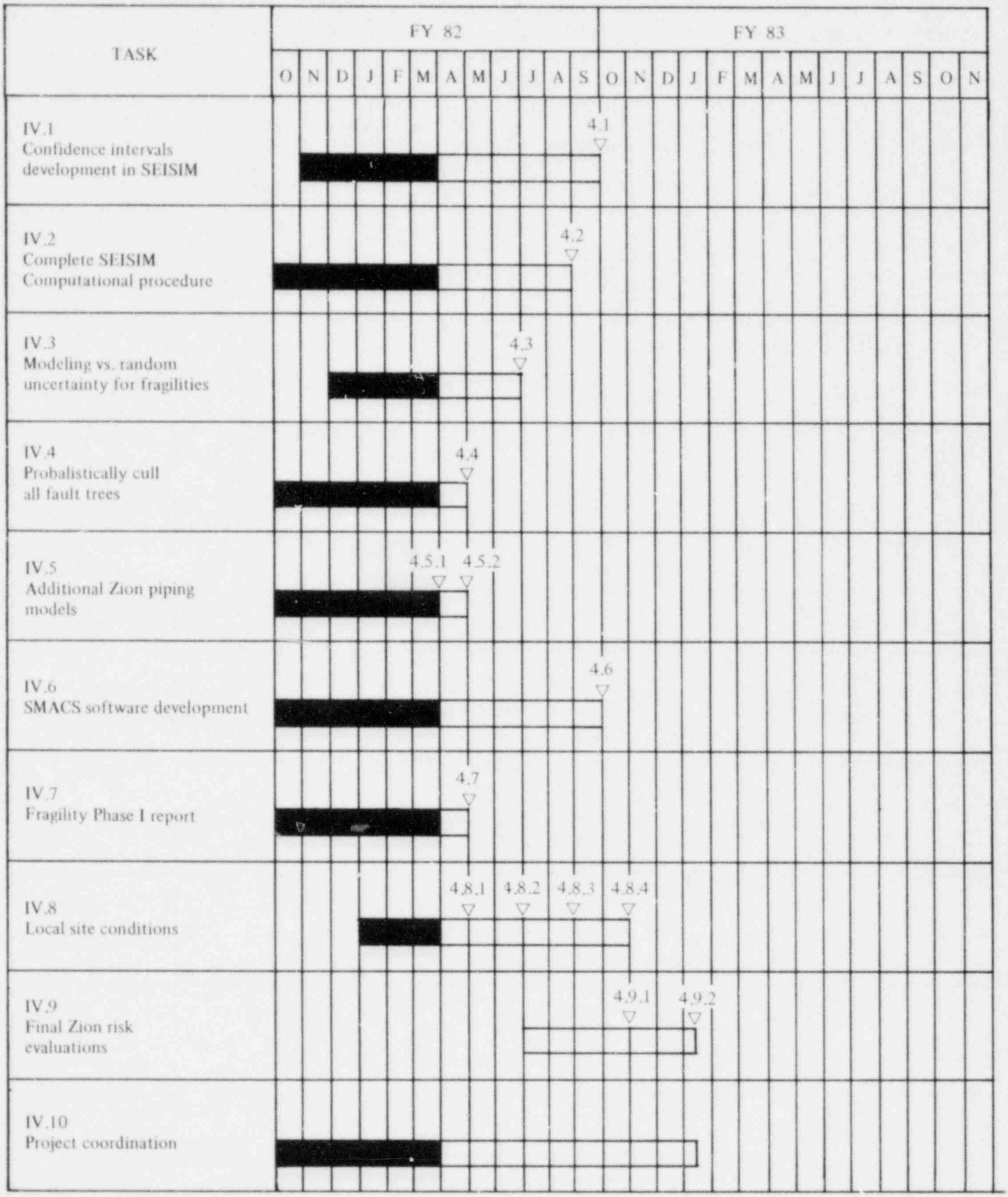
Task IV.9 – Final Zion Risk Evaluations

After completion of all the above tasks, a final SMACS evaluation of the building and component responses will be made, followed by a final SEISIM evaluation of risk of core melt and radioactive release.

Task IV.10 – Project Coordination

To provide coordination between projects within the SSMRP and coordination with outside projects whose work is related to the tasks and goals of the SSMRP.

Project IV Schedule



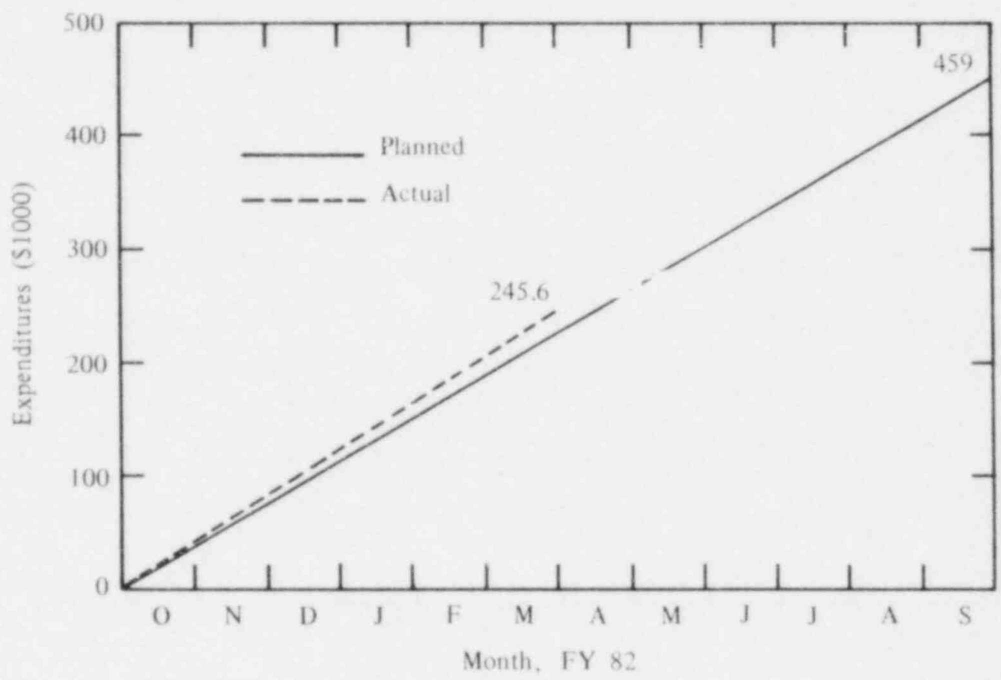
Project IV Milestone Dates

| | Milestone | Original Target Date | Revised Target Date | Completed Date |
|---|---|---|---|---|
| 4.1 | Confidence intervals and bounds probability | 10-1-82 | | |
| 4.2 | Complete SEISIM computational procedure | 9-1-82 | | |
| 4.3 | Random vs. modeling uncertainties separated for all fragility curves | 7-1-82 | | |
| 4.4 | Fault trees culled probabilistically | 5-1-82 | | |
| 4.5.1 | Piping models developed | 3-1-82 | 5-1-82 | |
| 4.5.2 | Fault trees coordinated | 5-1-82 | | |
| 4.6 | Complete SMACS development | 10-1-82 | | |
| 4.7 | Fragility Phase I Final Report | 5-1-82 | | |
| 4.8.1 | Local site effect considerations – data review | 5-1-82 | | |
| 4.8.2 | Analytical model for Zion development complete | 7-1-82 | | |
| 4.8.3 | Compare analytical results and recorded data | 8-30-82 | | |
| 4.8.4 | Documentation of results from local site condition study, draft report transmitted to NRC | 10-30-82 | | |
| 4.9.1 | Final Zion risk evaluation | 11-1-82 | | |
| 4.9.2 | Final report | 1-15-83 | | |

**Subcontractors**

1. Structural Mechanics Associates (SMA)
2. EG&G Inc.
3. Howard Lambert (consultant)
4. Science Applications Inc. (SAI)
5. Professor George Apostolakis, UCLA

Expenditures for FY 82, Project IV, Completion of Zion Risk Analysis (FIN A0126)



Project IV, FY 82 Cost Breakdown

| Task | | FY 82 Budget | YTD Spent |
|---|---|---|---|
| | | Amounts ($1000) | |
| IV.1 | Confidence intervals development in SEISIM | 60 | 41 |
| IV.2 | Complete SEISIM computational procedure | 65 | 48.1 |
| IV.3 | Modeling vs. random uncertainty for fragilities | 16 | 4 |
| IV.4 | Probabilistically cull all fault trees | 20 | 10 |
| IV.5 | Additional Zion piping models | 60 | 55 |
| IV.6 | SMACS software development | 40 | 24.5 |
| IV.7 | Fragility Phase I report | 8 | 2 |
| IV.8 | Local site conditions | 120 | 44 |
| IV.9 | Final Zion risk evaluations | 20 | 0 |
| IV.10 | Project coordination | 50 | 17 |
| | Totals | 459 | 245.6 |

## PROJECT IV, COMPLETION OF ZION RISK ASSESSMENT

### A. Accomplishments

**Task IV.1, Confidence Intervals Development in SEISIM** – The completed work included a review of various methods to determine potentially available computer confidence intervals on failure and release probabilities. Four of these were selected for further evaluation. The inputs for confidence limits computations have been agreed upon. The methods selected for Zion are being developed and programmed in the SEISIM code.

**Task IV.2, Complete SEISIM Computational Procedure** – The following were completed during the report period:

1. Birnbaum's component importance measure (derivative of top event probability with respect to component failure probability) was programmed. The Vesely-Fussel importance measure compares well with Birnbaum's measure.
2. A preliminary Monte Carlo version of SEISIM was programmed. It is being incorporated into SEISIM during the next quarter and includes three statistical confidence limits on the release histogram.
3. Programming of SEISIM part 2 (sensitivity and importance analyses).
4. A more efficient method to compute the sensitivity measure of release probabilities to changes of component strength and response parameters, including correlation.
5. Programming of statistical ranking of importance measures involved over all earthquake levels.

**Task IV.3, Modeling vs. Random Uncertainty for Fragilities** – To compute confidence intervals on SEISIM probabilities, uncertainty in inputs must be quantified. The inputs are response and fragility parameters, random component failure probabilities, and the seismic hazard curve. We quantify the uncertainty in response and fragility parameters by specifying joint probability distributions for them. We quantify uncertainty in random component failure probabilities by specifying beta distributions for them. We quantify uncertainty in seismic hazard by specifying alternative seismic hazard curves and probabilities for each.

**Task IV.4, Probabilistically Cull Fault Trees** – All fault trees are being culled to throw out minimal cut sets according to the following rules: (1) the minimum probability of any basic event is less than some value, for example, $10^{-5}$, or (2) the product of all basic events is less than some value, for example, $10^{-10}$.

The definition of basic event is the occurrence of component failure and earthquake per year. The culling will be completed next quarter.

**Task IV.5, Develop Additional Zion Piping Models** – Four models for the piping running from steam generators to the turbine driven auxiliary feedwater pump were developed. These four models and the auxiliary feedwater piping models developed in Phase I are considered to constitute all the models required for the auxiliary feedwater system of Zion Unit 1.

Piping/fault tree coordination was initiated during the report period.

**Task IV.6, SMACS Software Development** – No activity.

**Task IV.7, Fragility Phase I Final Report** – No activity.

**Task IV.8, Analysis of Local Site Conditions** – The task was initiated during the report period. Available empirical data obtained from earthquake and nuclear explosions were reviewed. Several sites were selected for data analysis. Ideally, three types of recorded data from sites experiencing one or more earthquakes are sought: records on soil sites and nearby rock sites, records from downhole arrays, and records on horizontal live arrays or concentric ring arrays. Initial work concentrated on the 1976 Friuli earthquake, which falls in the first category above. In the 1976 Friuli earthquake, one rock outcropping station and three nearby soil stations recorded five strong aftershocks with magnitude 4.4 to 6.1 that will be used.

A computer code capable of correcting the baseline uncorrected accelerograms has been developed. Development of a second computer code to compute the transfer functions and spectral ratios on the basis of earthquake records was initiated.

**Task IV.10, Project Coordination** – This task concentrated on project planning and searching for methods to compute confidence intervals on failure and release probabilities. A meeting was held to discuss the candidates of methods to compute confidence intervals.

**B. Next Quarter**

In the next quarter we will:

1. Continue the development of confidence intervals in SEISIM.
2. Continue incorporating acceleration-dependent containment isolation valve failure probability in SEISIM and development of machine independent versions of SEISIM computer code.
3. Develop procedures for delineating random and modeling uncertainty for the fragilities. The programming required to implement these procedures on SEISIM will be started during the next quarter.
4. Complete probabilistic culling of all fault trees.
5. Complete the generation of additional piping model and piping/fault tree coordination for these piping models.
6. Add an option to SMACS for modifying input time histories to account for local site effects. This modification, to be done in the frequency domain, will require as input material properties of the soil layers.
7. Complete the Fragility Phase I Final Report.
8. Complete the data review of local site condition considerations.
9. Complete the analytical model for Zion development.

**C. Concerns**

1. **Technical**
   None.
2. **Schedule**
   None.
3. **Cost**
   None.

**D. Meeting Attended**

March 26, 1982 – Confidence Intervals discussion, Lawrence Livermore National Laboratory, Livermore, California, attended by D. L. Bernreuter, M. P. Bohn, E. Carpenter, G. E. Cummings, L. L. George, R. Mensing, W. J. O'Connell, P. D. Smith, R. M. Thather, J. E. Wells and J. J. Johnson (SMA), C. A. Cornell (Dept. of CE, Stanford University), J. Collins - Consultant (formerly of J. E. Wiggins), R. W. Wolff (Dept. of IE & OR, UC, Berkeley).

**E. Reports Released**

"Seismic Safety Margins Research Program, Phase I Final Report – Soil Structure Interaction," Lawrence Livermore National Laboratory, UCRL-53021, Vol. 4, NUREG/CR-2015, Vol. 4.

## PROJECT V
## DEVELOPMENT OF SIMPLIFIED MODELS
## FIN A0126

**Personnel**

NRC Program Manager: D. J. Guzy
NRC Project Manager: D. J. Guzy
Contractor: Lawrence Livermore National Laboratory
LLNL Project Manager: M. P. Bohn (acting)

**Objective**

The goal of the project is to develop a simplified methodology for routine probabilistic risk assessments that can be implemented at a cost of roughly $600,000 and in 6-8 months for any specific plant. The methodology will use the tools, codes, and databases developed in Phase II of the SSMRP, but will employ responses calibrated from the plant design calculations developed from our detailed analysis of the Zion plant.

A major task in the development of a complete, simplified seismic risk assessment methodology is to devise a unified scheme for inferring the seismic hazard curve at any given site. This will be accomplished by developing consistent tectonic zonation and attenuation models for all parts of the U.S. east of the Rocky Mountains. Much of this work was already accomplished for the northwest U.S. as part of the Zion hazard definition in Phase I. The seismic hazard characterization work has been transferred to FIN A0392, under the direction of the NRC Earth Sciences Branch.

The tasks remaining are those associated with developing simplified building and piping response models, functional PWR accident sequences, and testing the simplified methodology against the more detailed risk calculations performed for Zion under Project IV.

**Task Description**

Task V.1 – Building Response Calibration

A set of guidelines will be developed for scaling design building responses to best-estimate responses for input to the SEISIM code. This will include a review of existing simplified response modeling techniques. It will also include categorization of different design approaches used in the nuclear industry. Uncertainties will be derived from our detailed Zion response calculations, as well as an appropriate means of including all necessary response cross-correlation.

Task V.2 – Piping Response Calibration

This task has the same definition as for building response calibration above, and will be approached in the same fashion. However, a number of other issues (combination of loads, non-category I systems, and so on) must also be considered. The level of approximation here will be guided by our experience with previously computed estimates of piping failure probability made for Zion.

Task V.3 – Selection of PWR Generic Accident Sequences

Based on sensitivity studies and dominance ranks for the Zion plant, and on a review of different PWR Safety System interactions, a sufficiently general set of generic accident sequences will be selected to be recommended as a standardized basis for probabilistic seismic risk assessment of PWRs.

Task V.4 – Categorize PWR Fault Trees

In this task we will seek to develop a set of functional PWR fault trees whose level of detail will be guided by our experience at Zion. They should be sufficiently general to apply to any U.S. designed PWR and should have provisions for tailoring them to any specific design. The important feature is that the recommended level of detail should be such that all essential seismically induced basic events (failures) are included. Here again we will be guided by our sensitivity studies and dominance rankings.

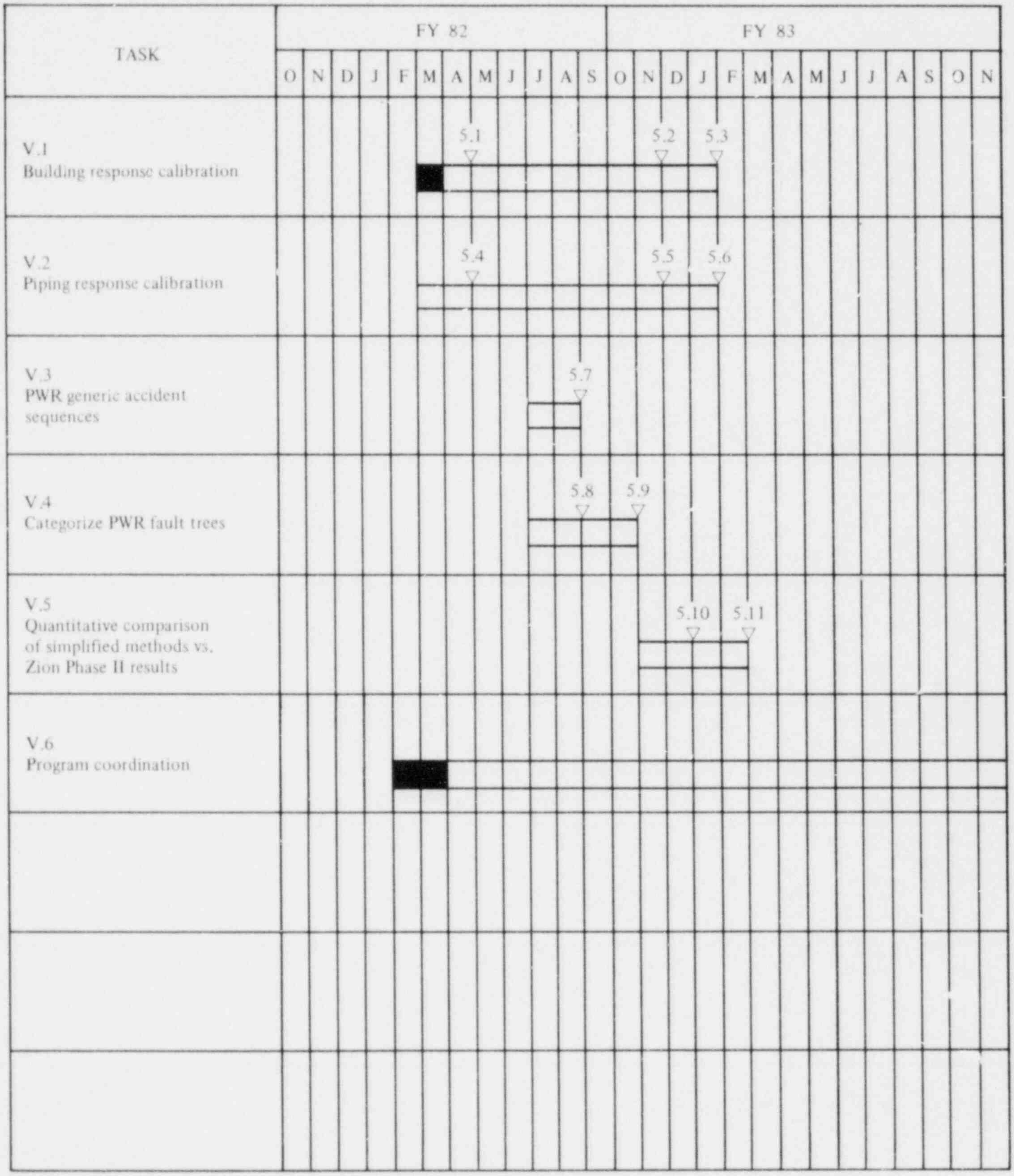
Task V.5 – Quantitative Comparison of Simplified Methods vs. Zion Phase II Results

The simplified methodology will be applied to Zion, and detailed comparison with the Phase II results will be made to quantify the approximations made in applying this methodology.

Task V.6 – Program Coordination

This task will coordinate projects within the SSMRP and outside projects whose work is related to the tasks and goals of the SSMRP.

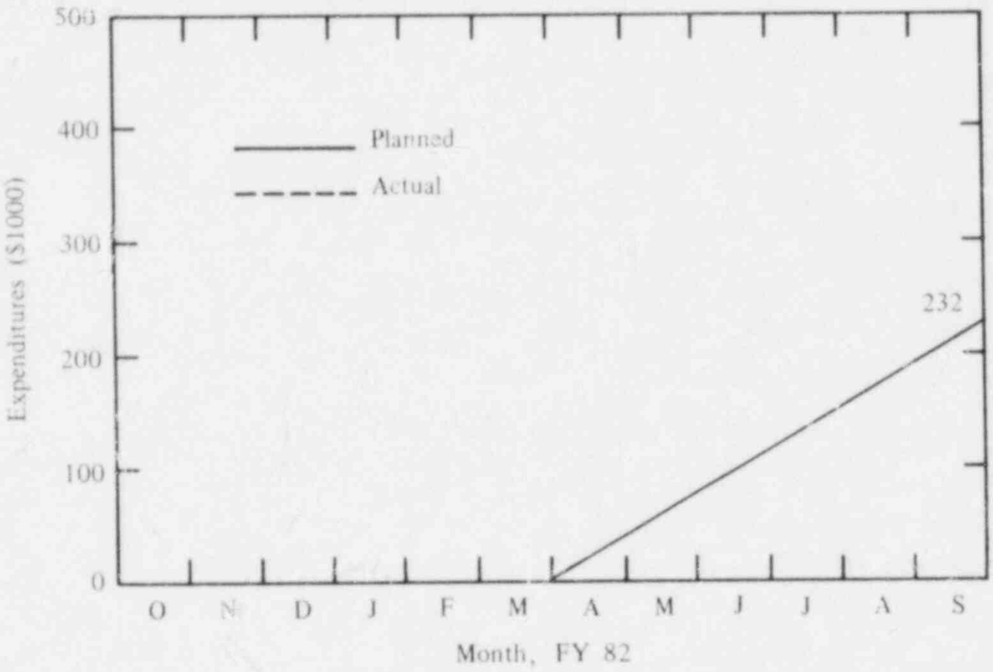
Project V Schedule



Project V Milestone Dates

| | Milestone | Original Target Date | Revised Target Date | Completed Date |
|---|---|---|---|---|
| 5.1 | Review of building design and SSI methodologies complete | 9-1-82 | | |
| 5.2 | Calibration factors derived from Zion analysis | 12-1-82 | | |
| 5.3 | Recommendations for simplified building response made | 2-1-83 | | |
| 5.4 | Review of piping design methodologies complete | 9-1-82 | | |
| 5.5 | Calibration factors derived from Zion, SONGS analyses | 12-1-82 | | |
| 5.6 | Recommendations for simplified piping response made | 2-1-83 | | |
| 5.7 | Generic PWR accident sequences identified | 9-1-82 | | |
| 5.8 | Review of typical PWR safety systems interactions completed | 9-1-82 | | |
| 5.9 | Functional PWR fault trees identified | 11-1-82 | | |
| 5.10 | Final comparison for Zion between simplified methods and Phase II results complete | 3-1-83 | | |
| 5.11 | Final report | 6-1-83 | | |

Expenditures for FY 82, Project V, Development of Simplified Models (FIN A0126)



Project V, FY 82 Cost Breakdown

| Task | | Amounts ($1000) | |
|---|---|---|---|
| | | FY 82 Budget | YTD Spent |
| V.1 | Building response calibration | 60 | 0 |
| V.2 | Piping response calibration | 100 | 0 |
| V.3 | PWR generic accident sequences | 10 | 0 |
| V.4 | Categorize PWR fault trees | 12 | 0 |
| V.5 | Quantitative comparison of simplified methods vs. Zion Phase II results | 0 | 0 |
| V.6 | Program coordination | 50 | |
| | Totals | 232 | |

## PROJECT V, DEVELOPMENT OF SIMPLIFIED MODELS

### A. Accomplishments

**Task V.1, Building Response Calibration** — The task of developing simplified methods was initiated on two topics during the reporting period. One was review and summarizing of the seismic analysis and design procedures for exiting nuclear power plants (the result to indicate candidate methodologies for benchmarking simplified methods). The other was examination of the Zion specific design results for comparison with SSMRP Phase I data. Detailed information was assembled for all nuclear power plants with operating licenses. For the 75 to 100 units in various stages of completion but without operating licenses, limited information was also available. In-structure response spectra for the Zion structures developed during the SSMRP Phase II were compared with Zion design values. The former spectra were mean and mean-plus-and-minus-one-standard-deviation values. Our objective was to compare median response with design values. The results showed varying degrees of conservatism for the design values relative to median responses.

### B. Next Quarter

In the next quarter we plan to select candidate sites and structures for which benchmarking calculations will be performed.

### C. Concerns

1. **Technical**
   None.
2. **Schedule**
   None.
3. **Cost**
   None.

### D. Meetings Attended

None.

### E. Reports Released

None.

## PROJECT VI
## VALIDATION OF SSMRP METHODOLOGY
## FIN A0126

**Personnel**

NRC Program Manager: D. J. Guzy
NRC Project Manager: D. J. Guzy
Contractor: Lawrence Livermore National Laboratory
LLNL Project Manager: L. E. Cover

**Objective**

The objective of this project is to provide ongoing assessment and overall validation of the tools and methodology developed in the SSMRP. This includes evaluation and update of the seismic and fragility databases, quality control and benchmarking of the computer codes, and validation of the entire calculational scheme by comparison with actual data where possible. Potential data sources for such overall validation are the ongoing tests being performed at the HDR facility in W. Germany (in which the NRC is an active participant), tests at the Indian Point Power Plant in the United States, and (possibly) data from the Ochiba field station tests in Japan.

A major effort begun in FY 81 and continuing through FY 82 and beyond will benchmark the fragility curves developed from the expert opinion survey prepared in FY 80. A large part of this effort will be to obtain data from sources identified during the expert opinion survey performed in FY 80 and to seek new sources of data existing outside the nuclear community. To understand the data and its relation to the preliminary fragility curves developed in Phase I of the SSMRP, a number of consultants will be retained. The experts will be selected from those expressing both interest and evident capability to participate further in the expert opinion survey.

**Task Description**

Task VI.1 – Fragility Data Gathering and Reduction

The effort to obtain and correlate existing fragility data will be completed. Data will be sought from two main sources. The first source is the component manufacturers and independent testing laboratories who indicated that they had access to failure data during the expert opinion survey. The second source is known testing programs associated with U. S. military site-hardening and crashworthiness programs. The data obtained will be compiled and compared with the preliminary fragility curves developed from expert opinion during Phase I. The data will be used to benchmark the preliminary fragility curves developed in Phase I and to resolve a number of questions identified in Phase I, as described in Task VI.2.

Task VI.2 – Benchmark and Revise Fragility Descriptions

A number of questions have been identified concerning the results of the expert opinion survey. The questions must be answered before we can use the fragility curves in a calculation of magnitude of seismic hazard. Especially important are (1) whether the identified generic categories are too broad and the present uncertainty in fragility would be reduced by a finer resolution in generic category definition, (2) the wide spread in fragility levels associated with different definitions of failure from different expert opinion respondents, and (3) whether the independent fragility parameters are truly those most applicable to failure or were chosen because they were most convenient for specification of qualification testing.

To answer these and other fundamental questions and to benchmark the fragility curves developed for Phase I, experts will be identified for each generic category. These experts will have experience with the performance of the components involved. They will review the data obtained in Task VI.1 and new data as it becomes available, review their own data sources, and help evaluate the data to see whether it applies to seismic loading conditions and resolution of the questions raised above. This is a continuation of a task begun in FY 81.

After incorporating all new data and after the re-evaluation and revision of the fragilities, the resulting fragility curves used for the final Zion risk analysis will be documented in an update of the Phase I Fragility database report.

Task VI.3 – Fragilities Panel

The present panel will continue to review and guide the entire fragilities effort. The panel consists of:

| | |
|---|---|
| Spencer H. Bush | Battelle Pacific Northwest Labs |
| Robert P. Kennedy | Structural Mechanics Associates |
| George D. Shipway | Wyle Laboratories |
| John D. Stevenson | Stevenson & Associates |
| Jerrell M. Thomas | Failure Analysis Associates |
| Peter P. Zemanick | Westinghouse Electric Corporation |
| Everett C. Rodabaugh | E. C. Rodabaugh & Associates, Inc. |

The panel made an outstanding contribution to the direction and scope of the fragilities definition work performed in Phase I, and their continued involvement is considered essential.

Task VI.4 – Structural Damping

The objective is to review and assess structural damping data presently available. We will categorize existing data in natural groupings, identify deficiencies, and recommend additional testing.

The approach is to acquire and assess data. Work will include identification and acquisition of damping data and the review, evaluation, and categorization of the data. Particular emphasis will be placed on soil-structure interaction effects, structural types (material, type of construction, plan-height), and the excitation (type and level).

This task, a joint effort partially funded by LLNL, consists of a Ph.D. thesis of an LLNL employee.

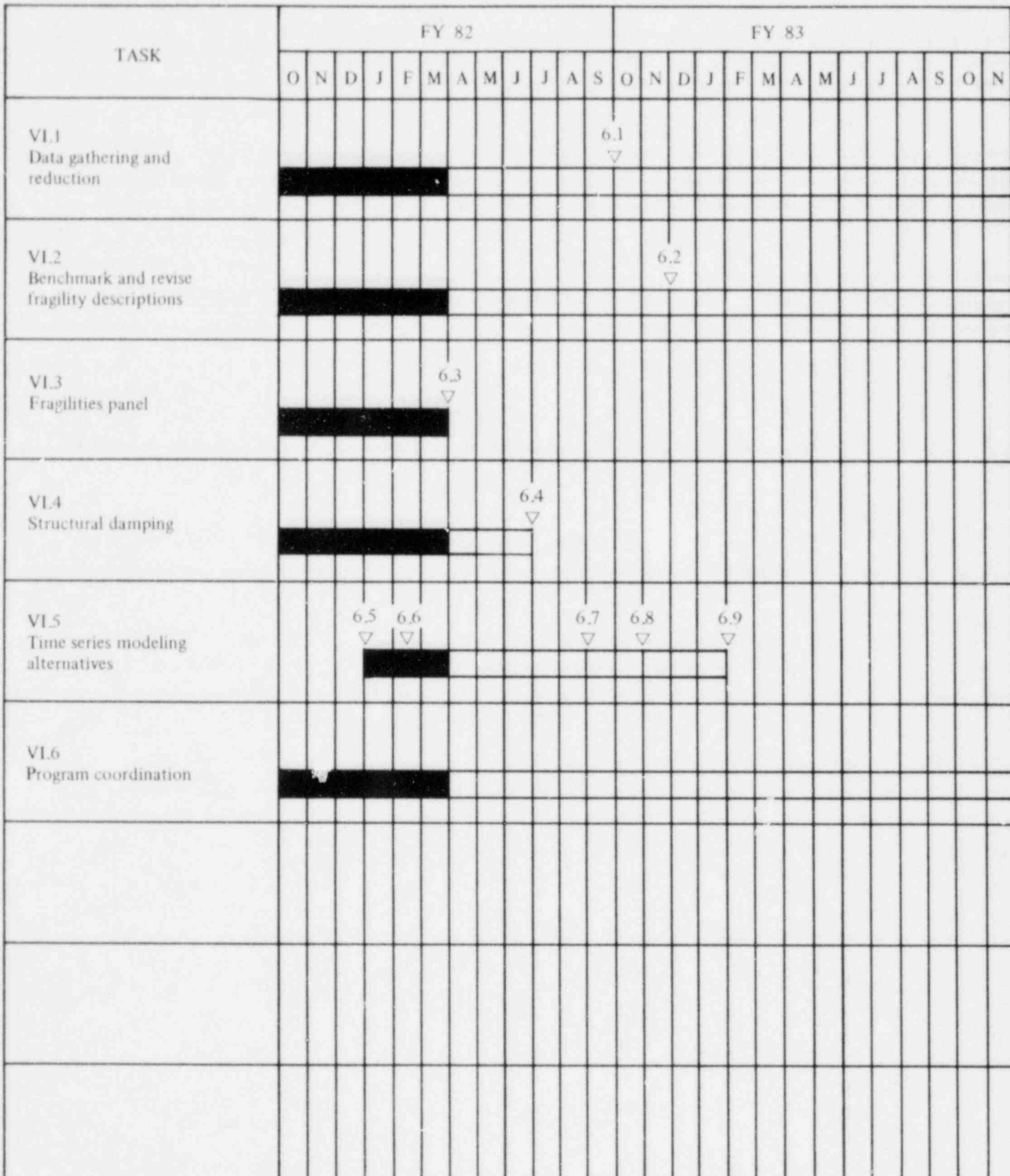
Task VI.5 – Time Series Modeling Alternatives

Currently available methods to generate time histories simply try to match only the Fourier amplitude spectrum. Thus, such approaches may not be an adequate representation of the set of real time histories from earthquakes. To overcome this problem in Phase I, we began a research effort to study the time series directly. One model commonly used to study time series is the ARMA model. While considerable progress was made, it was not possible to complete our effort. Hence for FY 82 the objectives of this task are to (1) complete the ARMA model started in Phase I, (2) develop new sets of time histories using overall hazard models of Phase I for input to SMACS, and (3) assess the importance of the correlation between earthquake components in time series modeling.

Task VI.6 – Program Coordination

To provide coordination between projects within the SSMRP and coordination with outside projects whose work is related to the tasks and goals of the SSMRP.

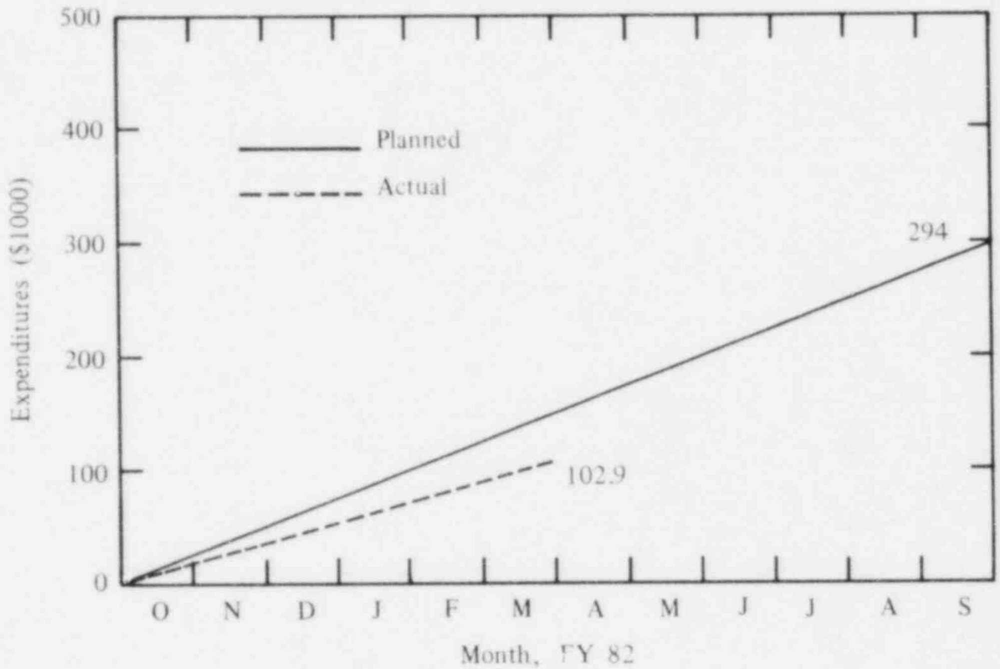
## Project VI Schedule



Project VI Milestone Dates

| | Milestone | Original Target Date | Revised Target Date | Completed Date |
|---|---|---|---|---|
| 6.1 | Final date for new data to be included in revised fragility database report | 10-1-82 | | |
| 6.2 | Fragilities database report revision draft complete | 12-1-82 | | |
| 6.3 | Hold Fragilities Panel meeting | 4-1-82 | | 2-23-82 |
| 6.4 | Documentation of structural damping study, draft report transmitted to NRC | 4-30-82 | 6-30-82 | |
| 6.5 | Begin setting up required computer software and developing parameters of ARMA model | 1-1-82 | | 1-1-82 |
| 6.6 | Start development of model used to assess correlation between earthquake components | 2-15-82 | | 2-15-82 |
| 6.7 | With ARMA parameters defined, start development of new time histories (no correlation between components) | 9-1-82 | | |
| 6.8 | Transmit ARMA time histories to SMACS for evaluation of impact and start development of time histories with correlation | 11-1-82 | | |
| 6.9 | Time histories with correlation sent to SMACS for evaluation | 2-1-83 | | |

Expenditures for FY 82, Project VI,
Validation of SSMRP Methodology (FIN A0126)



Project VI, FY 82 Cost Breakdown

| Task | | Amounts ($1000) | |
|---|---|---|---|
| | | FY 82 Budget | YTD Spent |
| VI.1 | Fragility data gathering and reduction | 73 | 0 |
| VI.2 | Benchmark and revise fragility descriptions | 71 | 21.4 |
| VI.3 | Fragilities panel | 30 | 23.2 |
| VI.4 | Structural damping | 30 | 28 |
| VI.5 | Time series modeling alternatives | 40 | 13.3 |
| VI.6 | Program coordination | 50 | 17 |
| | Totals | 294 | 102.9 |

## PROJECT VI, VALIDATION OF SSMRP METHODOLOGY

### A. Accomplishments

**Task VI.1, Fragility Data Gathering and Reduction** — During Phase I, the fragility data accumulated from various sources were stored in the LLNL computer system using the FRAMIS database management system. The database has been documented in a UCRL report due for release soon.

**Task VI.2, Benchmark and Revise Fragility Descriptions** — Experts have been identified who may be willing to contribute to this effort, and some meetings have already been held both at LLNL and other laboratories to evaluate and revise the fragility descriptions as appropriate. Significant input was also obtained for this task from discussions during the Fragility Panel Meeting (Task VI.3).

**Task VI.3, Fragilities Panel** — The fourth meeting of the SSMRP Fragility Panel was held on February 23-24, 1982, at Livermore. The purposes of the meeting were to:

1. Review the seismic fragilities developed for the SSMRP and reported in NUREG/ CR-2320 and NUREG/CR-2405.
2. Review the seismic fragilities developed from the expert opinion survey conducted during Phase I.
3. Obtain panel participation in efforts to quantify the opinions.

The Fragilities Panel meeting held during this period provided useful input to several areas of concern in validation. Discussions included considerations of not only fragilities, but a wide range of topics related to SSMRP methodology.

**Task VI.4, Structural Damping** — A detailed evaluation of the many mathematical forms used to incorporate damping effects in structural analysis has been made. Additionally, an in-depth review of damping test data from real buildings has been made to determine statistical damping characteristics based on excitation level and structure type. This investigation includes damping test data from office-type buildings and nuclear power plant containment buildings, and a compilation of test data on isolated structural components and equipment. In addition, rigid-body rocking, SSI effects, on damping values from test data from buildings has been identified and isolated in the data of building damping values.

The effect of this SSI contamination has been demonstrated by an example problem using an axisymmetric stick model of the Zion containment building founded on a hard site and an intermediate site. Structural damping and frequency values were determined from the response records, using transfer function identification techniques. Results of this example problem demonstrate the necessity of instrumenting structures founded on relatively soft sites to obtain rigid-body rotation response as well as translational responses. The draft final report is near completion.

**Task VI.5, Time Series Modeling Alternatives** — Efforts have been started to develop the required computer software for this task and to develop the model that will be used to assess correlation between earthquake components.

### B. Next Quarter

Documentation of the structural damping study (Task VI.4) should be completed during the next quarter.

When wrap-up work for the SONGS-1 AFWS project is complete in April, more effort can be directed to the validation tasks.

### C. Concerns

1. **Technical**

   Progress on the various tasks was limited by the heavy involvement in Project II, SONGS-Unit 1 AFWS, of most of the personnel providing support for this project.
2. **Schedule**

   None.
3. **Cost**

   None.

D. **Meetings Attended**
February 23-24, 1982, SSMRP Fragility Panel meeting at Livermore (see Task VI.3 above).

E. **Reports Released**
None.

PROJECT VII
TECHNOLOGY TRANSFER
FIN A0126

**Personnel**

NRC Program Manager: D. J. Guzy
NRC Project Manager: D. J. Guzy
Contractor: Lawrence Livermore National Laboratory
LLNL Project Manager: S. N. Shukla

**Objective**

To provide for a timely transfer of tools, computer codes, and databases both to groups within the NRC and to the general nuclear community. This includes generating and maintaining publicly accessible versions of the computer codes developed as part of the SSMRP, generation of code user's manuals and standard problems, and code configuration control. Also included is a certain amount of on-call user assistance.

In addition, groundwork will be laid (in FY 82) for a Seismic Risk Assessment Code User's Workshop to be held in FY 83.

**Task Description**

Task VII.1 – Public Version of SMACS Code

A simplified version of the SMACS code will be set up and checked out on the Lawrence Berkeley Laboratory CDC 7600 computer system. This version will then be accessible to any interested party via a standard telephone-computer link-up. A user's manual and standard problem with example input and output will be generated.

Task VII.2 – CSNI Conference

Funds made available by the NRC in support of the international CSNI conference to be held at LLNL in the spring of 1983 will be used in FY 82 in setting up this conference.

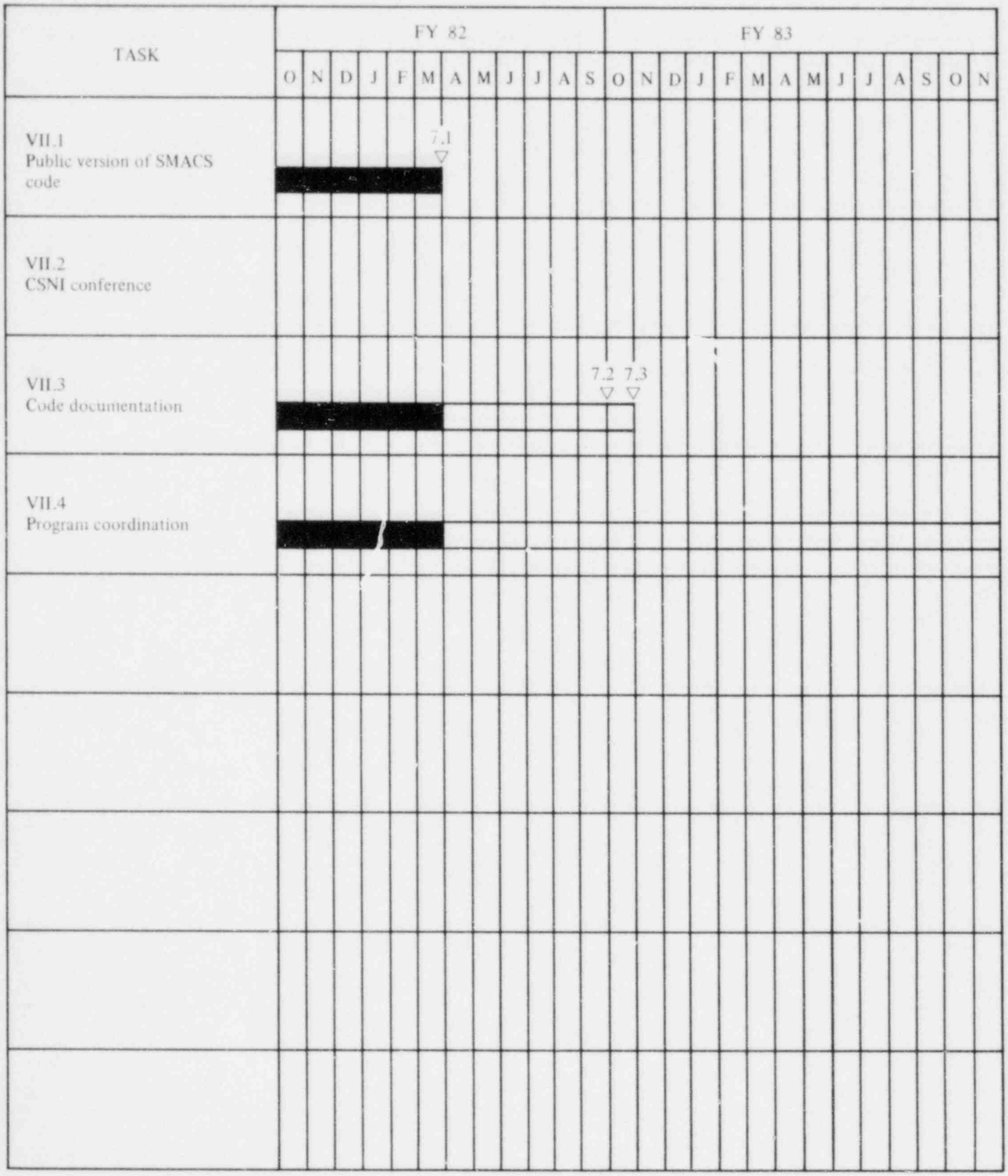
Task VII.3 – Code Documentation

User's manuals for the SEISIM and HAZARD computer codes will be prepared.

Task VII.4 – Program Coordination

To provide coordination between projects within the SSMRP and coordination with outside projects whose work is related to the tasks and goals of the SSMRP.

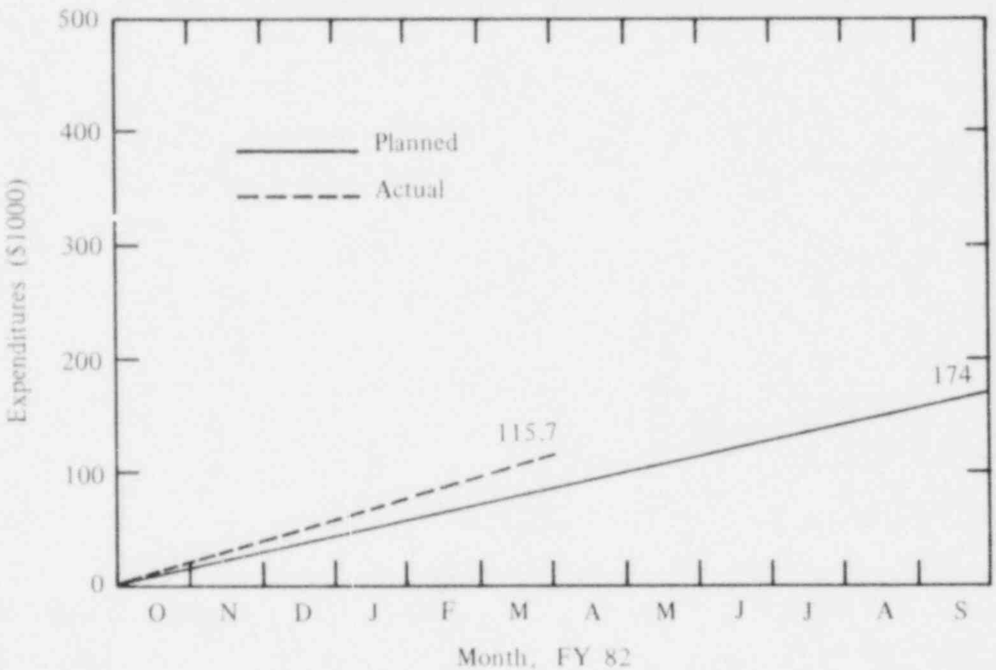
## Project VII Schedule



Project VII Milestone Dates

| | Milestone | Original Target Date | Revised Target Date | Completed Date |
|---|---|---|---|---|
| 7.1 | SMACS option 1 with user's manual released | 4-1-82 | | |
| 7.2 | User's manual for SEISIM updated and released | 9-30-82 | | |
| 7.3 | User's manual for HAZARD released | 10-30-82 | | |

Expenditures for FY 82, Project VII, Technology Transfer (FIN A0126)



Project VII, FY 82 Cost Breakdown

| Task | | Amounts ($1000) | |
|---|---|---|---|
| | | FY 82 Budget | YTD Spent |
| VII.1 | Public version of SMACS code | 84 | 92.7 |
| VII.2 | CSNI conference | 10 | 0 |
| VII.3 | Code documentation | 30 | 0 |
| VII.4 | Program coordination | 50 | 23 |
| | Totals | 174 | 115.7 |

# PROJECT VII. TECHNOLOGY TRANSFER

A. **Accomplishments**

**Task VII.1, Public Version of SMACS Code** — A simplified version of SMACS was made available on the LBL computer system in February. The user's manual for SMACS in draft form was completed and transmitted to the NRC. The final version of the user's manual will be completed early in the next quarter.

**Task VII.2, CSNI Conference** — There was limited planning activity in this task.

**Task VII.3, Code Documentation** — In-house versions of the SEISIM and HAZARD codes exist. In the coming two quarters efforts will be made to write user's manuals in final form for both programs.

**Task VII.4, Program Coordination** — During the last quarter the main task was the preparation of the user's manual for SMACS.

B. **Next Quarter**

In the next quarter, we will issue the final version of the user's manual for SMACS and begin writing user's manuals for the SEISIM and HAZARD codes.

C. **Concerns**

1. **Technical**

   None.

2. **Schedule**

   None.

3. **Cost**

   None.

D. **Meetings Attended**

None.

E. **Reports Released**

User's Manual for SMACS in draft form.

# PROJECT VIII
# BWR RISK ANALYSIS
# FIN A0126

**Personnel**

NRC Program Manager: D. J. Guzy
NRC Project Manager: D. J. Guzy
Contractor: Lawrence Livermore National Laboratory
LLNL Project Manager: Vacant

**Objectives**

1. To develop complete event trees and fault trees for a typical BWR. They will be used subsequently to develop simplified systems analysis models for the BWR.
2. To identify any salient differences between a BWR and PWR (from a seismic risk viewpoint) that might require additions or modifications to the Phase I SSMRP methodology.
3. To compare the seismic risk between a typical BWR and PWR using a comparable level of risk analysis methodology.

**Task Description**

General

The seismic risk methodology developed in Phase I of the SSMRP was demonstrated by application to the Zion PWR. Thus all the systems analysis models (initiating events, event trees, and fault trees) and all the structural and piping models were developed for a PWR. Yet the methodology developed in the SSMRP must be equally applicable to both PWR and BWR systems. To identify any fundamental differences between PWR and BWR, and to verify the applicability of the SSMRP methodology to a BWR, a risk analysis of a BWR will be performed.

In FY 82, the BWR analysis will begin by developing complete systems models (fault trees and event trees). In FY 83 these systems models will be studied to ascertain any systematic differences between the systems aspects of BWRs and PWRs. Simplified systems models can then be obtained by performing sensitivity studies on them.

Task VIII.1 – Development of BWR Fault Trees

The fault trees developed by the Idaho National Engineering Laboratory as part of the NRC IREP program will be modified to include seismically induced passive failures.

## Project VIII Schedule

| TASK | FY 82 | | | | | | | | | | | | FY 83 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N |
| VIII.1<br>BWR fault trees | | | | | | | | | | | | | | | | | | | | | | | | | | |
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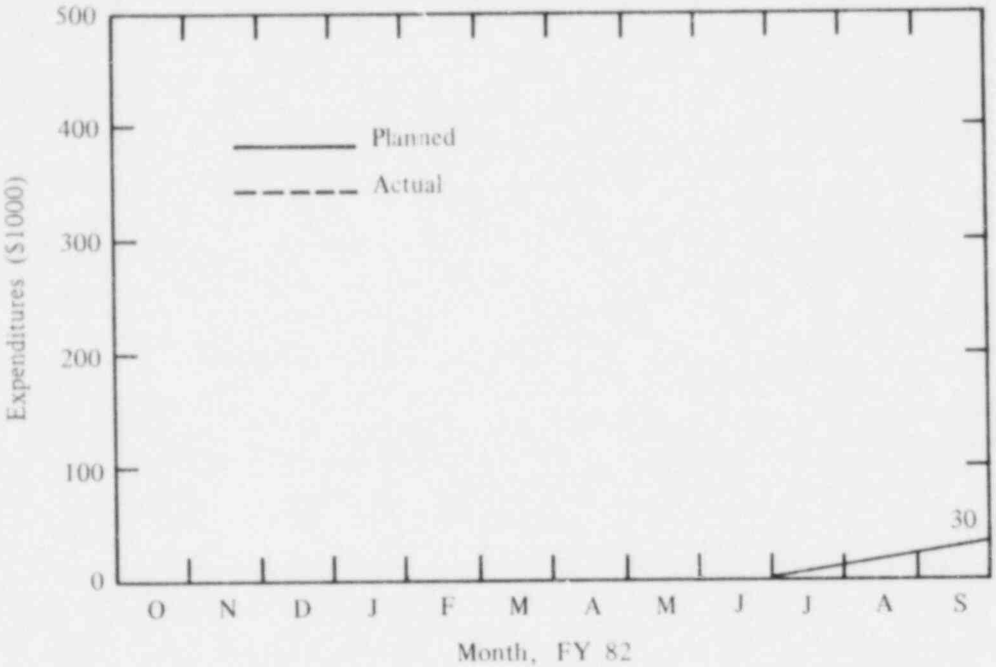
Expenditures for FY 82, Project VIII, BWR Risk Analysis (FIN A0126)



# PROJECT VIII, BWR RISK ANALYSIS

## A. Accomplishments

No activity on this task is scheduled to begin until next quarter. Groundwork was begun in the past quarters, however, by meeting with A. Murphy of the NRC Division of Risk Analysis and by examining the random event fault trees generated as part of the IREP program. This led to a meeting with J. Trainer and S. Mayes of the Idaho National Engineering Laboratory who prepared the fault trees we examined. Based on our meeting and discussion, we determined that it would be feasible to modify these trees to include seismic induced failures, and that this approach could cost much less than developing new trees. It is hoped that this approach could be used in the SSMRP BWR analysis and that such work could begin this summer.

## REPORTS GENERATED BY THE SSMRP

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B. J. Benda and J. J. Johnson, "Variability in Dynamic Characteristics and Seismic Response due to the Mathematical Modeling of Nuclear Power Plant Structures," UCRL-53017, November 1981.

J. J. Johnson et al., "Phase I Final Report – Soil Structure Interaction," NUREG/CR-2015, Vol. 4, February 1982.

M. P. Bohn, "Seismic Safety of Nuclear Power Plants," in Energy and Technology Review, April 1982, published by Lawrence Livermore National Laboratory.

**Reports Planned**

| Report | Target Date |
|---|---|
| D. L. Bernreuter et al., "Phase I Final Report – Seismic Input," NUREG/CR-2015, Vol. 3. | |
| J. E. Wells et al., "Phase I Final Report – Systems Analysis," NUREG/CR-2015, Vol. 8. | 6-1-82 |
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| J. J. Johnson et al., "Soil-Structure Interaction Sensitivity Studies." | 7-30-82 |
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Meeting Attendance Summary

| Date | Meeting | Location | LLNL Personnel Attending* | Comments |
|---|---|---|---|---|
| 10/26/81 | 9th WRSM | Gaithersburg, MD | MPB, SNS, JEW, TYC | Overview of progress since last meeting. |
| 11/16/81 | NRC Staff Review | Silver Spring, MD | MPB | First meeting of Sr. Research Review Group. |
| 3/2/82 | NRC Staff Review | Silver Spring, MD | MPB | Second meeting of Sr. Research Review Group. |
| 12/21/81 | Meeting with SCE/Bechtel | Los Angeles, CA | TYC, LCS | SONGS coordination meeting. |
| 1/20/82 | SONGS | Washington, DC | TYC | SONGS masonary wall evaluation. |

*LLNL personnel abbreviations:

| | | | | | |
|---|---|---|---|---|---|
| DLB | = | D. L. BERNREUTER | SNS | = | S. N. SHUKLA |
| MPB | = | M. P. BOHN | TYC | = | T. Y. CHUANG |
| ORM | = | O. R. MASLENIKOV | LCS | = | L. C. SHIEH |

NRC FORM 335 (7-77)

U.S. NUCLEAR REGULATORY COMMISSION

**BIBLIOGRAPHIC DATA SHEET**

1. REPORT NUMBER (Assigned by DDC): NUREG/CR-1120, Vol. 9

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Seismic Safety Margins
Research Program
Progress Report No. 13

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3. RECIPIENT'S ACCESSION NO.

7. AUTHOR(S)
M. P. Bohn, D. L. Bernreuter. T. Y. Chuang, L. E. Cover,
J. J. Johnson, S. N. Shukla, J. E. Wells, L. C. Shieh

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MONTH: August | YEAR: 1982

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Division of Engineering Technology
Office of Nuclear Regulatory Research
Washington, D. C. 20555

10. PROJECT/TASK/WORK UNIT NO.

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FIN Nos. A0126, A0362
A0382

13. TYPE OF REPORT
Technical

PERIOD COVERED (Inclusive dates)

15. SUPPLEMENTARY NOTES

14. (Leave blank)

16. ABSTRACT (200 words or less)

The Seismic Safety Margins Research Program (SSMRP) is an NRC-funded, multiyear program conducted by Lawrence Livermore National Laboratory (LLNL). Its goal is to develop a complete, fully coupled analysis procedure (including methods and computer codes) for estimating the risk of an earthquake-caused radioactive release from a commercial nuclear power plant. The analysis procedure is based on a state-of-the-art evaluation of the current seismic analysis and design process and explicitly includes the uncertainties inherent in such a process. The results will be used to improve seismic licensing requirements for nuclear power plants.

This document is a progress report on the Seismic Safety Margins Research Program covering the period October 1, 1981, through March 31, 1982. The report gives a general description of the program, together with financial summaries and individual project details. Each project is summarized to show accomplishments, schedules, milestones and completion dates, budget and expenditures, and any concerns that may affect the project.

17. KEY WORDS AND DOCUMENT ANALYSIS

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17b. IDENTIFIERS/OPEN-ENDED TERMS

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