NOAA SPECIAL PROJECTS STAFF

FY 84 TECHNICAL PLAN FOR OTEC RESEARCH AND TECHNOLOGY DEVELOPMENT

NOVEMBER 1983

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I. INTRODUCTION

The scope and pace of NOAA's OTEC Ocean Engineering Research and Technology Development Program are based on Department of Energy (DOE) objectives and priorities for research and development needs. It is concerned with resolving the major research issues in high technical risk areas. NOAA reduces technology risk and uncertainty by conducting generic ocean engineering research and performing at-sea experiments of critical subsystems. The NOAA Research and Technology Development Program provides a technology information base that can assist the private sector in future development of OTEC systems.

The concept of Minimum Essential Unknowns (MEUs) has been the Department of Energy's basis for guiding research and technology development related to Ocean Thermal Energy Conversion (OTEC). The current MEU's are listed in Ocean Energy Technology Assessment, a July 1983 report distributed by DOE. MEU's are statements of technology risk that must be resolved before construction of an OTEC plant can proceed. Projects are defined and selected based on their contribution to the elimination of risk associated with these unknowns. Once defined, the ocean engineering research and technology development projects related to OTEC are included in a formal NOAA/DOE Interagency Agreement (IAA). The IAA includes a project summary for each project which is a brief description of the research to be conducted. The proposed IAA for FY 84 is shown in Appendix A.

The process of project definition required for the IAA constitutes the long and mid-range planning process for ocean engineering research for the OTEC Program. The execution of these projects requires detailed short range plans to describe the activity that the technical manager must accomplish for the project to proceed. This document fulfills that short range planning need by providing detailed technical plans for OTEC projects that will be undertaken by NOAA's Special Projects Staff. The technical plans for the projects included in this document have been derived from the FY 84 IAA and recent DOE direction and are shown in Figure 1. Technical plans for new projects will be prepared and included when authorized by DOE. Inasmuch as this is a new format for planning documentation, technical plans for ongoing work funded by the FY 83 Interagency Agreement are not included in this document.

The project technical plans are intended to provide a presentation of the detailed actions that the responsible NOAA project engineer must take to execute and complete his assigned projects. As such, it compliments the planning documentation cycle by showing detailed, short-range plans. These plans are written from the perspective of the project engineer and the Contracting Officer's Technical Representative (COTR) in that they provide a project description in greater depth than that provided in the IAA. They include a detailed technical approach, a listing of project milestones, and a detailed schedule.

Technical plans will be implemented by the project engineer upon receipt of an approved IAA and funding from the Department of Energy. The detailed information in these plans will provide the information necessary for preparation of contractor statements of work. The NOAA project engineers will use these plans as the basis for all project reviews, control, and status reporting.

It should be noted that the technical plans are planning documents and as such, they are expected to change to reflect revisions in fiscal climate, program policy, and to incorporate technical feedback from other projects. Project engineers will revise their technical plans when required by such issues.

II. PROJECT PLANS

This section contains the technical plans for the projects that are planned to be started in FY 84. It should be noted that in some instances the FY 84 projects are broad. When this occurs the Technical Plan will be subdivided into tasks of reasonable size. Technical plans will then be written at the subproject level. Additionally, the schedules provided for each plan are based on the receipt of FY 84 funding by November 1, 1983, except for Project 2, "Small Scale Shelf-Mounted Cold Water Pipe Modeling", which is being initiated with FY 83 funding.

FY 84 PROJECTS

PRIORITY	TECHNOLOGY DEVELOPMENT PROJECTS	COST	O N D J F M A M J J A S	COMPLETION
1.	RESEARCH IN PLATFORM AND CWP FOUNDATIONS	300K	———→	NOV 84
2.	SMALL SCALE SHELF MOUNTED COLD WATER PIPE MODELING *	200K	———→	DEC 84
3.	RESEARCH TOOLS FOR IN-SITU GEOTECHNICAL MEASUREMENTS	300K	———→	JAN 85
4.	COLD WATER PIPE MATERIALS—LABORATORY EXPERIMENTS	300K	———→	DEC 84
5.	RESEARCH IN FRP COLD WATER PIPE INSPECTION AND REPAIR.	300K	———→	FEB 85
	TOTAL	1200K		

* FUNDED IN FY 83. NOT INCLUDED IN TOTAL

Figure 1. Projects whose technical plans are included in this document

83-1711-2

1. RESEARCH IN CWP AND PLATFORM FOUNDATIONS

Objective: To study alternative CWP foundation and installation systems that are adaptable to near shore OTEC plant sites having a 40 to 80 degree underwater escarpment.

Technical Approach:

1. Considering geotechnical and environmental conditions common to OTEC plant sites, conduct alternative slope-mounted CWP foundation design studies which satisfy the following technical and economical requirements:

   a. foundation adaptable to stable and unstable bottom formations;

   b. minimal site preparation on rough and steep slopes;

   c. minimal installation difficulties and associated costs; and

   d. minimal repair and maintenance needs with projected 20 to 30 year service life.

2. Conduct loading and stress analysis of two or more alternative systems and their components, especially the 30-foot diameter pipe, its joint arrangement and anchoring devices, under the design storm conditions to determine the dynamic responses of the whole system and to develop suitable installation procedures.

3. Based on results of the above analyses and a small scale slope-mounted CWP model tests which are being conducted at CBI, assess the capability of the selected systems to withstand the static and dynamic loadings. Then, develop the project plans for small scale model experiments which will be conducted in FY 85 to validate the effectiveness of the selected systems by testing anchor holding, the interaction of the foundation and specific bottom formations, as well as the installation procedures.

4. Conduct comparative evaluation of the selected systems at a specific OTEC site. The site at Kahe Point, Hawaii is recommended for this effort.

Participants:

TBD

Deliverables:

CWP Foundation Design Study Report
Alternative Foundation Loading and Stress Analysis Report
Loading Capability Assessment Report
Small Scale Model Experiment Project Plan
OTEC Site Foundation System Application Study

Budget:

$ 300K

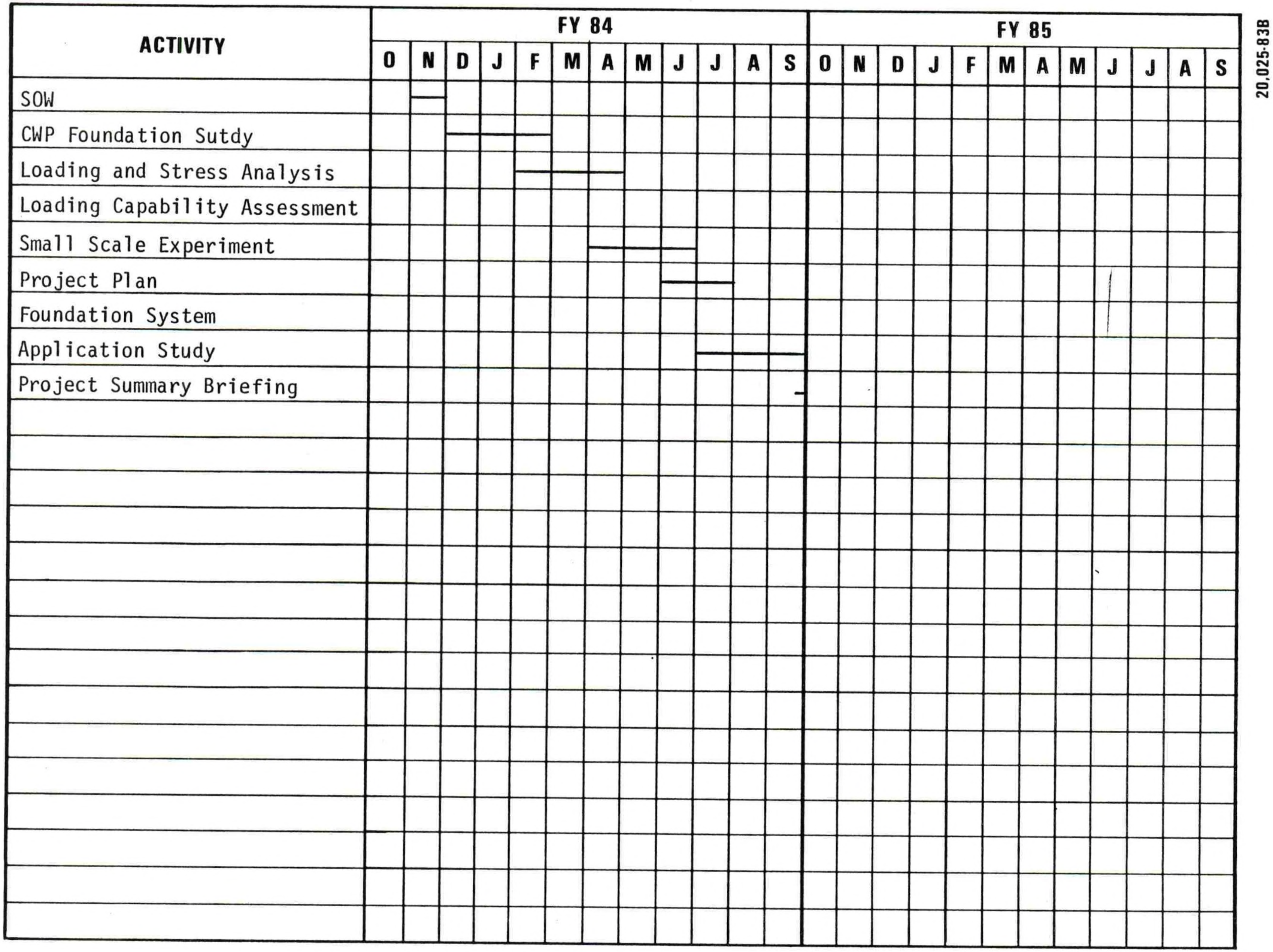
Travel:

2 trips/1 person to contractor facility

MEU's:

From Ocean Energy Technology Assessment (July 1983)
1, 2, 9, 14, 20, 34

RESEARCH IN CWP AND PLATFORM FOUNDATIONS



2. SMALL SCALE SHELF MOUNTED COLD WATER PIPE MODEL TESTS

Objective: To conduct small scale model testing to determine wave and current induced forces acting on a bottom mounted cold water pipe.

Technical Approach:

1. Develop Project Plan.

2. Develop statement of work for small scale model test at CBI (contract modification). The statement of work will require the contractor to conduct three separate series of tests:

a. Model tests of a cold water section resting on the bottom from 100-foot depth (prototype) to 300-foot depth. The upper end of the pipe will be trenched or covered with bottom material. The slope will be variable from 0° to 20° and wave angle of impingement will be varied from 0° to 90° relative to the centerline of the pipe. Wave characteristics for Kahe Point will be modeled and will include operational and extreme event (100 year) waves modeled as regular and random seas. Current at Kahe Point will be modeled during the test to the extent possible in the contractor's tank. A 1/30 scaling ratio will be utilized for the 30-foot diameter prototype size.

b. Model tests will be conducted of a cold water pipe section mounted on an escarpment varying in angle from 40° to near vertical. The top of the escarpment will be located at a depth of 300 feet and the bottom of the pipe will be in a 700-foot depth. Wave characteristics will include random and regular waves characteristic of those found at Kahe Point. Currents will also be modeled. Wave angle of approach will vary from 0 to 90° relative to the centerline of the pipe. The separation distance between the face of the escarpment and the pipe will be adjustable between 0 and a distance equivalent to one pipe diameter. A model scale ratio of 1/40 will be utilized.

c. 1/8 scale model tests will be conducted using the configuration for the Phase III down-the-slope experiment. Prototype depth ranges from 50 to 160 feet on a slope of 40°. The centerline of the eight-foot diameter pipe is located ten feet from the bottom. Wave characteristics will be those utilized for the experimental design (ten-year storm) at Keahole Point as well as those characteristic of Kahe Point. Wave angle of approach will vary from 0 to 90° relative to the pipe centerline. Currents will also be modeled.

During the three tanks test described above, the following parameters will be measured:

1. Wave heights (at two locations)
2. Wave periods
3. Current speed
4. Pressure distribution around pipe (contingent upon existing contractor capability)
5. Three dimensional support point loads on the pipe test section

Photo (moving and still) documentation will be provided which covers all phases of the tests. Data analysis will include reduction and display of test data, including statistical analysis of each time series. A comparison will be made between theoretical wave characteristics and those measured in the tank as well as a comparison between measured pipe loads and those predicted by the contractor's submerged object loading model.

3. Develop statement of work to compare the small scale test results with the 1/3 scale at-sea test results.

4. Modify CBI contract ($125K).

5. Conduct tests at CBI.

6. Award contract for data set comparison (Garrison, Sarpkaya, Noda, Makai, CBI, EG&G).

7. Final report from CBI.

8. Final report from data set comparison contractor.

Participants:

Chicago Bridge & Iron (CBI) - Model Tests
Data Comparison & Analysis - TBD

Deliverables:

CBI - Final Report, 2 reviews, one technical paper
Data C&A - Final Report, 2 reviews, one technical paper

Budget:

Model Tests/CBI -	$125K
Data C&A -	75K
Total	$200K

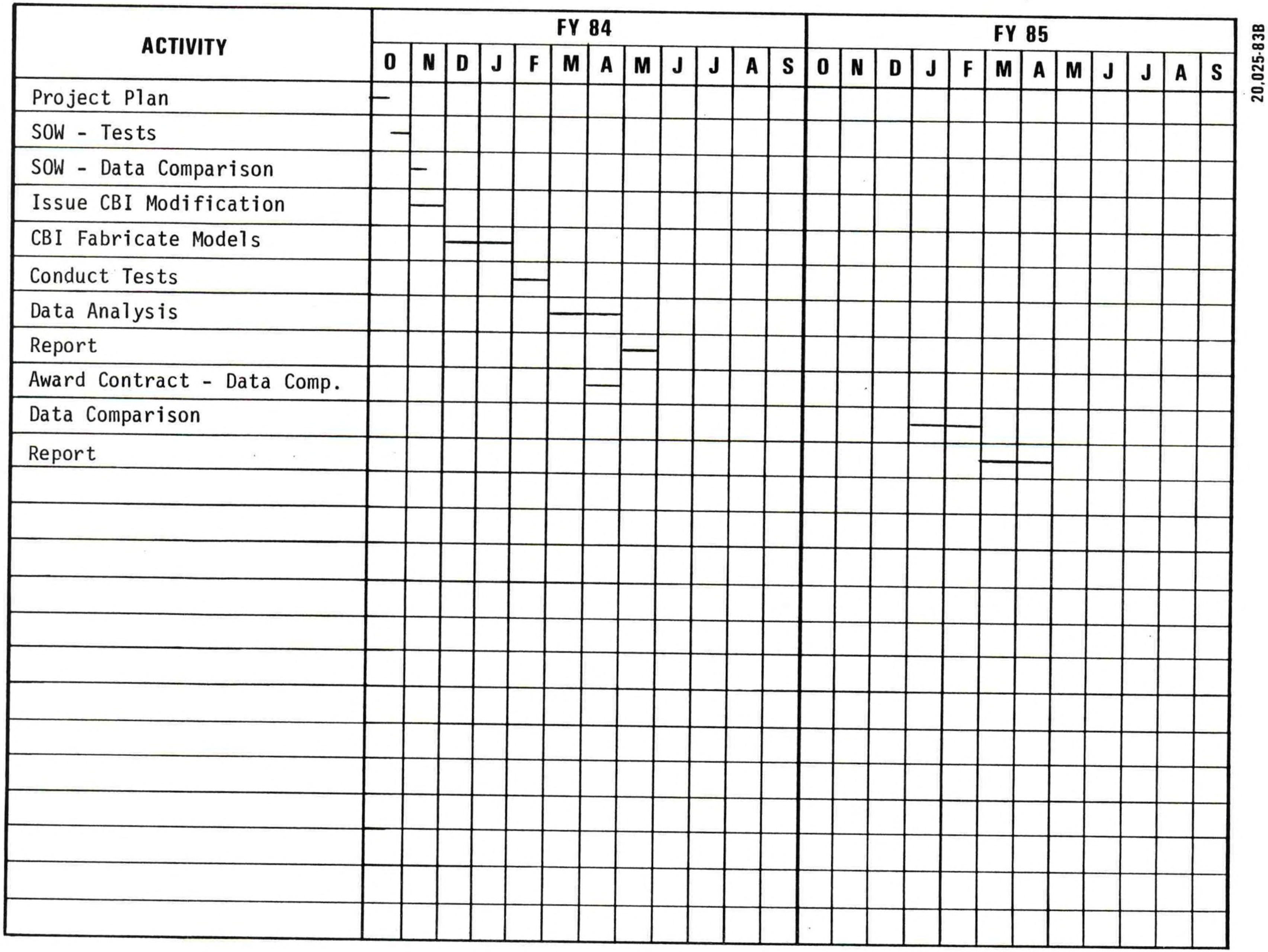
Travel:

2 trips/2 people to CBI
1 trip/2 people to C&A contractor site

MEU's:

From report by Meridian 6B, 14

SMALL SCALE SHELF MOUNTED COLD WATER PIPE MODEL TESTS



3. RESEARCH TOOLS FOR IN SITU GEOTECHNICAL MEASUREMENTS

Objective: To determine geotechnic data requirements for OTEC shelf-mounted foundations and anchor systems and to evaluate advanced in situ geotechnic measurement systems. Conduct a geotechnic measurement program as part of a nearshore site survey, in support of the shelf-mounted CWP test at the Natural Energy Laboratory of Hawaii at Keahole Point.

Technical Approach:

Geotechnic data obtained from in situ and laboratory tests and experiments are used as parameters to evaluate soil behavior and foundation characteristics for the emplacement of structures on the seafloor. Predictive capabilities and reliable engineering judgement are critical elements with design and construction of offshore structures such as down-the-slope OTEC designs. The following approach will be used to increase the understanding of geotechnical properties, parameters and measurements:

1. Conduct a study to identify and prioritize marine geotechnic requirements, including geotechnic characteristics, measurements and specific parameters required for the design of underwater OTEC structures and foundations.

2. Conduct a detailed geotechnical survey at the NELH site that will provide additional design inputs for the 8-foot, down-the-slope experiment scheduled for the spring, 1984.

3. Identify specific geotechnic data requirements for designing full scale, shelf-mounted OTEC pipes and structures with emphasis on measurements on slopes greater than 20 degrees and water depths to 1,000 meters.

4. Identify SOA geotechnical tools, device and instrumentation for intercomparison purposes.

5. Conduct a research experiment at NELH involving items identified in Item 4 in order to compare performance.

6. Prepare work statements for Items 1-5.

Participants:

Woodward/Clyde Consultants
NCEL (or equivalent)
NORDA Marine Geotechnical Branch

Deliverables:

Report documenting geotechnic requirements, data, tools, devices, and parameters
Geotechnic survey report of NELH DTS site
Geotechnic measurement techniques for slopes greater than 20 degrees and up to 1,000 meters in depth
In situ intercomparison report of SOA geotechnic instrumentation and tools

Budget:

Woodward/Clyde Consultants	$ 10K
NORDA Marine Geotechnical Branch	60K
NCEL (or equivalent)	230K
Total	$ 300K

Travel:

2 trips/2 people to NCEL
2 trips/2 people to NORDA
1 trip to NELH test site

MEU's:

From report by Meridian (Table 9, Item 2)

RESEARCH TOOLS FOR IN SITU GEOTECHNICAL MEASUREMENTS

ACTIVITY	FY 84												FY 85											
	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
General Marine Geotechnic Requirements/Measurements				—																				
Outline SOWs					—	—																		
Geotechnic Survey at NELH						—	—																	
OTEC Requirements						—	—																	
SOA Tools/Instruments					—	—	—																	
Field Experiment Plan							—	—																
Conduct Experiment at NELH									—	—														
Data Comparison & Report												—	—	—	—									

20,025-83B

4. COLD WATER PIPE MATERIALS - LABORATORY EXPERIMENTS

Objective: The primary objective of this broadbased materials test program is to provide engineering data on the performance of candidate materials (e.g., FRP) that can be used on an OTEC CWP. These test results will assist the CWP designer in projecting the potential degradation in material characteristics that will be induced by environmental stresses, associated pipe dynamics, hydrostatic presence and subsequent seawater permeation. This will be accomplished by conducting static strength, fatigue and seawater conditioning tests on candidate CWP materials.

Technical Approach:

The following approach will be used to generate engineering data on several materials and configurations that appear optimum for CWP systems. A statement of work will be developed incorporating these tasks:

1. Conduct a study to predict the physical loads that a CWP must withstand.
2. Select candidate materials and configurations to be investigated.
3. Generate a detailed test plan which incorporates types of tests, test matrix, pre-conditioning of specimens, and parameters measured.
4. Incorporate accelerated aging experiments and validation techniques to simulate the long-term effects on CWP materials under exposure to seawater.
5. The experimental results will provide information on material strength and bending modulus degradation, changes in fatigue strength and other significant parameters.

Participants:

TRW

Deliverables:

Materials test plan
CWP load analysis
Data acquisition and analysis plan
Interim Report
Final report including engineering data and accelerated aging projections on candidate CWP materials

Budget:

$ 300K

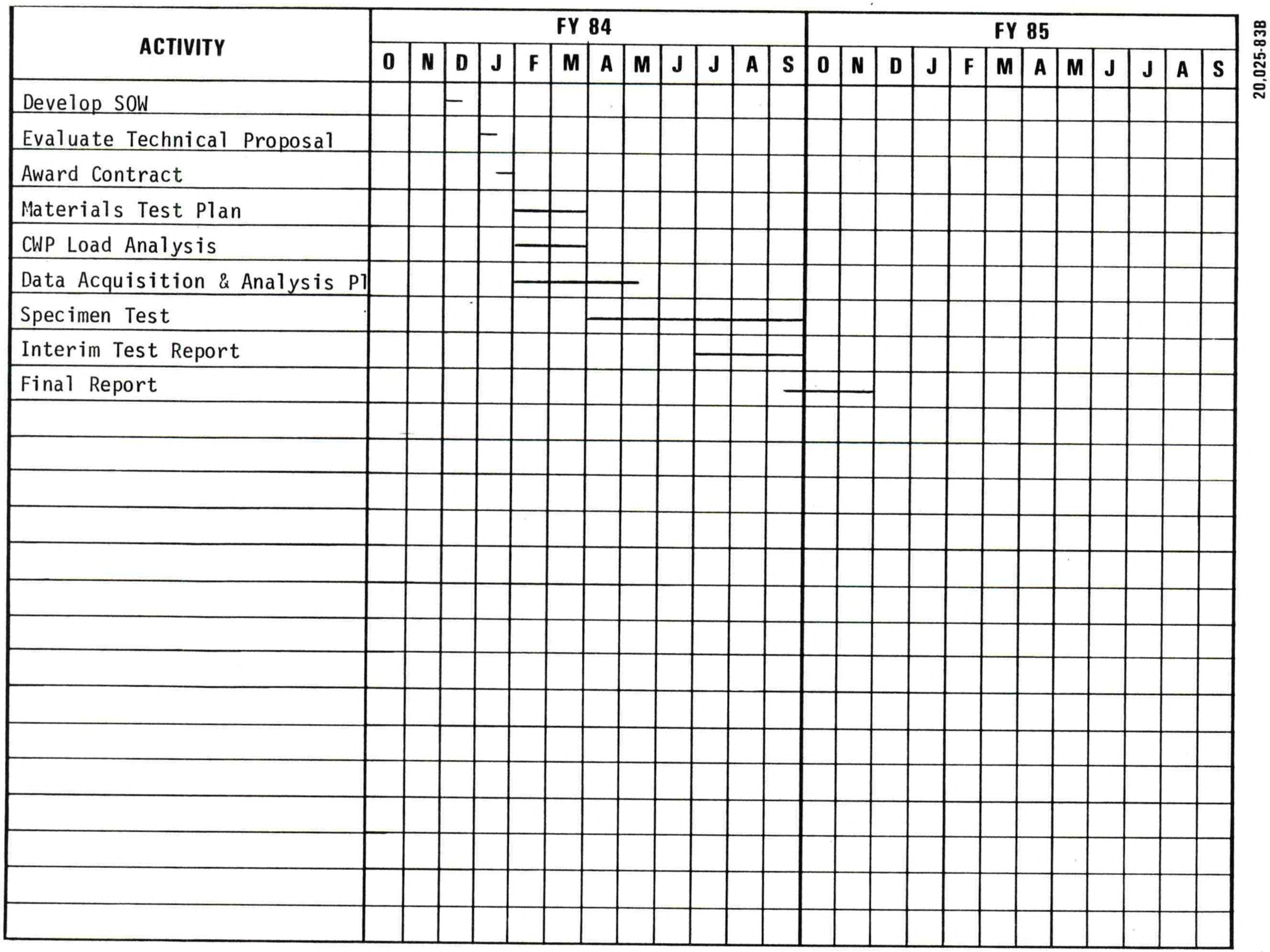
Travel:

3 trips to Los Angeles, California (TRW)

MEU's:

From Ocean Energy Technology Assessment, Meridian Corporation

COLD WATER PIPE MATERIALS - LABORATORY EXPERIMENTS



5. RESEARCH IN FRP COLD WATER PIPE INSPECTION AND REPAIR

Objective: To establish inspection requirements for OTEC FRP cold water pipes (CWP) and to explore methods of inspection which will meet these requirements.

Technical Approach:

1. Develop Project Plan.

2. Develop statement of work to define CWP inspection requirements and identify potential failure modes. Based on the characteristics of FRP in deep-submerged application and considering the types of loads and stresses a CWP may experience during fabrication, deployment, and operation, the contractor shall perform analyses to determine the types of failure modes that might occur during the planned 30-year life of an FRP CWP. The contractor shall also assess the threshold limits of these failure modes beyond which repair would be necessary to avoid structural failure of the pipes or degradation of thermal resource to the power plant. From this assessment, the contractor shall preliminarily identify the potential needs for periodic inspection and maintenance in order to prevent such a failure. (Gibbs & Cox)

3. Develop statement of work to evaluate resolution of high frequency (500 KHz) side scan sonar (SSS) for inspection of FRP CWP. The contractor will conduct three separate tasks. (Klein/Busby)

   A. Test SSS return signal from a flat 10' x 30' sheet of fiberglass. Resolution of a variety of hole sizes and configurations will be investigated.

   B. Test SSS return signal from a 8' x 30' FRP pipe. Again, investigate SSS resolution of a variety of defects and configurations at Snug Harbor, Hawaii.

   C. Test SSS capability for inspection of slope-mounted FRP at Keahole Point using various sensor target separations, tow speeds, and tow angles. This will demonstrate foundation inspection, as well as local bottom typography.

4. Develop statement of work to test capability of atmospheric diving suits to perform inspection of CWP's using non-destructive testing tools such as ultrasonics, video, or side scan sonar. This research is also applicable to repair of pipe sections. (Busby)

5. Develop a statement of work to ascertain acoustic properties of FRP within the proposed range of materials for CWP's. Estimate the ability of side scan sonar to adequately observe FRP pipes and resolve defects. In an anechoic chamber, measurements will be taken of acoustic impedance, reflection coefficient, and absorption coefficient for FRP test sections. These properties will then be used to evaluate the potential of existing SSS equipment or to determine requirements for SSS designed specifically for CWP inspection. (NPG)

6. Develop statement of work to investigate fiber optics (FO) application in an FRP of a large surface area. Apply FO to a section of FRP to demonstrate application techniques, effects of sea water, and observation of various modes of failure.

7. Conduct SSS/material tests.

8. Conduct diving suit tests.

9. Conduct FRP acoustic tests.

10. Final report form Tasks 2 through 6.

Participants:

Gibbs & Cox - Failure modes and threshold limits
Klein/Busby - SSS resolution
Busby - Diving suits
NPG - FRP acoustic properties
NSRDC - Fiber optics

Deliverables:

Gibbs & Cox - Final report, one review
Klein/Busby - Final report, two interim reports, one technical paper
Busby - Final report
NPG - Final report
NSRDC - Final report, one interim report/review, one technical paper

Budget:

Gibbs & Cox	$ 10K
Klein/Busby	210K
Busby	10K
NPG	10K
NSRDC	60K
	$ 300K

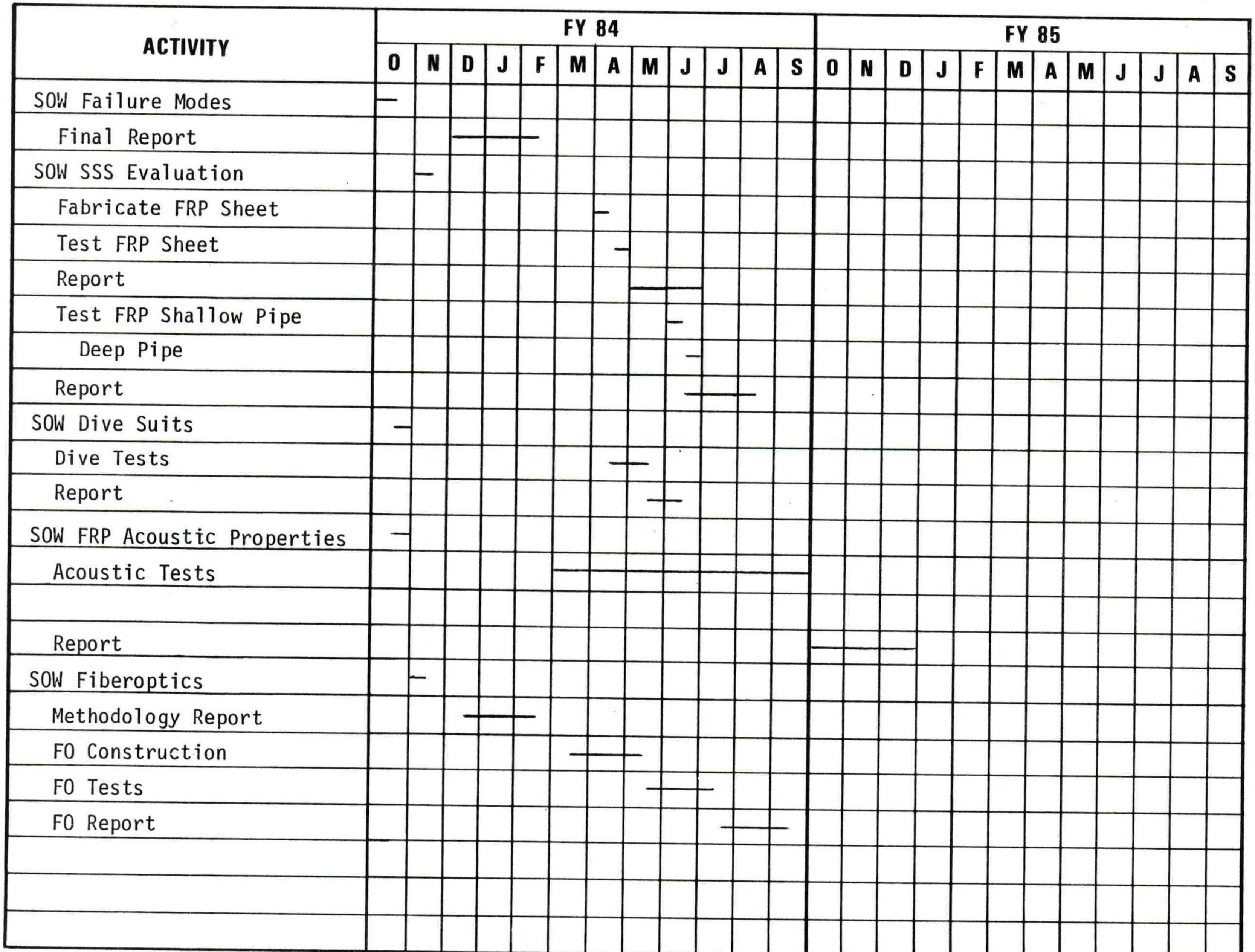
Travel:

1 trip/2 people to Hawaii for SSS test
1 trip/1 person to contractor site for SSS test
1 trip to Texas for diving suit test
1 trip to California for acoustic tests

MEU's:

From Ocean Energy Technology Assessment, July 1983
1, 8, 11, 23, 28, 35

RESEARCH IN FRP COLD WATER PIPE INSPECTION AND REPAIR



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APPENDIX A

Proposal for

FY 84 INTERAGENCY AGREEMENT

to provide

Technical Management

for the Ocean Thermal Energy Conversion (OTEC)

Ocean Engineering

Research and Technology Development Program

prepared for

DIVISION OF OCEAN ENERGY TECHNOLOGY

OFFICE OF SOLAR ELECTRIC TECHNOLOGIES

DEPARTMENT OF ENERGY

prepared by

Special Projects Staff

Office of Oceanography and Marine Services

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

July 25, 1983

(Reviewed by DOE July 26, 1983)

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1. BACKGROUND

Through a Memorandum of Understanding and an Interagency Agreement (IAA) (DE-AI01-77ET-20396, Modification No. A-010) between the Department of Energy (DOE) and the National Oceanic and Atmospheric Administration (NOAA), NOAA's Special Projects Staff (SPS) of the Office of Oceanography and Marine Services has been providing technical assistance since fiscal year (FY) 1977 to the Ocean Thermal Energy Conversion (OTEC) Program of DOE's Division of Ocean Energy Technology, Research and Technology Development Branch. The DOE organizational structure showing NOAA's relationship is given in Figure 1.

A NOAA Special Projects Staff for OTEC was established in FY 77 and has been functioning since then to provide this technical management assistance to DOE. Specifically, the areas of ocean engineering research falling within the purview of the NOAA include: platforms, cold water pipes, sea water systems, moorings, and foundation systems. NOAA responsibilities include the following tasks:

- Assessment of the state of the art of technology relevant to the OTEC ocean engineering development program
- Determination of technology deficiencies, and establishment of project priorities
- Definition of and planning for research projects
- Preparation of work scope and procurement documentation
- Evaluation of technical contract proposals
- Technical contract management
- Analysis and assessment of technical results and development of an information base for guiding future technology development
- Analysis of results and integration of research
- Participation in technical planning sessions, management briefings, and system integration contractor meetings
- Transfer of technical information by means of NOAA/DOE sponsored technical workshops, professional meetings, and public briefings of contract project results

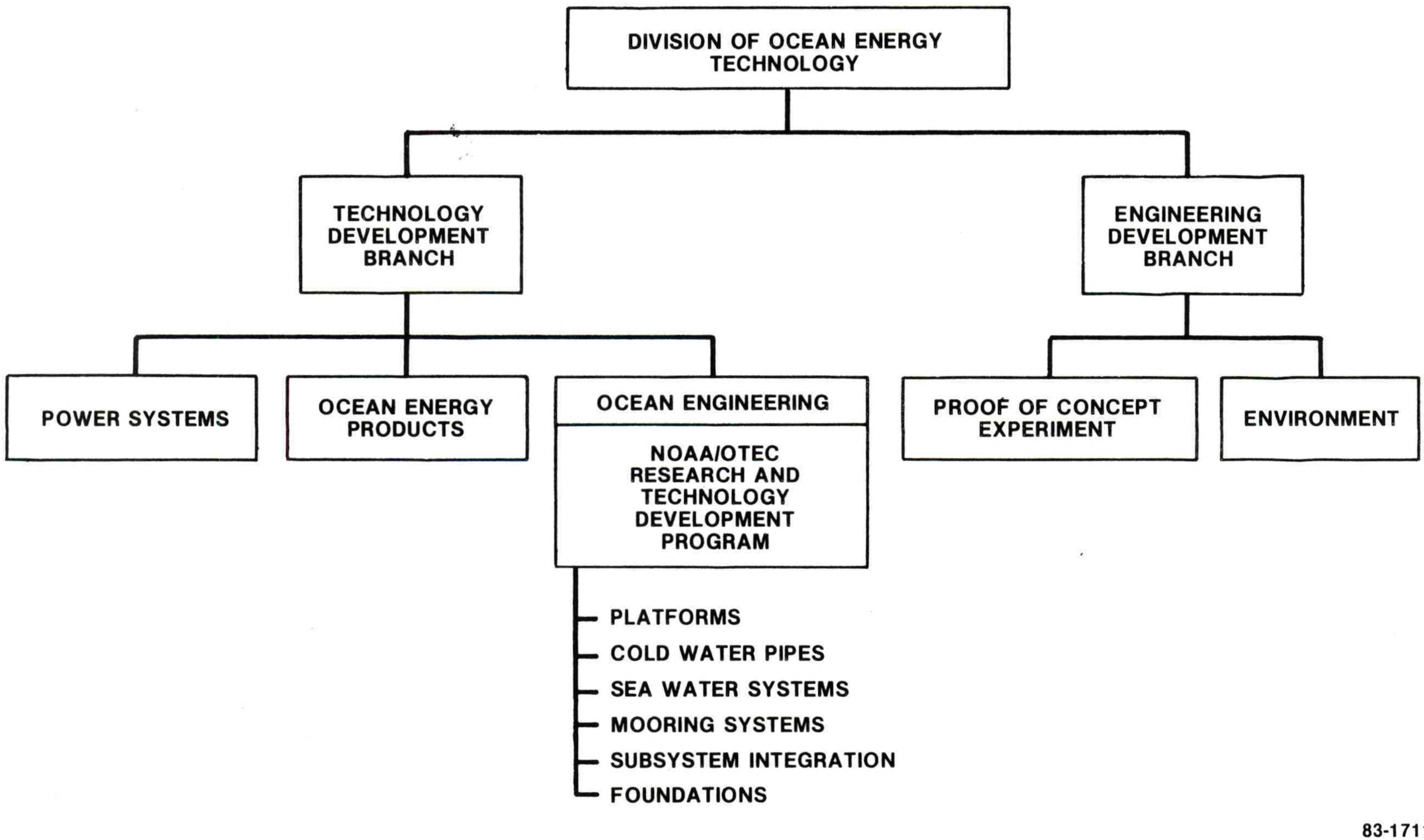

FIGURE 1 DOE OTEC ORGANIZATIONAL STRUCTURE

NOAA's Special Projects Staff for OTEC proposes to continue to provide ocean engineering research and technology development assistance during FY 84 based on an assessment of the research needs of the OTEC Program. To carry out these functions, NOAA will work under the broad guidance of DOE policy within the framework of this IAA. The execution of the work described herein, including task assignments, management procedures, selection of personnel, and deliverable schedules will be the responsibility of NOAA. The DOE Program Manager for Ocean Engineering will be informed on the status of all projects through monthly and quarterly progress reports.

2. INTRODUCTION

The scope and pace of NOAA's OTEC Ocean Engineering Research and Technology Development Program are based on DOE objectives and priorities for research and development projects. It is concerned with resolving the major engineering research issues in high technical risk areas. DOE's technology development objective is to have industrial consortia complete the preliminary design of a 40-MWe Proof of Concept Experiment (POCE). NOAA can reduce technology risk and uncertainty by performing at-sea experiments of critical subsystems and components and thereby reduce the risk of OTEC plant construction. The NOAA Research and Technology Development Program will provide a technology information base that can assist the private sector in future construction of OTEC systems.

In FY 83 the NOAA OTEC program completed a major portion of the Cold Water Pipe (CWP) At-Sea Test Program. In this phase, a cold water pipe of fiberglass reinforced plastic sandwich construction, 400 feet in length and 8 feet in diameter, was fabricated, instrumented, and deployed from a specially designed barge in an at-sea environment . All aspects of this test were completed successfully, thereby contributing significantly to the knowledge of CWP construction, performance, and cost. Analysis of the data recorded during the Suspended Pipe Test is proposed in this IAA. The objective of this analysis is the validation of the computer models used in the CWP design. The third phase of the At-Sea Test Program, installation of a cold water pipe on a steep underwater slope, has been initiated. The results of this testing are expected to establish the technical feasibility of installing cold water pipes of useful size, in an ocean environment, on a steep slope. Another project, small scale model testing of shelf-mounted platform, was initiated in FY 83. This test program will provide measurements of hydrodynamic loading due to wave and current forces on a shelf-mounted platform configuration that has a large submerged module. These research projects reflect the current DOE emphasis on shelf-mounted systems.

The NOAA OTEC program will conduct research and exploratory development in high risk areas to support the POCE. Major POCE projects and milestones are shown in Figure 2. The POCE conceptual design phase is complete, and the Ocean Thermal Corporation (OTC) has been selected to prepare the preliminary design

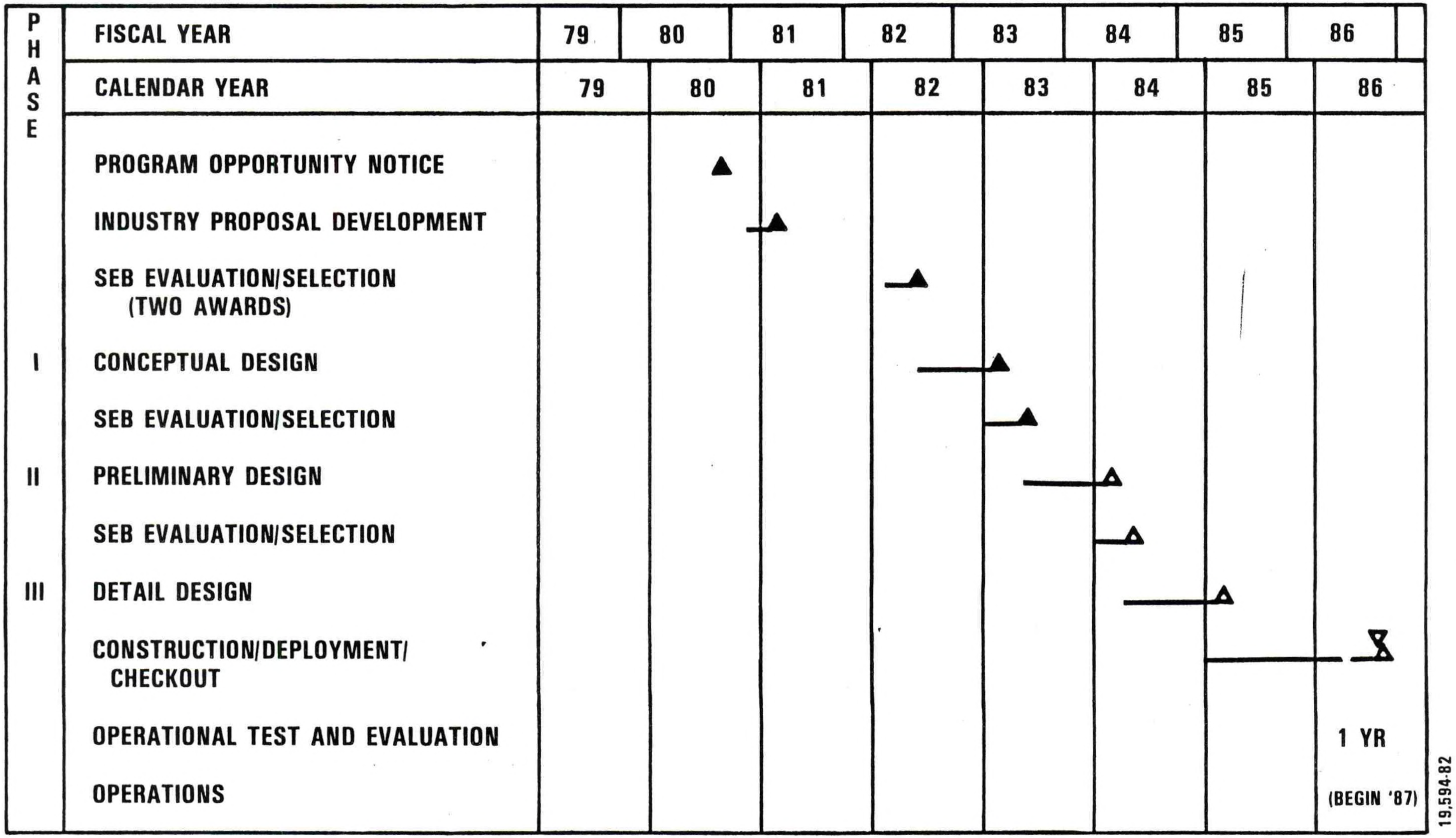

FIGURE 2 POCE PROJECTS AND MILESTONES

for the 40-MWe pilot plant. It will take eighteen months to complete this design project. Meanwhile, the ocean engineering research projects described in this Interagency Agreement will help provide the information most needed in the design to reduce risk in the future construction of a 40-MWe pilot plant. The scope of these projects addresses the most important risks that must be reduced if a pilot plant is to be considered feasible. These include material specifications, determination of CWP hydrodynamic loading, acquiring knowledge concerning the structural interaction between OTEC subsystems and the seafloor, techniques for inspection and repair of cold water pipes, alternative CWP construction and material concepts, and advanced capabilities for in-situ geotechnical measurements. In summary, the FY 84 program emphasizes research in areas of high technical risk.

As the POCE progresses through the design cycle, unexpected problems and new or modified technical requirements may emerge. NOAA will accommodate these changing needs, in response to DOE requirements.

The remainder of this document outlines the program, schedule, and resources required for NOAA's FY 84 Program based on the research needs discussed in Section 3. The technical management plan and project summaries are presented in Section 4. The program management and engineering analysis function, and personnel to perform the proposed FY 84 efforts, are described in Section 5. The FY 84 NOAA financial operating plan for the Special Projects Staff is presented in Section 6.

3. RESEARCH NEEDS

The projects in the NOAA/DOE Ocean Engineering Research and Technology Development Program have been undertaken on the basis of the prevailing research priorities. The Minimum Essential Unknowns (MEU) have been the mechanism by which research needs have been formally stated. The MEUs applicable to the OTEC program are listed in Appendix A.

An independent assessment of the OTEC ocean engineering program was obtained from a national panel of experts from the Marine Board of the National Research Council. The panelists assessed the research conducted to date and reviewed the state of the practice in ocean engineering necessary to design, construct, and operate OTEC plants. The panel generally concurred with the direction of ocean engineering research undertaken to date and the research needs embodied in the Minimum Essential Unknowns. They identified the remaining technical problems, and made recommendations for further research and development to minimize technical risk of applying OTEC technologies. These conclusions have recently been complimented by a July 1983 DOE assessment of the overall OTEC program. The MEUs listed in Appendix A are from a preliminary version of the report of this study. The MEUs of primary interest for ocean engineering research are:

- Fabrication and Deployment Techniques for CWP/Foundations (Floating and Bottom-Mounted)
- Geotechnic and Soil Mechanics Factors (including slope stability) for Soil/Platform and Soil/CWP Interactions
- Operational Safety and IM&R and Retrieval of Submerged Components
- Validated Computer Codes for Predicting CWP (shelf-mounted and suspended) Loads and Responses
- Long-Term Materials Characteristics for CWP
- Hydrodynamic Loads on CWP (suspended or shelf-mounted) Above Reynold's Number of 10^6
- Anchor Hardware for Both Steep Slopes and Rock Conditions
- SWS and Components/Platform Dynamic Interactions
- Slope and Foundation Stability for Shelf-Mounted Platform and CWP Installation
- Validity of Mooring System Analytical Techniques and Models

Thus, there are a number of high technical risks in critical areas of OTEC ocean engineering that must be minimized so that industry can embark on independent commercial ventures. The major technical issues relative to shelf-mounted platforms and foundations pertain to geotechnical considerations. Selection and design of foundations depend upon the environmental and seafloor conditions. Designs and installations in stable sediments and rocks have been demonstrated by the drilling and oil production industry. However, this work was not at the depths required of OTEC system designs, and it does not consider the lifespan of OTEC system installations. Then, as the bottom slope increases, it may be necessary to prepare the site prior to driving piles, if pile foundations are necessary. Under some conditions, prefabricated templates will be required. These technologies have not been demonstrated for steep slopes and deep water. Soil conditions may be encountered that are so different from those previously experienced that the validity of existing design tools would be questionable. Specialized studies and experimental research are required to either confirm the validity of existing design tools, or develop new ones.

Recognition of these research needs has been an integral part of the planning and definition of the projects recommended by this IAA. A review of the objective statements from the project summaries provided in Section 4 shows a strong correlation between the research needs described above and the projects recommended by this Interagency Agreement.

4. FY 84 TECHNICAL PLAN

The technical projects to be managed by NOAA's Special Projects Staff in FY 84 are presented in Figure 3. Objectives, brief descriptions, justification, and other information concerning each of the projects are presented below in project summary format. These projects directly support the DOE program priorities. Hence, special effort has been taken to assure that these projects address the MEUs and research needs presented in Section 3. Figure 4 shows the flow of the NOAA ocean engineering research projects in support of OTEC in general, and the Proof of Concept Experiment in particular.

The funding required for the basic FY 84 research and technology program is $1.5M. The estimates given in the project summaries are based on the present understanding of the work to be accomplished. Previous experience has demonstrated that the scope of work is often modified to accommodate changes in objectives officially directed by DOE to the Special Projects Staff (SPS), and the results of ongoing SPS technical efforts. Therefore it should be understood, as in past IAAs, that these estimates are based on level of effort. Once this IAA, or portion thereof, is approved, action will be initiated by the SPS to contract, or otherwise assign responsibility for project execution.

PRIORITY	TECHNOLOGY DEVELOPMENT PROJECTS	COST	O N D J F M A M J J A S	COMPLETION
1.	DATA ANALYSIS FOR SUSPENDED PIPE RESEARCH (NOTE 1)	250K	O → S	SEP 84
2.	SMALL SCALE SHELF MOUNTED COLD WATER PIPE MODELING	200K	J → S	DEC 84
3.	RESEARCH TOOLS FOR IN-SITU GEOTECHNICAL MEASUREMENTS	225K	J → S	JAN 85
4.	COLD WATER PIPE CONSTRUCTION/MATERIAL CONCEPTS	200K	J → S	DEC 84
5.	RESEARCH IN FRP COLD WATER PIPE INSPECTION AND REPAIR.	200K	J → S	FEB 85
6.	ANALYTICAL MODEL VALIDATION (NOTE 2)	150K	J → S	DEC 84
7.	PROOF OF CONCEPT-PRELIMINARY DESIGN SUPPORT (NOTE 3)	75K	O → S	OCT 84
	TOTAL	1275K		

NOTE 1 INCLUDES $58K OF TECHNICAL ANALYSIS BY NOAA/SPS
NOTE 2 INCLUDES $40K OF TECHNICAL ANALYSIS BY NOAA/SPS
NOTE 3 INCLUDES $40K OF TECHNICAL ANALYSIS BY NOAA/SPS

FIGURE 3 PROPOSED NOAA OTEC FY84 TECHNOLOGY DEVELOPMENT PROGRAM - PROGRAM SUMMARY

83-1711-2

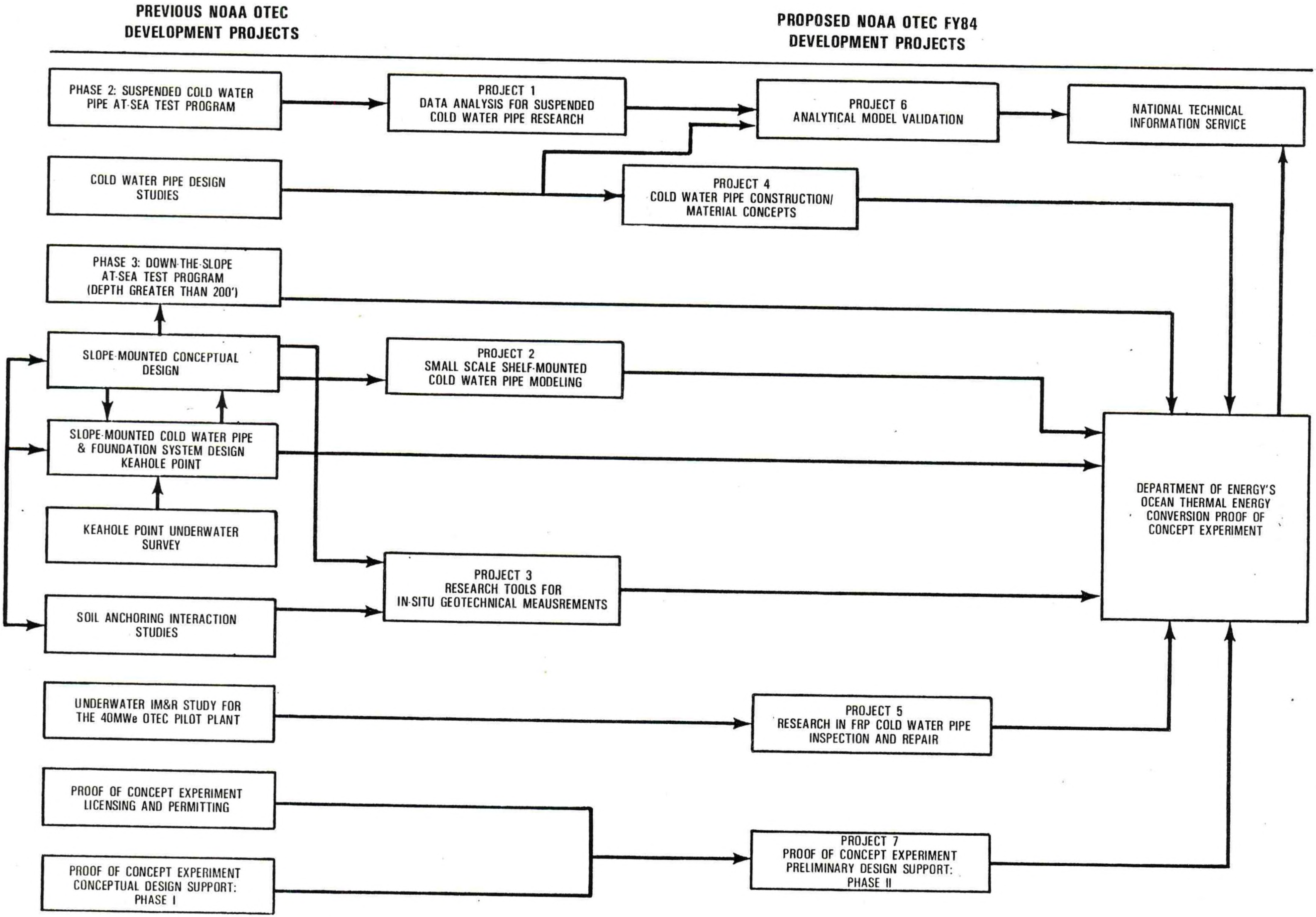

FIGURE 4 PROPOSED NOAA OTEC PROGRAM
FY 84 & CONTRIBUTIONS FROM PREVIOUS PROJECTS

PROJECT 1: Data Analysis for Suspended Pipe Research

OBJECTIVE: The purpose of this investigation is to reduce and interpret data recorded during the CWP at-sea test, and to use this information to validate the CWP response predicted by the computer models used in the design phase of the At-Sea Test Program.

DESCRIPTION: Ninety six channels of data were recorded on 5-1/2 in. magnetic disks during the Suspended Pipe Test phase of the Cold Water Pipe At-Sea Test Program. These data will be transferred to 1/2 in. computer compatible magnetic tape in ANSI format and converted to engineering units for data quality analysis. These data will be used to calculate the engineering parameters of interest for the CWP such as, bending strains and stresses, tensions, pipe accelerations, torque, torsion angles, etc. Additional data processing will produce the statistics for each test, power spectral density estimates at selected locations, and pipe displacement as a function of time. This information will be used to establish the CWP's dynamic characteristics and the hydrodynamic forces that acted on the pipe. These, in turn, will be analyzed to detect the presence of vortex shedding. A similar treatment will be used to calculate the dynamic parameters of the platform such as heading, platform and gimbal translational positions, and roll rate and angle. Additional processing will determine the observed environmental conditions and the environmental forcing functions that acted on the platform and CWP. These data will be used in the next segment of this project.

The second segment of this research project is the validation of the computer models used in the design phase of the CWP At-Sea Test Program. The primary means to validate NOAA/TRW and ROTECF models is to compare the calculated power spectral density estimates with the measured data sets. Comparisons will be performed graphically. ROTECF numerically solves the equations of pipe bending and platform response in the frequency domain, and NOAA/TRW solves the coupled equations of the CWP and platform in the time domain. Both computer programs require the same inputs for the platform, CWP, and the environment. All comparisons will reflect measured environmental data.

JUSTIFICATION: The DOE/NOAA sponsored computer programs (ROTECF and TRW) used to design the CWP require validation using measurements obtained from field experiments. Validation of these computer programs will establish realistic margins for future CWP designs. Realistic margins will reduce the cost of the pipe, since its size may be based upon calculated stresses due to assumed loading. If this project is not funded, the design uncertainties in CWP projects will be costly, limiting the investment opportunities by the non-federal sector. Therefore, federal research in this area is considered essential and of the highest priority.

BUDGET: $250K

DURATION: 12 months

DELIVERABLES:
- Data Analysis Report on the Suspended Pipe Test.
- Formal assessment and calibration of the CWP design methodology.

PROJECT 2: Small Scale Shelf Mounted Cold Water Pipe Model Test

OBJECTIVE: To conduct research to measure the wave and current induced loading that will act on a bottom mounted cold water pipe as a function of incident wave angle, wave height, current speed, and bottom slope.

DESCRIPTION: Presently, there is no analytical model that predicts the hydrodynamic forces acting on a shelf-mounted cold water pipe which extends from the surface to over 1000 meters deep. Similarly, there is no analytical method of determining these forces. Such a model will be developed as part of the down-the-slope CWP at-sea test experiment.

This research will utilize a recirculating wave tank which is capable of simultaneously generating various wave spectra and current velocities. A one foot diameter model of a cold water pipe will be constructed and mounted to a wave tank bottom whose slope can be varied. The Reynolds Number will be maintained on the order of 10^5 during tests. The pipe will extend from the surface to the bottom of the tank. The bottom slope will be 10° where the wave force is dominant. Below this depth, the bottom slope will be varied from 15° to 75°, in 10° increments. Wave loading and current induced forces will be measured independently. Current speeds will be varied in quarter-knot increments from one-quarter knot to three knots (scale). Incident wave direction will be varied from 10° steps from both left and right of normal direction, to within 20° of the beach direction. Model irregular wave spectra are to be selected for the wave scale ratio chosen on the basis of the cold water pipe scale dimensions. The model unidirectional wave spectra will be of the Bretschneider form, with a prototype significant wave height, H_s, and modal wave period, T_o, as follows:

Operational Wave Condition
H_s = 18.0 ft, T_o = 9.8 sec

Puerto Rico Hurricane Condition
H_s = 35.9 ft, T_o = 13.1 sec

Hawaii Hurricane Condition
H_s = 28.0 ft, T_o = 12.0 sec

During each test run the following measurements will be taken:

1. Wave profiles at two locations;
2. Cold water pipe forces and moments at the surface and at each foundation location;

3. Pressure distribution at four equally spaced radial positions at the ends and middle of each pipe segment;
4. Current measurements at three vertical locations.

Data will be stored on ANSI compatible magnetic tape.

JUSTIFICATION: The design and installation of a cold water pipe on a steep slope has been identified as the highest risk item associated with the Proof of Concept Experiment. Since there are no data currently available, this research will advance the state-of-the-art. The results will provide measurements which can be used directly in the design process. These measurements will also be used to validate the research which is planned for the Cold Water Pipe Down-the-Slope At-Sea Test experiment.

BUDGET: $200K

DURATION: 6 months

DELIVERABLES: Two copies of magnetic tape, a written description of the model and experimental procedures, graphical and tabular displays of all measured parameters, and a 160-hour data analysis study and report.

PROJECT 3: Research Tools for In-situ Geotechnical Measurements

OBJECTIVE: To determine the geotechnical data requirements for shelf-mounted foundation and anchor systems and to evaluate advanced in-situ geotechnical measurement systems.

DESCRIPTION: This project will define the types of geotechnical data required for designing shelf-mounted foundations for pipes and structures associated with shelf-mounted OTEC plants. Available equipment and procedures for gathering such data will be described and their capabilities will be compared. In-situ research experiments at the Seacoast Test Facility will be conducted using the best available equipment from various manufacturers, and the results will be compared. The capabilities and shortcomings in the available technology will be assessed and technical approaches for improvements will be recommended.

JUSTIFICATION: One of the most critical risks of OTEC plant designs is the lack of geotechnic and soil mechanics design data necessary for platform/foundation and cold water pipe/foundation design. The need for this information is recognized by the high priority given to the Minimum Essential Unknown that acknowledges the need for geotechnic design information.

BUDGET: $200K

DURATION: 12 months

DELIVERABLES: Geotechnical Data Requirements Report; Geotechnical Equipment Requirements; Advanced Geotechnical Equipment Test Findings

PROJECT 4: CWP Construction/Material Concepts

OBJECTIVE: Research will be conducted to determine if advances in materials and construction techniques have produced techniques which might be adopted since the original cold water pipe materials and construction design concepts were selected.

DESCRIPTION: The most significant engineering challenge, generic to all OTEC concepts, is the cold water pipe. For land based systems, it must be installed on a steeply sloping bottom and extend through the high energy surf zone to at least 1000 meters in depth. An adequate data base describing the properties of steel and concrete alone for cold water pipe construction presently exists. The knowledge of the material properties of elastomers, fiberglass, and FRP was inadequate to predict their behavior for up to 30 years when originally evaluated for use as components in a cold water pipe, since there were no similar structures from which to gain experience.

Additional material property testing and new construction concepts such as sandwich steel, polypropylene bonded to steel (for buoyancy), aerodynamically shaped pipes (to reduce drag and generate negative lift), and pipes with built-in buoyancy tanks indicate that the material selection and sandwich type FRP cold water design should be re-examined to determine if the original materials and construction techniques are still the most effective.

Considerations for the selection of material research include:

- material properties
- corrosion
- erosion
- susceptibility to fouling
- fabrication
- installation
- cost

Construction of the cold water pipe includes:

- new fabrication techniques
- availability of shipyard and offshore industrial facilities

- composite material construction techniques (e.g., sandwich steel, polypropylene bonded to steel, aerodynamic shapes, pipes with built-in buoyancy tanks).

JUSTIFICATION: The Proof of Concept contractors have identified the design and installation of the cold water pipe on a steep slope as the highest risk item associated with the Proof of Concept Experiment. Much research has been done in materials and different concepts for cold water pipe construction since the original selections were made. This research will insure that the original choice still is the most cost effective choice.

BUDGET: $200K

DURATION: 12 months

DELIVERABLES: Reports which include assessment of presently available materials and construction techniques.

PROJECT 5: Research in Fiberglass Reinforced Plastic (FRP) Cold Water Pipe Inspection and Repair.

PURPOSE: To conduct experimental research to characterize FRP material failures relative to the cold water pipe delivery system, and to develop techniques for pipe inspection, fault detection, and submarine fiberglass repair that can be used along the entire length of a cold water pipe.

DESCRIPTION: In this project, an 80 ft long section of the 8 ft diameter FRP cold water pipe that remains from the At-Sea Test Program will be used to quantify the effects of pipe failure and material defects. Cutouts of increasing severity will be inspected using high frequency side scan sonar to generate fault detection criteria relative to CWP efficiency. Experiments will be conducted with underwater video and acoustic response techniques to quantify the ability of these processes to identify FRP faults.

In a second phase of this project, a survey will be made to determine availability of procedures for working with plastic resins in an underwater environment. Laboratory experiments will be conducted to investigate the curing and bonding quality that can be achieved with these procedures and currently available resins for eventual application to repair FRP, steel, and concrete cold water pipes.

JUSTIFICATION: The design life of an OTEC plant will be 30 to 40 years. The CWP must be inspected upon installation, periodically thereafter, and after any catastrophic event. Present CWP inspection processes are restricted to diver depths and are not cost effective. Previous studies show that the economic viability of an OTEC system depends on a reliable, efficient inspection and repair capability for all submerged structures of an OTEC plant. Current fiberglass technology does not presently encompass submarine repair using plastic resins in the submarine environment. The high cost of CWP recovery and deployment, and the undesireable impact of shutting down an OTEC plant make Federal expenditure for the investigation of underwater FRP repair processes consistent with government support of OTEC development.

BUDGET: $200K

DURATION: 12 months

DELIVERABLES:

- A report describing the effect of CWP defects on CWP efficiency.
- A report stating the ability of various inspection techniques to detect CWP defects.
- A report of the use of plastic resin for underwater repair of cold water pipes.

PROJECT 6: Analytical Model Validation

OBJECTIVE: Research to determine if the computer programs, ROTECF, NOAA/TRW, NOAA/DOE, and SWS perform as intended.

DESCRIPTION: The Department of Energy through the Special Projects Staff of NOAA developed 11 computer programs and user/operator guides in support of OTEC subsystem designs. The documentation of these programs is being entered into the National Technical Information System (NTIS) for access by the public domain. Existing user and operator guides are preliminary versions, and vary widely in quality and format. This documentation is required to be in accordance with DOC's Federal Information Processing Standards Publications (FIPS) Standards for computer programs. The two applicable publications are FIPS Pub. 38 "Guidelines for Documentation of Computer Programs and Automated Data Systems" and FIPS Pub. 64 "Guidelines for Documentation of Computer Programs and Automated Data Systems for the Initiation Phase." This project will uniformly apply the FIPS standards to the OTEC computer programs to assure that the models perform as intended with an increased degree of user friendliness.

JUSTIFICATION: NOAA/DOE consists of the computer programs CWPFLEX, COTEC, XOTEC, and CWPEXT. Of 18 NOAA/DOE users, seven replied to questionnaires indicating that preliminary user manuals are not user oriented and contain many errors. They also reported that the programs are machine dependent and contain many errors.

The programs ROTECF and NOAA/TRW were designed to be run sequentially, i.e., in the ROTECF suite of programs, SPFOR (ship form, a program which contains the platform characteristics) would be run, followed by ROTECF. The output of ROTECF (the frequency domain model which calculates the mean loads) has to be manipulated by hand for approximately eight hours to obtain the RAOs used as input to NOAA/TRW (the time domain model which calculates the peak loads). Input and output requirements must be made compatible to permit the total analysis of peak and mean loads to be easily determined.

All of the above analytical models were developed to provide tools for qualified design engineers associated with the OTEC program. The utility of these computer programs to design engineers must be evaluated and validated by the use of field data. Outputs from NOAA/TRW and ROTECF will be compared with field data in Project 1.

BUDGET: $150K

DURATION: 15 months

DELIVERABLES: Rewritten user guides and operator guides following FIPS Pub. 38 and 64 guidelines; valid benchmark test cases; and computer programs which perform as intended.

PROJECT 7: Proof of Concept - Preliminary Design Support

OBJECTIVE: Provide critical review and evaluation of preliminary design work being performed for Phase II of the Proof of Concept Experiment.

DESCRIPTION: Starting in June 1983, contractors will conduct a preliminary design effort for DOE's Proof of Concept Experiment. The preliminary design phase will involve collection of test data, modeling, and design of all pilot plant subsystems with emphasis on those subsystems representing the highest risk. A significant effort will be put forth in the ocean engineering and design required for the cold water pipe, foundations, platform, and seawater systems. This task will provide review of contractor designs and testing, as well as guidance where necessary, for the ocean engineering activities associated with Phase II of the Proof of Concept Experiment.

JUSTIFICATION: Critical design and testing functions will be performed by contractors during the preliminary design Phase II, of the Proof of Concept Experiment. To assure the design, testing, and results meet DOE's objectives for the Pilot Plant Program, it is imperative that the contractor's activities be subjected to close monitoring and independent review by qualified government ocean engineers. NOAA will provide this monitoring and review function, applying the expertise, technical information, and data base, developed over the years.

BUDGET: $75K

DURATION: Twelve months

DELIVERABLES: Review of technical documents to include review comments. Assist Pilot Plant Project Office in planning and coordinating design reviews.

5. PROGRAM MANAGEMENT AND ENGINEERING ANALYSIS

Management. Through the DOE/NOAA Memo of Understanding and this NOAA/DOE Interagency Agreement (IAA) for FY 84, NOAA is responsible for the technical management of the ocean engineering aspects of the DOE OTEC technology development program. DOE has delegated to NOAA the leading role in planning, implementing, coordinating, monitoring, and controlling the ocean engineering technology development program. NOAA's primary responsibilities in the ocean engineering programs pertain to the platform, cold water pipe, sea water systems, IM&R, and the mooring and foundation systems. NOAA has established and maintained a Special Projects Staff for OTEC in the Office of Oceanography and Marine Services to perform this role. Every effort will be made to maintain a small cadre of NOAA personnel to develop, sustain, and effectively utilize and apply knowledge gained in the OTEC technology development program. Temporary personnel will be used whenever special technical expertise or special assistance is required to meet objectives and schedules.

Engineering Analysis. Seven of the technical tasks associated with the projects covered by this IAA will be accomplished by personnel from the Special Projects Staff. Approximately one and a half man years of in-house effort will be applied to review or analysis tasks for which in-house capability exists. One-half staff year each will be applied to Projects 1, 6, and 7 as shown on Figure 3. Technical tasks to be addressed include:

1. Correlation of field test data for Phase II of the CWP experiment and data produced by analytical models.
2. Determination of loading coefficients through comparison of model data and measured data.
3. Review and analysis of computer generated test data.
4. Modification of computer programs to reflect incorporation of test data.
5. Modification of computer programs to make them more user friendly.
6. Technical review and analysis of Pilot Plant Preliminary Design Report.
7. Preparation of technical reports for items 1-6 above.

Special Projects Staff engineers will arrange for computer support services through new or existing contracts to support the in-house technical review and analysis.

In addition to performing technical analysis and review, SPS personnel will perform the contract management functions described above.

The personnel assigned to the SPS are in the following two categories:

- Positions Filled by NOAA Personnel ~~With~~ Full Time Permanent Appointments

  J. Vadus - Program Manager

  B. Taylor - Project Engineer

  A. Kalvaitis - Project Engineer

  T. Wolford - Project Engineer

- Positions Filled by NOAA Personnel With Full Time Permanent Appointments, Temporarily Assigned to the Special Projects Staff

  D. Tracy - Project Engineer

A. POSITIONS FILLED BY FULL TIME PERMANENT NOAA PERSONNEL

The Program Manager and project engineers provide the nucleus for NOAA continuity of the program and Government accountability. Three NOAA project engineers are assigned to the SPS on a full-time basis to manage projects for FY 84. Each project engineer serves as a Contracting Officer's Technical Representative (COTR)/Assistant COTR for projects undertaken by the SPS and each engineer reports to the Program Manager. As COTRs, their duties include program planning, technology assessment, statement of work preparation, analysis and evaluation of contractor performance, and project management. Areas of technical responsibility include laboratory and at-sea testing; inspection, maintenance, and repair; test planning, reliability and maintainability; classification, licensing, and insurability; system interface requirements; ocean engineering subsystem integration; and analytical model development and validation. The matrix in Figure 5 shows the projects that each engineer serves as COTR or as Assistant COTR. Technical integration is insured through close coordination with other project engineers in the PMO.

Full time permanent NOAA personnel currently assigned and projected for FY 84 are listed below, along with their areas of responsibility.

Program Manager - Joseph R. Vadus: The Program Manager provides the overall management and administrative direction of the NOAA OTEC program described

PROJECT	TAYLOR	KALVAITIS	WOLFORD	TRACY	VADUS
DATA ANALYSIS FOR SUSPENDED PIPE RESEARCH		1	2		
SMALL SCALE SHELF MOUNTED CWP MODELING	1		2		
RESEARCH TOOLS FOR IN-SITU GEOTECHNICAL MEASUREMENTS		1			2
COLD WATER PIPE CONSTRUCTION/ MATERIAL CONCEPTS	1	2			
RESEARCH IN FRP COLD WATER PIPE INSEPCTION AND REPAIR			2	1	
ANALYTICAL MODEL VALIDATION		2	1		
PROOF OF CONCEPT-PRELIMINARY DESIGN SUPPORT	1	2	2	2	2

(1) = PRIMARY
(2) = SECONDARY

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FIGURE 5 TECHNICAL ASSIGNMENTS

herein. Because of the reduced scope of this plan, the program manager will spend approximately 50% of his time on this program. This includes program definition and planning, preparation of the Interagency Agreement, and adherence to its terms. He is responsible for meeting the program goals and schedules in keeping with the IAA as it may be modified through mutual agreement during the fiscal year. He recruits and assigns qualified personnel to projects and tasks, and monitors and guides their performance. The Program Manager also serves as the Contracting Officer's Technical Representative for system support contracts. He assigns, reviews, approves, and monitors all tasks performed by that contractor. He reviews and approves monthly and quarterly reports, technology development plans, annual operating plans, statements of work, and procurement documentation, and participates in major technical reviews. He responds to NOAA management requests for program reviews, briefings, and administrative requests regarding requirements for staffing, space, and procurement services.

As Program Manager, he serves as the principal point of contact and interface with the Department of Energy Program Manager for OTEC Ocean Engineering Technology Development on all matters relating to this program including: formulation and execution of the Interagency Agreement; preparation of planning documents; progress and fiscal reporting; presentations, program scope implementation or redirection, personnel assignments; and other matters within the scope of responsibilities described above. All interfacing by DOE on such matters will be through the Program Manager. Technical discussions within the range of the program can be handled directly with the COTRs. The Program Manager's interface at DOE is Dr. Michael Kim, unless modified in writing by DOE.

Project Engineer - Mr. Algis N. Kalvaitis: During FY84, Mr. Kalvaitis will serve as assistant COTR for the CWP Shelf-Mounted At-Sea Test. He will be responsible for the instrumentation, measurements, and data quality assurance aspects of the program. Additionally, Mr. Kalvaitis will be the COTR for the Data Analysis for Suspended Pipe Research and for Research Tools for In-Situ Geotechnical Measurements.

Project Engineer - Mr. Bobby Taylor: Mr. Bobby Taylor will be the COTR for the shelf-mounted test of the cold water pipe. In this capacity, he will work closely with Hawaiian Dredging and Construction Company to assure the technical adequacy of the work as it progresses. Additionally, Mr. Taylor will be the contact point for the Special Projects Staff's support of the preliminary design of the 40 MWe Proof of Concept Experiment and the COTR for Cold Water Pipe Construction/Material Concepts.

Project Engineer - Dr. Thomas C. Wolford: Dr. Thomas C. Wolford has been responsible for the configuration management of all computer programs which support the OTEC program. This project will continue until all these programs have been submitted to the National Technical Information Service. He is presently serving as COTR on the Shelf Mounted Platform Scale Model Test project which Chicago Bridge and Iron Industries will perform under a firm fixed price contract. He will participate in the analysis of the data recorded during the Suspended Pipe Test. He will assist Mr. Taylor, as required, by providing technical support to the POCE program.

B. FTP NOAA PERSONNEL TEMPORARILY ASSIGNED TO SPS

Supplementing this staff is one full time NOAA Corps officer assigned to the Special Projects Staff for OTEC, mainly for assistance in the operational aspects of the program.

Project Engineer - LT. CMDR. Dan Tracy: Lt. Cmdr. Tracy possesses considerable operational experience that has been of significant benefit to the OTEC program. He is also a qualified diver. Lt. Cmdr. Tracy is the COTR for the Special Projects Staff's continuing efforts to identify and resolve the installation, maintenance, and repair issues that OTEC plant construction must face.

C. Technical Consultation: If special technical expertise is required, consultation services will be obtained on a temporary basis.

6. FY 84 FINANCIAL OPERATING PLAN

The financial operating plan for the FY 84 program is given as Table 1. The budgets included for personnel, travel, supplies; and materials, and other costs are based on similar needs and experience developed over previous years. It should be noted that the costs stated herein are level of effort estimates, and only the actual costs will be billed against DOE accounts. If any category funds are not used in the fiscal year budgeted, these funds will be carried over to the following year.

Direct Labor

Professional services provided from the NOAA staff include one program manager and three senior engineers. Two clerical assistants are also furnished by NOAA. Personnel requirements are based on the scope of work proposed.

Indirect Labor

The overhead rate on NOAA labor is 64.3%.

Travel

The amount of travel money actually used will be limited to the NOAA travel ceiling apportioned to the Special Projects Staff for FY 84.

The major thrust of the FY 84 NOAA/SPS OTEC technology development program involves the conduct of laboratory and at-sea research. A moderate amount of travel is anticipated in order to properly discharge the Government's managerial and engineering responsibilities in these test activities. The FY84 travel budget is based on a projection of the trips required to initiate and monitor contracts, conduct design reviews, witness tests, tour facilities, and attend conferences and meetings related to OTEC technology. In some cases the systems support contractor may act on the Government's behalf, particularly in the case of information gathering and coordination. Where such travel assignments are appropriate, they will be made. In many cases it is mandatory that a Government representative be in attendance to witness and approve test operations. Such attendance ensures closer knowledge of programmatic progress and problems, direct coordination of activities, and opportunity for on-site decisions at key points in the program.

TABLE 1

Financial Operating Plan - FY 84
NOAA - OTEC Program Management Office
and Contract Activities

OPERATING BUDGET

I. NOAA Program Management

Direct Labor:

Position File	Effort	Grade	Cost
Program Manager	(6 mos.)	15/7	$ 29,130
Senior Engineers	(18 mos.)	14/6	72,235
Secretary Typist	(12 mos.)	5/2	13,815
Clerk Typist	(6 mos.)	5/5	7,577
		SUBTOTAL	$ 122,757

Indirect Labor (64.3% Total Direct Labor)	$ 78,933	
Travel	20,000	
Supplies & Materials	$ 2,000	
SUBTOTAL	$ 100,933	
MANAGEMENT TOTAL . . .		$ 223,690

II. Technical Program

A. Engineering Analysis

Position File	Effort	Grade	Cost
Senior Engineer	(18 mos.)	14/6	$ 72,235
Clerk Typist	(6 mos.)	5/5	7,577
		SUBTOTAL	$ 79,812

Indirect Labor (64.3%)	$ 51,319	
Travel	5,000	
Supplies and Materials	$ 2,000	
SUBTOTAL	$ 58,319	
ENGINEERING ANALYSIS TOTAL . . .		$ 138,131
B. Contracts		$1,130,679
III. DOC Overhead (@ .5% of total obligation)		$ 7,500
PROGRAM TOTAL		**$1,500,000**

The number and length of such trips for Government employees has been minimized and in this sense the budget represents an austere approach to travel requirements. The budget does not make provision for extraordinary travel requirements, such as those which may result from participation review of the PCE design. Any reduction in travel ceiling would reduce the amount of time planned to spend with the contractors in review and assessment of their work including designs, construction, observation of tests, and other discussions with contractor staff. Such reductions would likely affect the quality and timeliness of the deliverable items and result in increased technical risks and greater ultimate costs.

Supplies and Material

The costs for supplies and materials pertain to such items as copying, preparing reports and presentations, and exhibits.

DOC Overhead

This cost is 0.5% of the total obligation and covers overall DOC administrative costs including procurement services.

Contracts

These costs pertain to all contracts for products or services exclusive of NOAA Program Management.

APPENDIX A

Minimum Essential Unknowns

- High Criticality

Ranking

Ranking	
1	Construction and Deployment Techniques for CWP (Floating and Bottom-Mounted)
2	Geotechnic and Soil Mechanics Factors (including slope stability) for Soil/Platform and Soil/CWP Interactions
3	Improvement of Heat Exchanger Water Side Heat Transfer and Analytical Modeling to Decrease Size of Heat Exchanger
4	Establish Life Expectancy (corrosion, fouling, structural integrity, materials) of Low-Cost Heat Exchangers
5	Understanding Coastal Zone Impacts, Including Validation of Analytical Models for Prediction of Recirculation and Discharge Plums
6	Determine Statistical Variability of Environmental Conditions and Associated Methodologies (oceanographical, meteorological and geophysical) to be Used in Operational Design and in Environmental Impact
7	Operational Scalable Data From a Fully-Integrated OTEC System in a Seawater Environment
8	Operational Safety and IM&R and Retrieval of Submerged Components
9	Validated Computer Codes for Predicting CWP (shelf-mounted and suspended) Loads and Responses
10	Distribution of Non-Condensible Gases in a Plant and their Impact on System Performance
11	Long-Term Materials Characteristics for CWP
12	Electrical Cable System Design, Construction, Deployment, and Life for Moored Plants

- Medium Criticality

13	Effect of Redistribution on Oceanic Properties
14	Hydrodynamic Loads on CWP (suspended or shelf-mounted) Above Reynold's Number of 10^6
15	Scalable Open-Cycle OTEC Turbine Performance Data

16 Electrolysis Efficiency for Plantships

17 CWP Platform Connection Hinge and Seal Validated Design and Test

18 Direct Contact Heat and Mass Characteristics of Seawater at OTEC Conditions

19 Major Effects of Impingement/Entrainment on Plant Design and the Environments

20 Anchor Hardware for Both Steep Slopes and Rock Conditions

21 Sorption Kinetics of Seawater Feed Streams

22 SWS and Components/Platform Dynamic Interactions

23 Ultrasonic Radiation and Other Alternative Methods for Control of Biofouling

24 Proof that Foam/Mist-Lift Cycle can Produce Net Power

25 Effects of Long-Term Biocide on the Environment and the OTEC Plant

26 Definition of Dischage Pipe Requirements

27 Off-Design (other than design conditions) Parametric Analysis of Advanced Power Systems Options - Impacts on Performance, Cost, and Control Strategies

28 Biofouling/Corrosion Data Base for Characterizing Warm Seawater (nearshore, open ocean, site specific)

29 Definition of Operational Sea State Based on Plant Performance Requirements

30 Composite Material Degradation in Seawater Vapor Stream

31 Development of Instrumentation and Control for Open-Cycle Systems

32 Hydrodynamic Loading on Shelf-Mounted Platforms Due to H_x Components

33 Platform Motion Effects on Product Processes

- Low Criticality

34 Slope and Foundation Stability for Shelf-Mounted Platform and CWP Installation

35 Life Time Effects on the Macro-Fouling Community on Cold and Warm SWS Components

36	Identification of Available Wave Resource in All Areas of Potential Benefit to U.S.
37	Thermal Plumes from Cruising Plantships and Multi-Plant Environmental Effects
38	Validity of Mooring System Analytical Techniques and Models
39	Technical Feasibility and Cost Effectiveness of Identified Wave Energy Extraction Techniques
40	Net Effect of OTEC Operation and Atmospheric and Climate Conditions