Project Development Plan

DOMES

DEEP OCEAN MINING ENVIRONMENTAL STUDY

September 1977

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
Environmental Research Laboratories

Marine Ecosystems Analysis Program

Mary Baker

Project Development Plan

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Marine EcoSystems Analysis Program Office

Boulder, Colorado

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U.S. DEPARTMENT OF COMMERCE
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ACRONYMS

CLB	Continuous Line Bucket
CTD	Conductivity-Temperature-Depth (Recorder)
DOMES	Deep Ocean Mining Environmental Study
EDS	Environmental Data Service
ERL	Environmental Research Laboratories
ESIC	Environmental Science and Information Center
FWPCA	Federal Water Pollution Control Act (Amended 1972)
MESA	Marine Ecosystems Analysis (Program)
MLC	Major Line Component (of NOAA)
MPRSA	Marine Protection, Research, and Sanctuaries Act (of 1972)
NESS	National Environmental Satellite Services
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Survey
NWS	National Weather Service
PDP	Project Development Plan
RFP	Request for Proposals
SPM	Suspended Particulate Matter
TDP	Technical Development Plan

EXECUTIVE SUMMARY

The Marine Ecosystems Analysis (MESA) Program initiated in 1972 by the National Oceanic and Atmospheric Administration, provides a mechanism whereby the capabilities existing in the various NOAA Major Line Components (MLC's) can be formed into a cohesive study effort in selected coastal areas. The MESA Program serves as the focus for cooperative efforts with these and other federal, state, and local agencies; universities; industry; environmental organizations; and others to investigate specific marine environmental problems beyond the research capability of a single government agency.

The Deep Ocean Mining Environmental Study (DOMES) was selected as a regional MESA Project in order to answer the myriad of questions which exist concerning the potential environmental effects of large scale manganese nodule mining on the little understood abyssal regions of the ocean and the living resources of oceanic surface waters.

At present, several international consortia are actively engaged in pre-mining research and development activities directed at recovering manganese nodules from ocean depths from 3700 to 5500 meters (2.3-3.4 mi.). The advances in deep ocean mining technology should, if an adequate legal regime exists, permit commencement of commercial scale exploitation within 5-6 years. Because of its broad mandate and specific authorities regarding the oceans and conservation of living marine resources, NOAA/MESA was assigned the responsibility for developing the DOMES Project in 1975. NOAA had previously sponsored deep ocean mining environmental studies as early as August 1972, with subsequent follow-on baseline studies.

The DOMES Project Development Plan (PDP) presented herein has been jointly prepared by the MESA Program Office and the DOMES Project Staff, and represents the overall plan for accomplishing the DOMES Project. It supercedes the DOMES PDP of April 1974, as well as the DOMES Draft Technical Development Plan of April 1975. The plan describes a systematic approach to achieving specifically identified goals and objectives of the Project. The overall goal of the DOMES Project is to assess the potential impact of deep-ocean manganese nodule mining on the marine environment. The objectives leading to the achievement of the goal are to:

1. Identify and characterize the disturbance to the marine environment induced by the mining systems.

2. Characterize the temporal and spatial dispersion of materials from the discharges of the mining systems.

3. Identify and characterize aspects of the marine ecosystem most susceptible to impact by the mining systems.

4. Characterize immediate environmental impacts imposed by the mining systems.

5. Synthesize, from all available information, an assessment of the potential cumulative impact of deep-ocean manganese nodule mining on the marine environment.

The DOMES at-sea investigations are planned to occur in two phases. Phase I involves studies prior to disturbance by mining, while Phase II involves the monitoring of precommercial tests of mining systems. Phase I field work was completed in 1976, and was designed to (1) establish a quantitative, statistically defensible baseline, (2) develop a first-order predictive capability to assess the marine environmental effects of deep-ocean mining, and (3) permit the development of preliminary environmental guidelines for deep-ocean mining.

Phase II, beginning in 1977, is designed (by extensive monitoring of prototype mining systems tests) to permit the refinement or modification of the predictive capability as well as the preliminary environmental guidelines established in Phase I.

In characterizing the cumulative ecological effects of environmental impacts imposed by deep-ocean mining, consideration is being given to the eventual development of a mature industry involving numerous mining ships operating in many areas of the nodule belt for several decades. Full commercial production will involve a number of mining ships, each capable of recovering from 5,000 to 10,000 metric tons (dry weight) of nodules per day, and operating 24 hours per day for about 300 days per year.

Initial priority has been placed on characterizing the immediate and cumulative ecological effects resulting from the surface plume created by the discharge of a slurry of mined materials (primarily sediments from the sea floor) during a mature or full-scale mining operation. This issue is deemed most important as this is the area where a potential exists for the impact to be felt by man.

The impact of the mining process on the deep-ocean benthic organisms also is being studied in order to provide an overall description of bottom disturbance both as a result of direct contact by the mining system and as a result of redistribution of sediment.

Three monitoring efforts presently are scheduled with the timing dependent on the test schedules of the mining companies. DOMES Phase II will therefore be required to retain a high degree of flexibility with regard to logistics and operational planning of their monitoring studies. DOMES Phase II monitoring studies are tentatively scheduled for January 1978, March 1978, and

November 1978. A fourth test may be monitored if available resources permit and if additional data is required by the Project.

DOMES will provide data and information directly to government and industry decision makers (and such regulatory agencies as may be established in the future) who are concerned with the development of deep-ocean mining and the protection of the environment. DOMES will provide a means of improved communication and information exchange among government, industry, and the general public -- the knowledge gained by DOMES will aid government in the establishment of wise laws and regulations and help industry to design environmentally acceptable techniques and equipment.

1. INTRODUCTION

1.1 PURPOSE OF THE PROGRAM

The formation of the National Oceanic and Atmospheric Administration in 1970 brought together a number of organizations with considerable experience in research related to coastal and deep-ocean areas. These organizations are now named: National Weather Service (NWS), National Ocean Survey (NOS), National Marine Fisheries Service (NMFS), Environmental Research Laboratories (ERL), National Environmental Satellite Service (NESS), and Environmental Data Service (EDS). Collectively, these agencies are referred to as NOAA Major Line Components (MLC). These NOAA components manage numerous programs that deal with specific problems related to the estuarine, coastal, and deep-ocean environments.

The National Oceanic and Atmospheric Administration (NOAA) initiated the Marine Ecosystems Analysis (MESA) Program in 1972. The MESA Program provides a mechanism whereby the capability existing in the various NOAA MLCs can be formed into a cohesive effort in selected marine areas. The MESA Program serves as a focus for cooperative efforts with these and other federal, state, and local agencies; universities; industries; environmental organizations; and others to help investigate specific marine environmental problems which are beyond the research capability of any single governmental agency.

The objectives of the MESA Program are designed to accomplish these tasks:

- Describe and understand regional marine ecosystems - Describe and understand the physical, geological, chemical and biological structures, processes, dynamics, and interactions of marine ecosystems in selected regions of coastal and offshore waters of concern to the United States.

- Improve ability to predict changes in regional marine ecosystems - Provide information for improved predictions of the effects of pollutants and other natural or man-induced changes upon the components of the ecosystem. In addition, identify and conduct experimental and other special studies to increase predictive capability and broaden knowledge of processes in the marine environment.

- Develop monitoring strategies - Identify critical parameters and sampling and logistics strategies that should be incorporated into a monitoring program.

1.2 PURPOSE OF THE PROJECT

The overall purpose of the Deep Ocean Mining Environmental Study (DOMES) Project is to assess and predict the potential environmental impact of deep-ocean mining of manganese nodules in the North Pacific nodule belt, and to accumulate and convey information to resource policy and decision-makers to aid in the minimization or avoidance of adverse impacts as a result of mining operations.

The DOMES Project Development Plan (DOMES PDP) presented herein is the MESA Program Office's overall plan for accomplishing the DOMES Project. The plan describes a systematic approach to achieving the specifically identified goal and objectives of the Project. The PDP was jointly prepared by the MESA Program Office and DOMES Project Office personnel, and is subject to approval by the MESA Program Office, the Director of ERL, and NOAA Headquarters.

Figure 1.1 shows the responsibilities of the various levels within NOAA for the development, review, and implementation of this Project Development Plan. It also illustrates the general approach to be used by MESA in developing future projects.

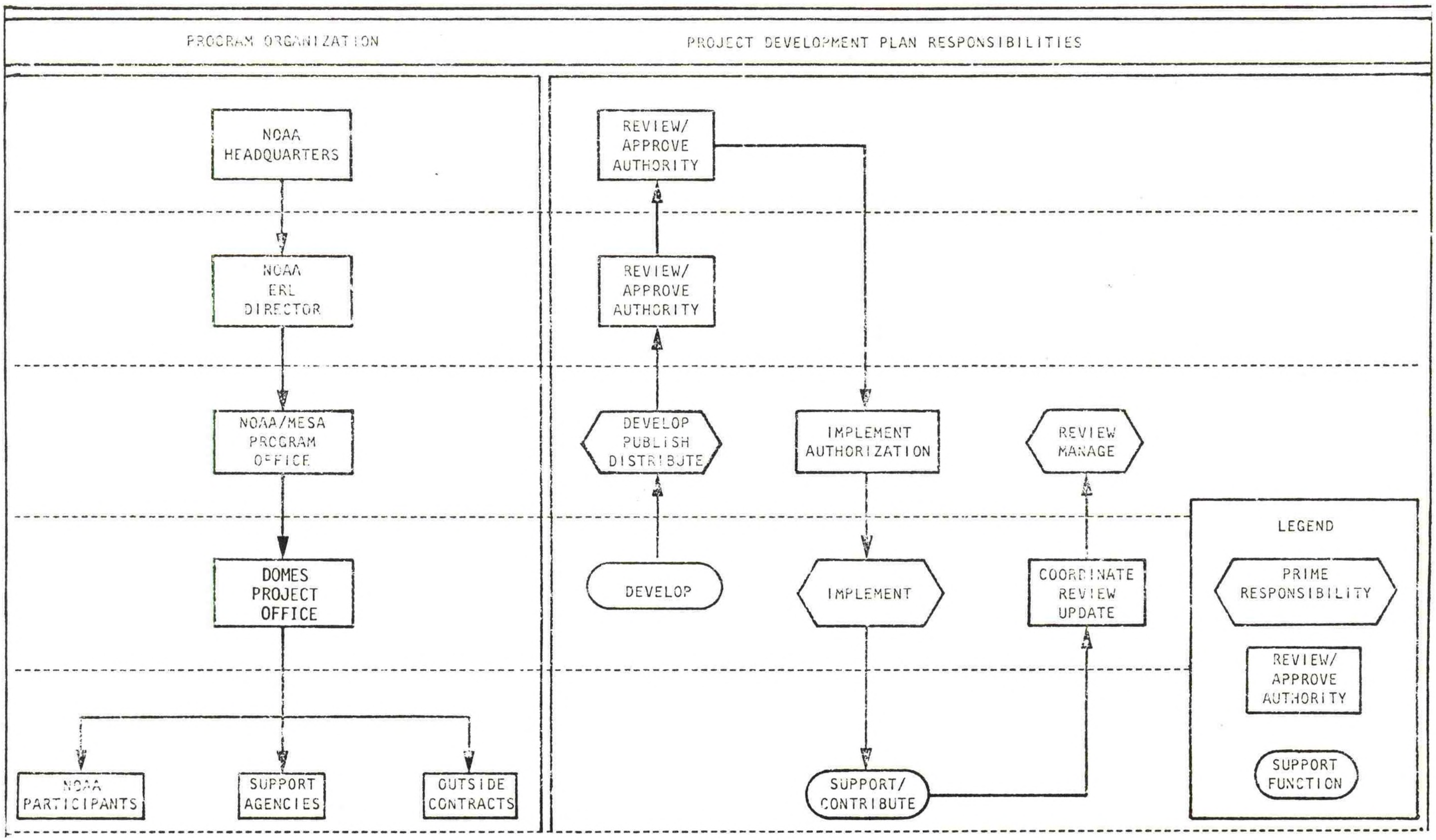

Figure 1.1. Schematic Approach to PDP Development, Review, and Implementation

1.3 LEGISLATION

The legislation under which the MESA Program and DOMES Project are implemented is the result of a FY72 line-item of the U.S. Department of Commerce/National Oceanic and Atmospheric Administration budget entitled, "Regional Studies and Ocean Dumping." However, several other legislated acts provide additional authority supporting the MESA Program and DOMES Project. These Acts include:

1.3.1 National Environmental Policy Act of 1969 (P.L. 91-190)

Relevant portions of this Act (Sections 101a and b) require federal policies aimed at the achievement of the widest range of beneficial uses of the environment without degradation or damage, and at the utilization of systematic, interdisciplinary approaches to environmental planning and decision making.

1.3.2 The Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500)

Title I, Sections 101 and 104, of the FWPCA Amendments state the national policy that a major research effort be made to develop the technology necessary to monitor and mitigate the discharges of pollutants into the navigable and contiguous waters of the United States and the oceans. This act identifies NOAA as one of several federal agencies authorized to conduct such research.

1.3.3 Marine Protection, Research and Sanctuaries Act of 1972 (P.L. 92-532)

Title II, Sections 201 and 202 of the MPRSA give to the Secretary of Commerce the responsibility for conducting research and monitoring on the effects of ocean dumping (Section 201) and on the long-range effects of pollution and other man-induced impacts on the ocean ecosystem (Section 202).

1.4 HISTORICAL BACKGROUND

1.4.1 Program Background

The concepts of a Marine Ecosystems Analysis Program were originally generated in 1971. The formation of the National Oceanic and Atmospheric Administration (NOAA) in 1970 brought together a number of organizations with considerable experience in research related to coastal and deep-ocean areas.

To aid in the preservation and management of our marine resources, a need was identified to further define and understand the processes by which man impacts the territorial, contiguous, boundary, and international waters of concern to the United States. To meet this challenge the Marine Ecosystems Analysis (MESA) Program was established in 1972 by NOAA.

It is a function of the MESA Program to integrate and focus NOAA capabilities in marine research into cohesive efforts applied to problems in selected geographic areas.

In addition, MESA issues grants and contracts for work to supplement NOAA's in-house capabilities; it also serves as a focus for cooperative efforts with other federal, state, and local government agencies, universities, industries, ecological and environmental groups, and others concerned with specific marine problems.

MESA activities are focused in the MESA Program Office within the Environmental Research Laboratories (ERL) in Boulder, Colorado. Among these activities is the Deep Ocean Mining Environmental Study (DOMES), assigned to MESA in 1975.

1.4.2 Project Background

Deep-ocean mining for manganese nodules has received considerable interest over the past decade. Nodule resources of current commercial interest are located at ocean depths of 3,700 to 5,500 meters. Over the past 15 years, significant advances in deep-ocean mining technology have occurred. These advances will, in all likelihood, permit commencement of commercial scale exploitation within 5 to 6 years. The main focus of present industrial interest is within a 13 million square kilometer area of the North Pacific (5°-20° north latitude and 110°-180° west longitude). Figure 1.2 shows the location of the three DOMES study sites, which were chosen to be representative of the range of environmental parameters to be encountered during the mining operations (see Section 3.2).

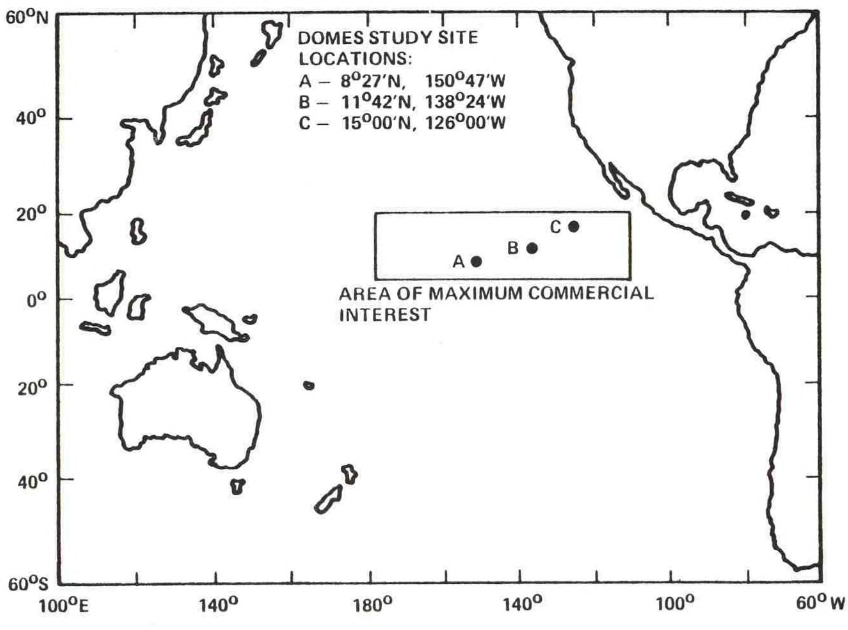

Figure 1.2. Deep Ocean Mining Environmental Study (DOMES) Project Area. Sites A, B, and C are the focal points of DOMES baseline studies.

At present, no federal authority exists specifically for management and regulation of deep ocean manganese nodule mining. However, because of its broad mandate and specific authorities regarding the oceans and conservation of living marine resources, NOAA was first urged to undertake deep ocean environmental impact studies in June 1972. The proposed program subsequently received the endorsement of industry, the Department of State, the Council on Environmental Quality, and others. Preliminary environmental impact investigations were sponsored by NOAA as early as August 1972. Field operations under the formal DOMES Program began in August 1975.

DOMES was organized in order to answer the myriad of environmental questions which exist concerning the potential effects of large scale manganese nodule mining on the little understood abyssal regions of the ocean, and the living resources of oceanic surface waters. In recognition of these concerns, Congress appropriated funds starting in fiscal year (FY) 1976 for initial studies of environmental impacts which may result from deep ocean mining. Responsibility for these studies was assigned to the National Oceanic and Atmospheric Administration which in turn initiated the first of two phases of the DOMES Project on the area described above.

DOMES Phase I field work was completed in 1976; it was aimed at establishing a baseline statement of those environmental factors which would be affected by mining operations. Phase II work is aimed at monitoring the prototype mining activities which are scheduled to begin in 1978.

1.5 PURPOSE AND ORGANIZATION OF THE PLAN

The PDP defines the goal and objectives of the DOMES Project and explains their rationale within the scope and resources of the Project. It supercedes the DOMES PDP of April 1974, as well as the Draft Technical Development Plan of April 1975. The PDP describes the Project rationale and organization, overall strategy, management schedule, and philosophy that will be employed during implementation of the Project. The benefits of the Project are discussed at length in Chapter 3. Chapter 5 summarizes the funding and organization of the work to be done. A detailed description of the research, delineated as a set of specific studies, and the scheduling, funding and products of these studies will be contained in the DOMES Technical Development Plan (TDP) which will appear as a separate volume.

1.6 PROBLEM DEFINITION

At present, several international consortia are actively engaged in pre-mining research and prototype development activities. They have expended considerable sums of money on nodule exploration, as well as on mining and metallurgical research.

The undertaking of basic environmental research in tandem with engineering and at a very early stage in the planning, development, and demonstration of a new industrial process, makes DOMES close to being an optimum implementation of Sections 101a and 101b of the National Environmental Policy Act of 1969, P.L. 91-190. This tandem development of information could help provide tangible environmental information sufficiently early in the planning process to influence decisions about industrial siting, engineering designs, and operational techniques in order to bring them into productive harmony with the environment.

Two main types of mining systems are being developed by industry: hydraulic (either towed or self-propelled); and mechanical. The towed hydraulic system is the one most commonly discussed by American industry and is the primary mode considered in DOMES Phase I studies. This system involves pumping water and nodules through a pipeline to a surface ship. The nodules will be acquired by a collector that will be towed along the ocean floor at the end of the pipe leading to the mining vessel. In addition to the nodules, the collector also will pick up sediment, interstitial and bottom water, and benthic biota. Most of the sediment and biota will be separated from the nodules close to the seafloor and released from the mining system, creating a benthic plume. The nodules arriving aboard the surface mining vessel will be separated from the remaining sediment. As presently envisioned, the latter material, including bottom water, will be discharged at the ocean surface.

It is this material that causes the greatest public concern about effects on the marine environment at the mining sites. Information must be obtained on the effects of the surface discharge on such factors as turbidity and heavy metal content of the water column in order to determine the impact of mining systems on the environment.

In characterizing the cumulative ecological effects of environmental impacts imposed by deep ocean mining, we must consider the eventual development of a mature industry involving numerous mining ships operating in many areas of the nodule belt for several decades. Full commercial production will involve a number of mining ships, each capable of recovering from 5,000 to 10,000 metric tons (dry weight) of nodules per day, and operating 24 hours per day for about 300 days per year. Although copper, cobalt, and, in some cases, manganese will be recovered and marketed, it is likely that the growth of the industry will parallel but not equal, the growth needed to supply the increasing world demand for nickel. This situation could result in two to four units of 5,000 metric tons per day production (although not necessarily 2 to 4 ships) by 1985 and 20 to 40 units around 2010 A.D.

2. GOALS AND OBJECTIVES

2.1 SCOPE

The DOMES Project deals with the potential marine environmental problems to be expected from the commercial-scale mining of deep ocean manganese nodules. There are two aspects to consider in contemplating the environmental effects of the development of a mature deep ocean mining industry: effects that occur at sea in the region of the mining activity; and effects that occur in the coastal zone as a result of the activities associated with land-based metallurgical processing plants where the metals of commercial interest are recovered.

This document deals with the at-sea effects. However, other NOAA studies (managed by the Marine Minerals Office) are examining the coastal zone problem with respect to: nodule transportation to shore, port requirements and traffic, and likely processing techniques and plant characteristics (including waste products and treatment methods). The possibility of at-sea waste disposal and/or processing is also under study.

The scope of the DOMES Project is also confined to short term (maximum of 5 years) studies which address effects of a limited time scale. It is recognized that long term effect studies will be essential as development of deep ocean mining progresses and that a monitoring program should be established as soon as possible. The data base obtained during the DOMES studies will be critically important in the long-term studies of pelagic and benthic biota, turbidity, water chemistry, or other aspects of the marine environment in the mining area.

The DOMES at-sea investigations are planned to occur in two phases. Phase I involves studies prior to disturbance by mining, while Phase II involves the monitoring of pre-commercial tests of mining systems. Phase I was designed to:

- Establish a quantitative, statistically defensible baseline;
- Develop a first-order predictive capability to assess the marine environmental effects of deep ocean mining; and
- Permit the development of preliminary environmental guidelines for deep ocean mining.

Phase II is designed (by extensive monitoring of prototype mining systems tests) to permit the refinement or modification of the predictive capability as well as the environmental guidelines established in Phase I.

2.2 GOAL AND OBJECTIVES

2.2.1 Goal

The goal of the DOMES Project is to assess the potential impact of deep-ocean manganese nodule mining on the marine environment.

2.2.2 Objectives and Rationale

Objective 1 Identify and characterize the disturbance to the marine environment induced by the mining systems.

The disturbance to the marine environment includes the discharge of materials from the mining systems and the impact of the nodule collector on the sea floor. The composition and discharge rates of these materials determine the initial concentrations of materials introduced into the marine environment. These discharges include a surface plume, a benthic plume, and possibly a mid-water discharge. Included in the discharges will be bottom and interstitial water, air, deep sea sediments, macerated biota, and abraded nodule materials.

The mining system will also impact the benthic environment through direct contact of the nodule collection apparatus with the sea floor. In order to adequately assess this impact, the extent of physical disturbance to the sea floor habitat must be known.

Objective 2 *Characterize the temporal and spatial dispersion of materials from the discharges of the mining systems.*

The discharges will result in direct and indirect exposure of the marine environment to these materials. In order to adequately assess the impact of this exposure, we must know the spatial dispersion of the plumes, concentration of materials, rates of dispersion, and manner of deterioration.

Objective 3 *Identify and characterize aspects of the marine ecosystem most susceptible to impact by the mining systems.*

Changes in the environment will affect the biota to different degrees, depending on tolerance of and exposure to those changes. Assessment of potential damage to the marine ecosystem will require knowledge of those components of the abiotic environment that are subject to change and the extent of that change. It will also require an inventory of the biological communities living in the area of potential mining impact, and knowledge of the sensitivity of the resident biota to changes in their physical-chemical environment.

Objective 4 *Characterize the immediate environmental impacts imposed by mining systems.*

An assessment of the beneficial, harmful, and inconsequential effects of the test mining operations and an evaluation of these effects by monitoring mining equipment tests are essential to supply a basis for determining the environmental impact of mining operations. Such an assessment requires studies which examine the biological effects of the surface and benthic plumes, and of collector contact on benthic biota, as well as studies conducted after completion of mining equipment tests which assess recovery rates of near surface and benthic biota.

Objective 5 *Synthesize, from all available information, an assessment of the potential cumulative impact of deep ocean manganese nodule mining on the marine environment.*

The assessment of potential cumulative impacts from full-scale mining operations will be the information on which government planning and decision-making involving the deep-ocean mining industry will be based. Such an assessment will require synthesis efforts utilizing information generated in DOMES studies as well as information contributed through scientific workshops or by outside investigators.

To satisfy the needs of its various users, Project DOMES will have to maintain a continuous flow of up-to-date research results to interested parties. In addition, future government efforts to protect the marine environment will need information detailing the necessary features of a monitoring program for mining operations that could give early warning of the development of hazards to the marine environment.

3. OVERALL STRATEGY AND RESEARCH

3.1 INTRODUCTION

The basic strategy embodied by the DOMES Project calls for the effective integration of the research capabilities of a wide variety of government laboratories, private industries, and universities. By means of this coordinated program, a basic understanding of the important natural systems, processes, stresses (as a result of mining operations), and responses to these stresses will be achieved. The approach is to concentrate on five areas of research: mining system characterization, ecosystem inventory, dynamics, effects, and synthesis.

The first three categories represent studies on the basic characteristics of the mining systems and of the open-ocean ecosystem. They will provide the data needed to allow an analysis of that ecosystem with respect to the potential damage caused by materials released into the system via benthic and surface discharges, and damage caused by direct contact of the collection device with the sea floor.

Mining System Characterization studies include tasks dealing with the identification and rates of materials discharged into the marine environment by the mining systems. Also included are studies assessing the physical disturbance to the sea floor. These tasks are addressed under Objective one.

Ecosystem Inventory work consists of baseline studies which characterize the ecosystem. Included in this category are tasks dealing with the distributions of the major indicator species in the area; the determination of the sources and rates of input of contaminants; the characterization of the geological, physical, and chemical parameters of the area; and the natural distribution and concentration of the most critical materials found in the discharge plumes. These tasks are addressed under Objective three.

Dynamics work deals with characterizing tides and currents; phytoplankton productivity; transport rates and fates of discharged materials through predictive modeling efforts; and the mass balance of sedimentological, physical, biological and chemical events such as sediment and nutrient flux. Tasks dealing with dynamics are addressed under Objectives two and three.

The category of effects addresses the specific relationships between aspects of the ecosystem and the various types of discharged materials, including such areas as uptake and retention of particulates and heavy metals, and changes in the distribution patterns of important species of marine animals. Tasks dealing with effects are addressed under Objective four.

Synthesis studies include the integration of multidisciplinary information on the marine environment, on transport processes (especially those affecting discharged materials), and on sensitive indicator species and physical factors that reflect changes on ecological conditions as a result of mining operations. Synthesis studies are addressed under Objectives four (immediate effects) and five (cumulative effects).

In general, inventory-associated objectives must be met before dynamics and ecological effects can be addressed. The latter in turn are required in order to affect a successful interdisciplinary synthesis of all data available in regard to the ecosystem and potential mining impacts.

Results of the synthesis effort will then permit the design and evaluation of a monitoring program that will measure the impact of commercial deep-ocean mining on the environment.

Figure 3.1, the DOMES Research Plan for Phase I and Phase II, displays the course of research in diagram form as a logical progression of scientific steps or tasks. It does not show all the stages at which results will be made available to users of Project data. Project outputs will be released during the course of the Project, and not only during the major synthesis steps shown in the figure. This figure illustrates most of the baseline studies and preliminary impact analysis (including modeling) that have been conducted as part of Phase I. Phase II addresses the actual effects of prototype mining and will verify impact predictions from Phase I. The research effort during Phase II consists of surface plume studies (left-hand branch) and benthic disturbance studies (right-hand branch).

Project implementation to carry out the above strategy will take the general steps outlined in Figure 3.2.

3.2 KEY TECHNICAL CONSIDERATIONS

3.2.1 <u>Site Selection</u>

The location of initial manganese nodule mining efforts covers a broad region of the North Pacific Ocean between 5^{o} and 20^{o} N, and 110^{o} and 180^{o} W. Based on best information available from within the public domain and from the mining industry, three sites were selected for the DOMES Phase I environmental baseline measurement program. These sites were chosen to be representative of the range of environmental parameters to be encountered during mining operations. The rationale for selection of the DOMES Phase I sites follows:

- The equatorial Pacific is characterized by a series of opposing east-west zonal flows. Within this area, plankton production (and consequently, distribution of organisms higher in the food chain) changes, mainly from north to south. Thus, in the potential mining area, there is considerable variation

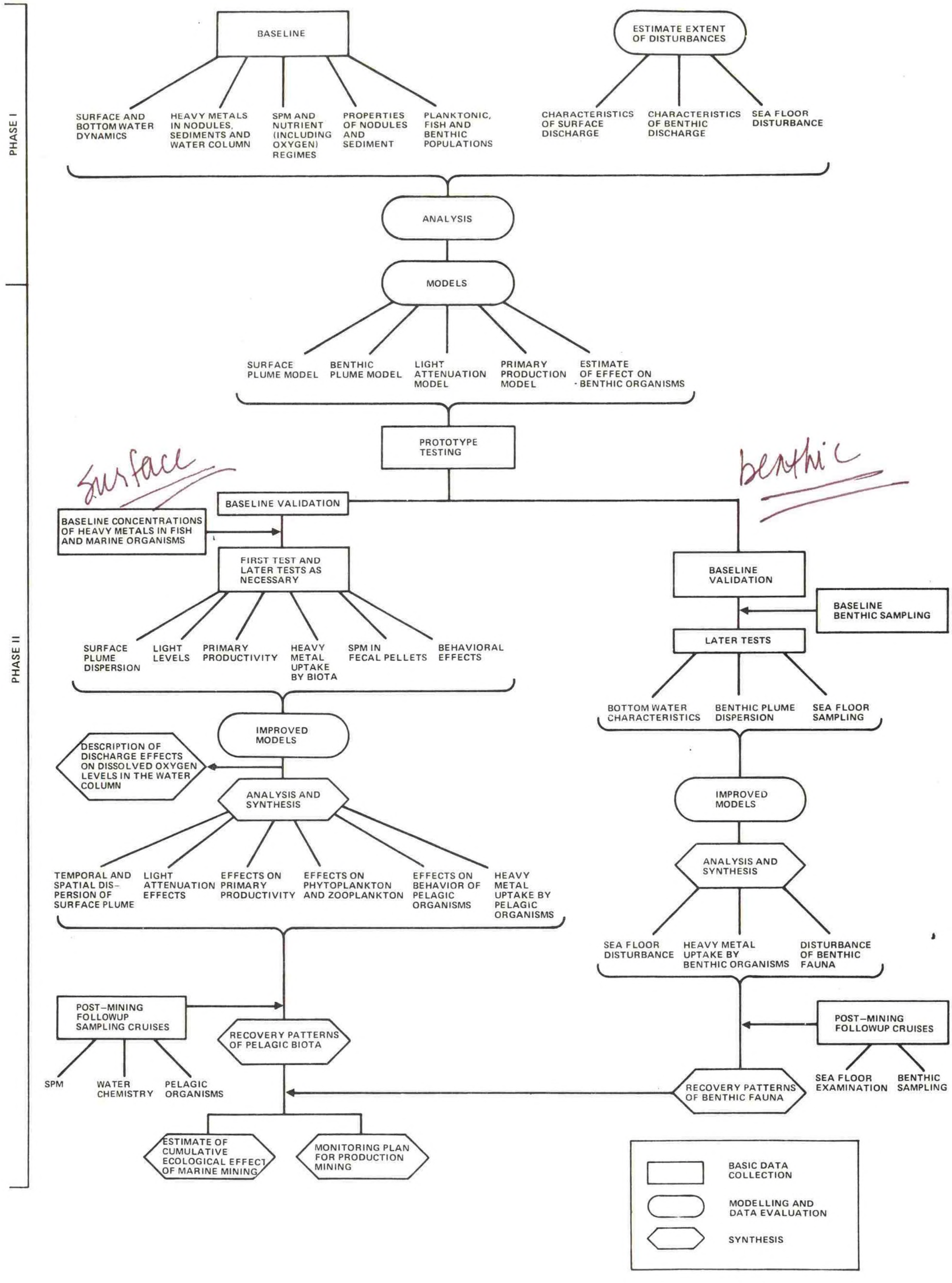

Figure 3.1. DOMES Research Plan for Phase I and Phase II

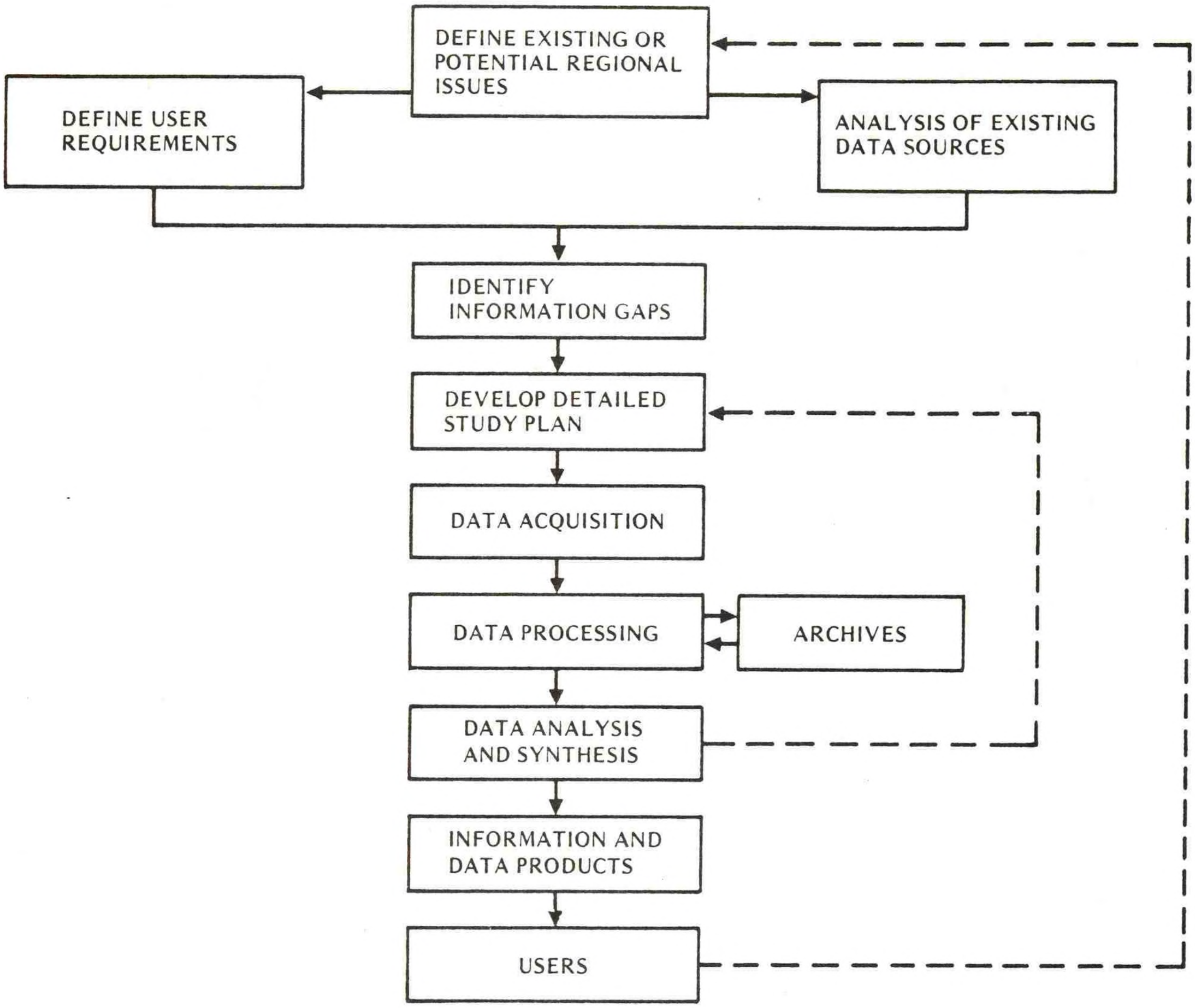

Figure 3.2. Project Implementation for DOMES

in marine life because of the variations in the water column induced by these zonal flows. In characterizing these surface and near-surface flows, the latitudinal length scale is shorter than the longitudinal.

- Site A (8°27'N, 150°47'W) serves as a representative site on the southern boundary of the North Equatorial Countercurrent. Ocean floor sediments in the area are mixed silicaceous ooze and red clay.

- Site B (11°42'N, 138°24'W) was selected to cover the range of expected environmental changes, both in a north-south and east-west direction. It is located in an area of mixed siliceous ooze and red clay ocean floor sediments.

- Site C (15°00'N, 126°00'W) is located in the North Equatorial Current, in an area where the ocean floor sediments are mainly red clay. One consortium has laid claim to a large area centered about this site. Although this claim was not recognized by the U.S. Department of State, it did identify a specific mining site. For realism, this area is being included as one of the three sites. Nodules in this area are reported to have high copper and nickel content and abundance is also high.

3.2.2 Baseline Characteristics

DOMES baseline studies began in the fall of 1975 following two NOAA-sponsored preliminary investigations by the Lamont-Doherty Geological Observatory of Columbia University. The first of these investigations was conducted from the R/V MOANA WAVE at Site A in May 1974; the second from the NOAA ship OCEANOGRAPHER at Site C in April 1975.

The DOMES baseline studies were designed to obtain sufficient baseline data to determine the range of natural variability of selected environmental parameters in the mining region, identify major processes that control the distribution and abundance of marine organisms in the DOMES area, identify environmental parameters sensitive to deep-ocean mining, and start developing predictive models of the consequences of ocean mining on the marine environment. The studies were carried out through the cooperative efforts of a number of Principal Investigators and were based on data obtained during the DOMES field efforts, supplemented with information derived from previous investigations, and reported in the literature.

Over a 14-month period ending in November 1976, ten field efforts were conducted from the OCEANOGRAPHER at Sites A, B, and C to acquire data and samples. Some of these field studies were integrated, multidisciplinary efforts, while others were concentrated studies of a more limited range of subjects.

Studies of the upper-water column were designed to emphasize the physical and chemical environment and the lower trophic levels (plankton). Benthic studies emphasized characteristics of the sediments and the organisms living within the sediments or upon the sea floor.

Preliminary analyses of data from the first three field efforts were reported in the DOMES Phase I Preliminary Report of August 1976. These results form the basis for the following baseline characterization.

Examination of the general physical/chemical structure in the DOMES area indicates that a divergence zone running east-west at about 9^{o} to 10^{o}N (between the westward flowing North Equatorial Current and the eastward flowing North Equatorial Countercurrent) controls the mixed layer depth which varies from 20 to 120 m in the area. Although the regional surface and sub-surface currents can be described from the literature, specific measurements of current distribution with depth have been lacking. Such a measurement program was conducted as part of the DOMES Phase I field operations.

The pycnocline (density gradient) is well developed at the base of the mixed layer in the DOMES area. The nutrient concentrations in the mixed layer are low everywhere (in μg/ℓ): phosphate, 0.4; silicate, 2.0; nitrate, 0.1; nitrite, 0.01; and ammonia, 0.05. The nutrient content increased sharply with depth within and through the pycnocline. Time series observations of continuous nutrient profiles over a 30 hr period at Site B revealed temporal variations within the mixed layer of nearly equal magnitude to the spatial changes observed over the entire DOMES area.

The oxygen concentration is near saturation (> 400 μg/ℓ) in the surface mixed layer. An oxygen minimum zone situated below the thermocline is characteristic of the entire region. The core of the oxygen minimum zone, with concentrations as low as 1.0 μg/ℓ, is centered about 300 m deep and is often greater than 500 m thick. These low values suggest denitrification processes in this zone. Dissolved oxygen concentration increases below the minimum and, in the near-bottom water, decreases from west to east with mean values (in μg/ℓ): 357 at Site A, 337 at Site B, 332 at Site C. This, in conjunction with an inverse trend in nutrient concentration, implies an eastward flow of the bottom water. Measurements of near-bottom currents have been extremely limited. Additional measurements are being made but the data are not available at present.

The heaviest concentrations of suspended particulate matter (50 μg/ℓ) were found in the surface mixed layer and at the pycnocline throughout the area. Most of the suspended particles are of biogenic origin and the median diameter at all depths is about 2.2 μm. The suspended particulate matter distribution showed very little temporal variability during a 40-hour period time series.

The phytoplankton showed a great species diversity. Coccolithophorids dominated in numbers of cells in the water column.

Most of the zooplankton stock occurred about 200 m in depth with extremely low concentrations found in bottom waters. Little daily vertical migration was noted below 200 m and this was probably due to the shallow depth of the oxygen minimum zone. The copepod fauna was relatively diverse.

The estimated total biomass of fish in the DOMES area is 2.17 g/m^2 (wet weight), of which 0.01 g/m^2 is heavily fished. The estimated annual commercial catch in the area is worth about $80 million. Yellowfin and big eye tuna are the most commercially important species.

The composition of the benthic communities at each site was relatively uniform. Four groups (echinoids, ophiuroids, actinarians, and holothurians) comprised 80% of the megafauna as determined from bottom photographs. The analysis of 25 box cores from Site C indicated that total wet weight of the benthic macrofauna was 0.8 g/m^2.

3.2.3 Mining Equipment

Two main types of mining systems are being developed by industry to mine deep-ocean manganese nodules: hydraulic collector (either towed or self-propelled) and mechanical collector (continuous-line bucket).

Towed Dredge Head Collector

This system (Figure 3.3) involves pumping water and nodules through a pipeline to a surface ship. The nodules are collected by a dredge that is towed along the ocean floor at the end of a pipeline leading to the surface mining ship. During operations the nodules and bottom water are pumped to the surface along with some bottom sediment. Most of the sediment, however, will be separated from the nodules and rejected from the system near the sea floor to form a benthic plume. The nodules pumped to the mining ship will be separated from the bottom water and sediments aboard the ship and the wastes will be discharged at the ocean surface.

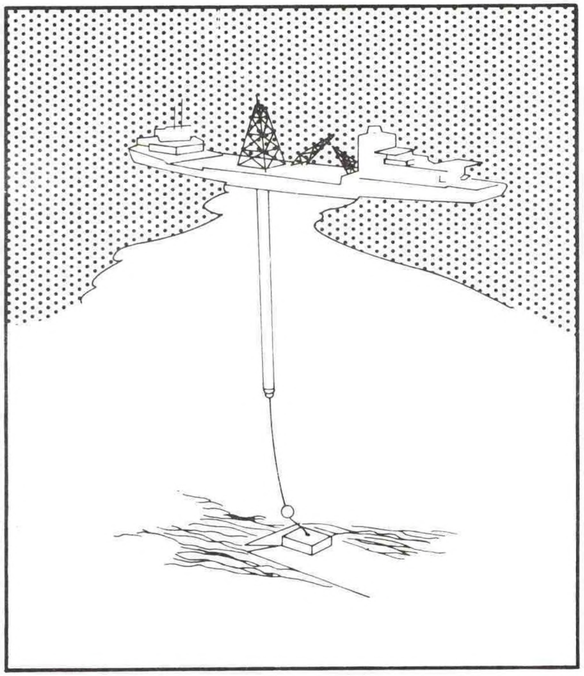

FIGURE 3.3 HYDRAULIC MINING SYSTEM WITH TOWED DREDGE HEAD

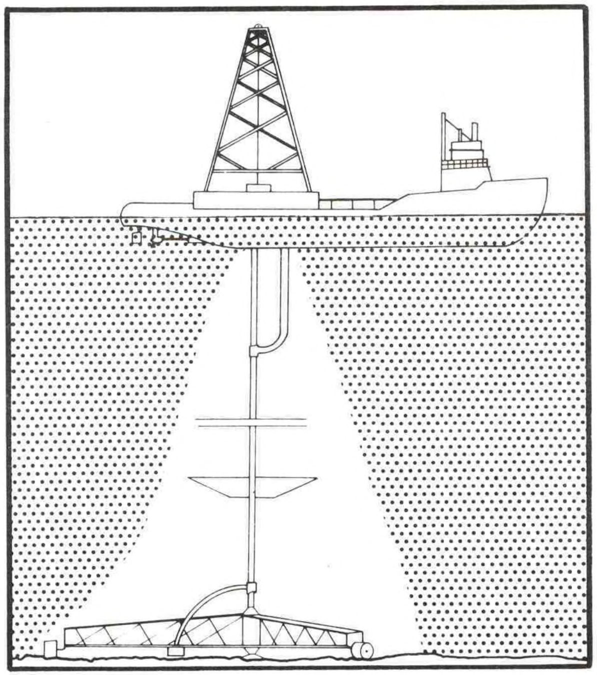

FIGURE 3.4 HYDRAULIC MINING SYSTEM WITH SELF-PROPELLED DREDGE HEAD

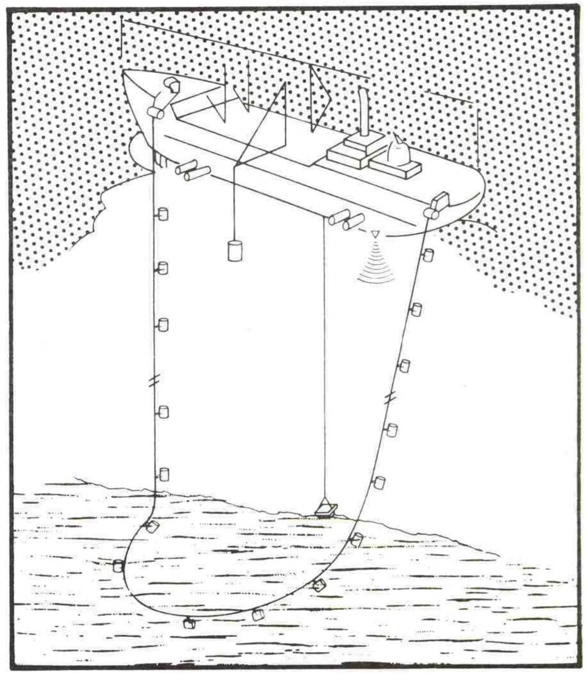

FIGURE 3.5 MECHANICAL MINING SYSTEM—CONTINUOUS LINE BUCKETS (CLB)

Self-Propelled Dredge Head Collector

This system is shown in Figure 3.4. Nodules and water will be pumped to a surface ship through a pipeline, as above, but the method of collecting the nodules will be different. The dredge head will be self-propelled, which may provide greater maneuverability than the towed system.

Continuous Line Bucket (CLB)

The CLB dredge system (Figure 3.5) consists of a series of buckets attached to a continous line that will travel from the stern of the ship to the ocean floor, along the bottom, up to the bow of the ship, to the stern, and back down again. As the line travels, the buckets will descend, scrape the ocean floor, and then ascend to the ship where they will be unloaded and lowered again. Two other methods, one bringing the buckets directly to the stern of the ship and the other employing two ships, are also under development. The CLB systems are designed to bring only nodules to the surface. Sediments will also be scraped into the buckets, but are expected to be washed out throughout the water column as the buckets ascend to the ship.

At present, hydraulic systems appear to be favored by American industry over the mechanical system. Both hydraulic and CLB systems have been tested on a pilot scale with additional pilot-scale and prototype testing scheduled for the near future.

3.2.4 Expected Perturbations

The mining discharges released into the marine environment are characterized in terms of water (including pertinent dissolved substances) and solid particulate matter. While the types of wastes will be identical for all mining systems, the relative and actual amounts of each will differ. The initial estimate of quantities is based upon a towed, two-phase hydraulic system, consisting of "mean parameter" characteristics (i.e., each parameter chosen mid-way between the extremes deemed practicable).

The initial estimates consider a mining ship recovering a daily unit production of 5,000 metric tons (mt) of nodules, dry weight. In order to obtain the production, each hydraulic deep-ocean mining system will mine a minimum of 1.9 km^2 of ocean floor each day. Of this area, the collector will come in contact with 1.1 km^2; the remaining 0.8 km^2 will remain untouched because of the likely impracticability of moving the collector in a series of perfectly overlapping swaths. Within the 1.1 km^2 contacted by the collector, 0.9 km^2 will be swept by the intake portion of the system; the remaining 0.2 km^2 of sea floor will be compacted beneath the collector's runners or tracks.

Surface discharges which are characteristic of presently planned hydraulic mining systems have been analyzed. Analysis of short-term near-field changes of properties of the surface water is based upon the rate of discharge and the speed of the ship. This analysis leads to the assumption of immediate dilution of system inputs by a value of 3×10^{-3}. Surface plume models have been developed which consider a "worst case" situation where all discharged sediment remains in the surface mixed layer, as well as situations where particles settle through the layer. Based upon model predictions, a further dilution of 10^{-3} occurs within one day.

The benthic discharge plume model estimates both spatial and temporal change of the plume itself as well as the thickness of the resultant blanket of redeposited sediment. In order to evaluate potential impacts, concentrations of discharge effluent are estimated at different points in space and time.

Potential impacts are evaluated both at the point of initial addition of mining discharge and at concentrations expected after 24 hours of dispersion.

3.2.5 Potential Environmental Effects

Estimates of the extent of environmental perturbations expected as a result of mining activities will enable Project investigators to decide which of these effects are cause for the greatest concern and merit the greatest study efforts. The following potential effects are summarized from the DOMES I Progress Report, August 1976 (NOAA-TM-ERL MESA-15) where they are described in greater detail.

The addition of particulate material has a measurable initial effect on ambient water. Large changes in particulate concentration result, both at initial input ($+ 10^5 \mu g/\ell$), and after 24 hours ($+ 10^2 \mu g/\ell$). In contrast, the effects of temperature and dissolved substances are so small that for the most part they would be difficult even to measure. For example, calculations show that additions of a limiting nutrient such as nitrate will stimulate production, but total enhancement would be small. Likewise, concentrations of dissolved trace metals, a subject of widespread concern, will not be altered to any detectable degree by the addition of the mining discharges.

The addition of discharged materials to the water column could produce serious impacts upon the environment in several ways. Light penetration into the upper water column will be reduced in the immediate vicinity of the surface discharge. This will result in some decrease in productivity near the ship. The impact is estimated to be localized and to occur within an area not greater than a few tens of kilometers from the mining ship - based upon conservative estimates.

The effect on higher trophic levels of change in productivity, standing stock, and distribution of phytoplankton has been examined, but the available information is sufficient only for a qualitative statement that zooplankton populations and perhaps fish stocks may decrease locally, but not in a linear fashion relative to phytoplankton decrease.

The increased particulate concentrations could affect organisms both physiologically and behaviorally. For example, sediment can interfere with respiratory and feeding appendages of zooplankton organisms. With fishes, respiration can be affected, but strong avoidance reactions might become important in minimizing potential adverse effects. Since finely abraded nodule material will probably be included in the discharges, ingestion by zooplankton could provide a mechanism whereby heavy metals will enter the food chain. However, information on the size distribution of abraded nodules is unknown at this time, and the latter impact cannot be quantified.

Biotic activity can also affect the time and level of exposure of the ecosystem to the mining discharges. One factor, ingestion of suspended particulate matter by filter-feeding organisms, appears to be important. Incorporation of sediments into fecal pellets can accelerate sinking velocities by orders of magnitude and may be an important mechanism in removing sediments from the upper water column.

Mining activity in the benthic zone will have very marked impacts both on the sea floor itself, and on the overlying 20-50 m of water where the benthic effluent is discharged. A direct effect could be complete mortality of the benthic fauna within a mining area, caused by the passage of the collection device and the resultant formation of a benthic discharge plume. In addition, the removal of nodules will eliminate part of the habitat of some organisms. The present state of knowledge on deep-sea biota is not adequate to allow a prediction of the rates of recolonization of benthic organisms other than the general statement that re-establishment of the community is expected to be exceedingly slow.

None of these potential effects can be regarded as established, or as having a known level of impact. To verify and evaluate these impacts, DOMES must deal with the significant environmental concerns outlined in Section 3.3.

3.3 RESEARCH PRIORITIES

The determination and assignment of research priorities from DOMES is imperative to ensure that the vital environmental issues of DOMES are addressed within available time and resources. Presently, all research work being done under the DOMES Project may be placed into two areas.

Initial priority has been placed on characterizing the immediate and cumulative ecological effects resulting from the surface plume created by the discharge of excess mining materials during a mature or full-scale mining operation. This issue is deemed most important as this is the area where a potential exists for the impact to be felt by man.

Emphasis has been placed on the establishment of a statistically defensible data base by taking large numbers of replicate samples and measurements at a limited number of stations. High priority has also been given to the determination of potential mining-induced concentration changes of suspended particulate matter (SPM) and dissolved components in the water column.

The impact of the mining process on the deep ocean benthic organisms will also be studied, but as a lower priority item initially. The benthos will be impacted, in all likelihood, and benthic studies are being structured to provide an overall description of bottom disturbance, both as a result of collector contact and redistribution of sediment. However, baseline characterization of the benthic fauna is regarded as especially important, because data from these studies will be essential to future, long-term assessment of mining impacts.

Assignment of research priorities will be periodically reassessed, generally on an annual basis, with a number of factors considered in the determination of relative priorities of research tasks. These factors include:

- Recommendations from Workshops or other critical evaluations of Project research;
- Overall objectives of the Project;
- Potential environmental damage;
- Available resources;
- Scientific information already available;
- Magnitude of individual research tasks; and
- Interrelationship with other studies.

The environmental issues being considered by DOMES are summarized in Table 3.1, Potential Environmental Impacts and Related Scientific Questions, which lists the mining disturbances, the anticipated physical and chemical changes which will result from each disturbance, and the subsequent potential environmental impacts of these changes. Scientific questions are listed which focus DOMES research on the various aspects of environmental impact, as well as major milestones (research products) which address these questions. The schedule of completion of each milestone is based on the relative priorities

Table 3.1 Potential Environmental Impacts and Related Scientific Questions with Contributing Project Milestones

DISTURBANCE	POTENTIAL PERTURBATION	POTENTIAL IMPACTS	SCIENTIFIC QUESTIONS	CONTRIBUTING PROJECT MILESTONES	DUE DATE
A. Surface discharge from the mining vessel.	1. Introduction of suspended particulate matter (SPM) into the water column consisting of: a) sediments b) nodules and nodule fragments c) benthic biota	1.1 Increase in turbidity may result in a decrease of phytoplankton productivity which may affect higher trophic levels.	1.1.1 How will the SPM discharged into the upper column be dispersed with time?	• Description of temporal and spatial dispersion of surface plume.	FY78
			1.1.2 To what extent will increased SPM affect primary productivity and higher trophic levels?	• Description of discharge effects on light attenuation. • Description of discharge effects on primary production. • Description of discharge effects on phytoplankton and zooplankton populations.	FY79 FY79 FY79
			1.1.3 What will be the effect of the "rain of fines" from the sea surface on mid and lower water columns and benthic organisms?	• Estimate of the effect of mining on mid and lower water column and benthic organisms.	FY80
		1.2 Effect on appendages and respiratory surfaces due to increased SPM concentration.	1.2.1 To what extent will discharge of SPM affect the feeding and respiratory activities of the organisms?	• Description of effects of discharge on behavior of pelagic organisms. • Description of discharge effects on phytoplankton and zooplankton populations.	FY79 FY79
		1.3 Alteration of feeding and behavioral patterns of zooplankton and nekton populations.	1.3.1 To what extent will the behavioral patterns of zooplankton and nekton be affected by surface sediment discharge?	• Description of discharge effects on phytoplankton and zooplankton populations. • Description of effects of discharge on behavior of pelagic organisms.	FY79 FY79
		1.4 Microbial growth on SPM surfaces and possible reduction of oxygen level in the oxygen minimum layer.	1.4.1 What will be the effect of surface discharge on the vertical distribution of oxygen?	• Description of discharge effects on dissolved oxygen levels in the water column.	FY78
			1.4.2 How would changes in the vertical distribution of oxygen affect the organisms?	• Estimate of the cumulative ecological effects of marine mining. • Description of discharge effects on phytoplankton and zooplankton populations. • Estimate of the effect of mining on mid and lower water column organisms.	FY81 FY79 FY80
			1.4.3 What role will bacteria play as a potential food source?	• Estimate of the cumulative ecological effects on marine mining.	FY81
		1.5 Release of heavy metals from sediments or nodule fragments.	1.5.1 To what extent will the heavy metals be taken up by organisms, and what will be their effect?	• Incorporation of heavy metals into marine organisms. • Estimate of the cumulative ecological effects on marine mining.	FY80 FY81
	2. Introduction of bottom water to the upper water column (including dissolved gases introduced by the mining vessel).	2.1 Water of different temperature and salinity is introduced to the upper water column.	2.1.1 How will the introduced water be dispersed with time?	• Description of temporal and spatial dispersion of surface plume.	FY78
		2.2 Addition of dissolved materials (nutrients, heavy metals, organic matter) and gases to the upper water column.	2.2.1 How will matter and energy (nutrients, heavy metals, heat) discharged into the upper layers affect primary production?	• Description of discharge effects on phytoplankton and zooplankton populations.	FY79
	3. Combined effects of introduction of suspended particulate matter and bottom layer.	3.1 Possible disturbance of biota in water column and benthos.	3.1.1 How will changes or primary productivity affect higher trophic levels?	• Estimate of the cumulative ecological effects of marine mining.	FY81
			3.1.2 Will the species composition of populations be affected?	• Estimate of the cumulative ecological effects of marine mining.	FY81
			3.1.3 How will change in primary productivity affect the benthic organisms?	• Estimate of the effect of mining on mid and lower water column and benthic organisms. • Estimate of the cumulative ecological effects of marine mining.	FY80 FY81
			3.1.4 What will be the recovery rates of any affected pelagic populations?	• Description of recovery patterns of pelagic biota.	FY80
B. Benthic Discharge Plume.	1. Increase of SPM in the lower water column consisting of: a) sediments b) nodules and nodule fragments c) biota.	1.1 Alteration of benthic feeding and other behavior of benthic organisms due to increased levels of SPM.	1.1.1 How will the SPM discharged into the lower layer be dispersed with time?	• Description of temporal and spatial dispersion of benthic plume.	FY80
			1.1.2 What is the rate and distribution of re-sedimentation of benthic plume particulates?	• Description of temporal and spatial dispersion of benthic plume.	FY80
			1.1.3 To what extent will the feeding and behavior patterns of benthic organisms be affected by increased turbidity?	• Description of disturbance to benthic fauna.	FY80
		1.2 Change in the behavior of the free swimming organisms in the lower water column.	1.2.1 To what extent will the behavior of the free swimming organisms in the lower water column be affected by the increased SPM concentration?	• Estimate of the effects of mining on mid and lower water column and benthic organisms. • Estimate of the cumulative ecological effects of marine mining.	FY80 FY81
		1.3 Clogging of respiratory surfaces due to increased SPM concentration.	1.3.1 Will the benthic discharge affect respiratory rates of benthic organisms?	• Estimate of the effect of mining on mid and lower water column and benthic organisms.	FY80
		1.4 Release of macerated biota into the benthic environment.	1.4.1 What is the effect on biota of particulate organic matter discharged in the benthic plume?	• Estimate of the cumulative ecological effects of marine mining.	FY81
		1.5 Change in the microbial activity within the lower water column.	1.5.1 What will be the effect of benthic discharge on the oxygen level of the lower water column?	• Estimate the cumulative ecological effects of marine mining.	FY81
			1.5.2 What role will the increased bacterial activity play in providing a new food source?	• Estimate the cumulative ecological effects of marine mining.	FY81
	2. Increased sedimentation rates.	2.1 Increased mortality of benthic organisms due to smothering or rapid deposition of sediments over food source.	2.1.1 What rate of sedimentation will smother the organisms?	• Estimate the effects of mining on mid and lower water column and benthic organisms.	FY80
			2.1.2 What is the effect of increased sedimentation rate on food source?	• Estimate the cumulative ecological effects on marine mining.	FY81
	3. Release of interstitial water to the lower water column.	3.1 Increased levels of nutrients and heavy metals in the lower water column.	3.1.1 Will increased levels of heavy metals affect benthic organisms?	• Description of discharge effects on uptake of heavy metals by benthic organisms.	FY80
C. Collector contact on the sea floor.	1. Displacement, compaction, or removal of sea floor sediments.	1.1 Destruction of benthic community in the path of the dredge head collector.	1.1.1 What will be the extent of disruption to the benthic community?	• Description of physical disturbance to sea floor. • Description of disturbance to benthic fauna.	FY79 FY80
			1.1.2 What will be the recovery and recolonization rates for the benthic fauna in the mining areas?	• Description of recovery patterns of benthic fauna.	FY81
	2. Removal, displacement, and fragmentation of nodules.	2.1 Destruction and removal of habitat for organisms living on the nodules.	2.1.1 What will be the recovery rate of the nodule-inhabiting community?	• Description of recovery patterns of benthic fauna.	FY81

of the research tasks which contribute to a given milestone (see Section 5, Technical Development Plan) as well as the interdependence of information between milestones. This table further describes the potential environmental impacts with related scientific questions being addressed by the DOMES Project, with contributing Project milestones. Due dates are tentative, depending on the industry's mining test schedule.

The goal and objectives identified in Section 2.2 are designed to provide data on the characterization of the environment in the mining area, the extent of potential environmental impact of deep ocean mining, and the generation of a methodology of operation. Thus, the major milestones are logically linked in time, and address the principal research/management problems that have to be solved if the goal of the Project is to be met adequately.

3.4 INTERDISCIPLINARY ANALYSIS AND SYNTHESIS

Synthesis activities involve research unit integration and interdisciplineary analysis of information and data products developed and analyzed by both MESA-sponsored and independent research efforts. These activities also serve to identify data gaps and research needs. Topics addressed by synthesis efforts are generally interdisciplineary and involve input from several DOMES research efforts or work units.

However, it is possible that individual work units may result in products or outputs that are in themselves a synthesis. Such synthesis involves research units that compile data on one topic from other agencies, from Project results, and from historical sources, into one final report.

Operational synthesis efforts tend to address the more user-oriented objectives in the PDP. One of, or a combination of, the following strategies will be used to accomplish a synthesis effort.

- Workshop Approach - Synthesis is effected by an interdisciplinary committee or series of interdisciplinary committees composed of "experts" from outside the MESA staff. A MESA staff member may be assigned to the steering committee of the workshop to be responsible for the organization, operation, and final synthesis product of the effort. This staff member may participate in the synthesis effort.

- Outside Investigator Approach - One or two independent investigators bear the primary responsibility for organizing and conducting the synthesis effort. The investigators may be either visiting scholars (e.g., sabbatical candidates or post-doctoral appointees) or contractors to MESA. A MESA staff member is responsible for overseeing the effort but does not participate in the actual synthesis.

- Project Approach - Project personnel as a team bear the primary responsibility for bringing about a synthesis. One project member is designated head of the effort and leads its planning and operation.

In order to facilitate communications between the numerous disciplines and organizations participating in the DOMES Phase I and Phase II Projects, synthesis workshops are planned to occur periodically during the life of the DOMES Project.

A major review of DOMES progress will be performed at least once a year. A public symposium open to all interested parties will be arranged, and individuals involved in DOMES-funded research will be given the opportunity to present papers summarizing their interim results and conclusions. Questions and discussions arising from the presentations can provide valuable ideas for guiding further research. These discussions will also provide ideas to be used by DOMES principal investigators, Program and Project Staff, and selected consultants from industry and the academic community who will hold meetings following the symposium to examine DOMES activities up to that time. A synthesis embracing all DOMES research activities and superseding previous syntheses will be developed, and an analysis will be made of the progress of research and of problems that can be foreseen which may affect research plans. This regular review and systhesis will serve both to disseminate and publicize DOMES results and to ensure that DOMES research plans are responsive to public concerns, the changing state of scientific knowledge, and industry plans. In addition, a second, smaller progress review will be held semi-annually involving industry, academic, and other federal agencies, and the public, to help insure rapid and adequate communications.

3.5 USER REQUIREMENTS AND BENEFITS

The successful completion of DOMES involves the dissemination of the vast data base that will be accumulated through Project investigations to those user groups that need it. These user groups (both domestic and international) involve government agencies, mining industries, and the general public.

DOMES will provide data and information directly to government and industry decision-makers (and such regulatory agencies as may be established in the future) who are concerned with the development of deep-ocean mining and the protection of the marine environment. DOMES will also provide a means of improved communication and information exchange among government, industry, and the general public -- the knowledge gained by DOMES will aid government in the establishment of wise laws and regulations and help industry to design efficient and environmentally acceptable techniques and equipment. Specific benefits (not necessarily in order of importance) are enumerated below.

3.5.1 Public

- Development, in an environmentally compatible way, and with a minimum of delay, of a new source of copper, cobalt, manganese and nickel.
- Provision to the public of information based on sound scientific knowledge to reduce concern over environmental issues.
- Identification of mining-induced effects on marine food chains which may lead to changes in the available supply of economically important marine species.
- Identification of potential hazards to public health, and provision of information useful in maintaining or improving marine environmental quality to reduce potential health hazards.
- Provision of a communication and information exchange to accurately portray to the public the intent of industry's development plans and the extent of planned environmental safeguards.

3.5.2 Industry

- Provision of a data and information base that will assist industry in systems design, and design of operational procedures in order to minimize the impact on ecosystems and reduce the possibility of costly retrofits.

3.5.3 Scientific Community

- Provision of an expanded technical data and information base on marine ecosystems in the geographical areas under study.
- Provision of new concepts (such as predictive models) which may be transferable to other nodule areas of interest.
- Analysis of the information from DOMES and other related special studies will provide an improved understanding of the interrelationship between the various components of marine ecosystems. These include identifying the most sensitive elements of the ecosystem in the area to be mined and estimating their responses to mining system perturbations.

3.5.4 Government

- Provision of both general and site-specific information necessary for action on environmental guidelines and regulations, licensing or leasing decisions, and development of operating orders and stipulations.

- Development of a mining site monitoring system whereby future enforcement agencies can make judgement on cumulative effects of mining operations in an area in order to prevent environmental damage.

- Provision of environmental data, analyses, and assessments to deliberative bodies charged with developing new legislation, and, where applicable, international laws and treaties.

- Establishment of a partnership philosophy between industry and government aimed at the acquisition of environmental impact information as early in the decision-making process as possible.

Figure 3.6 shows the interrelationship of Project objectives and user requirements, and summarizes the various forms of project output which will be made available to users.

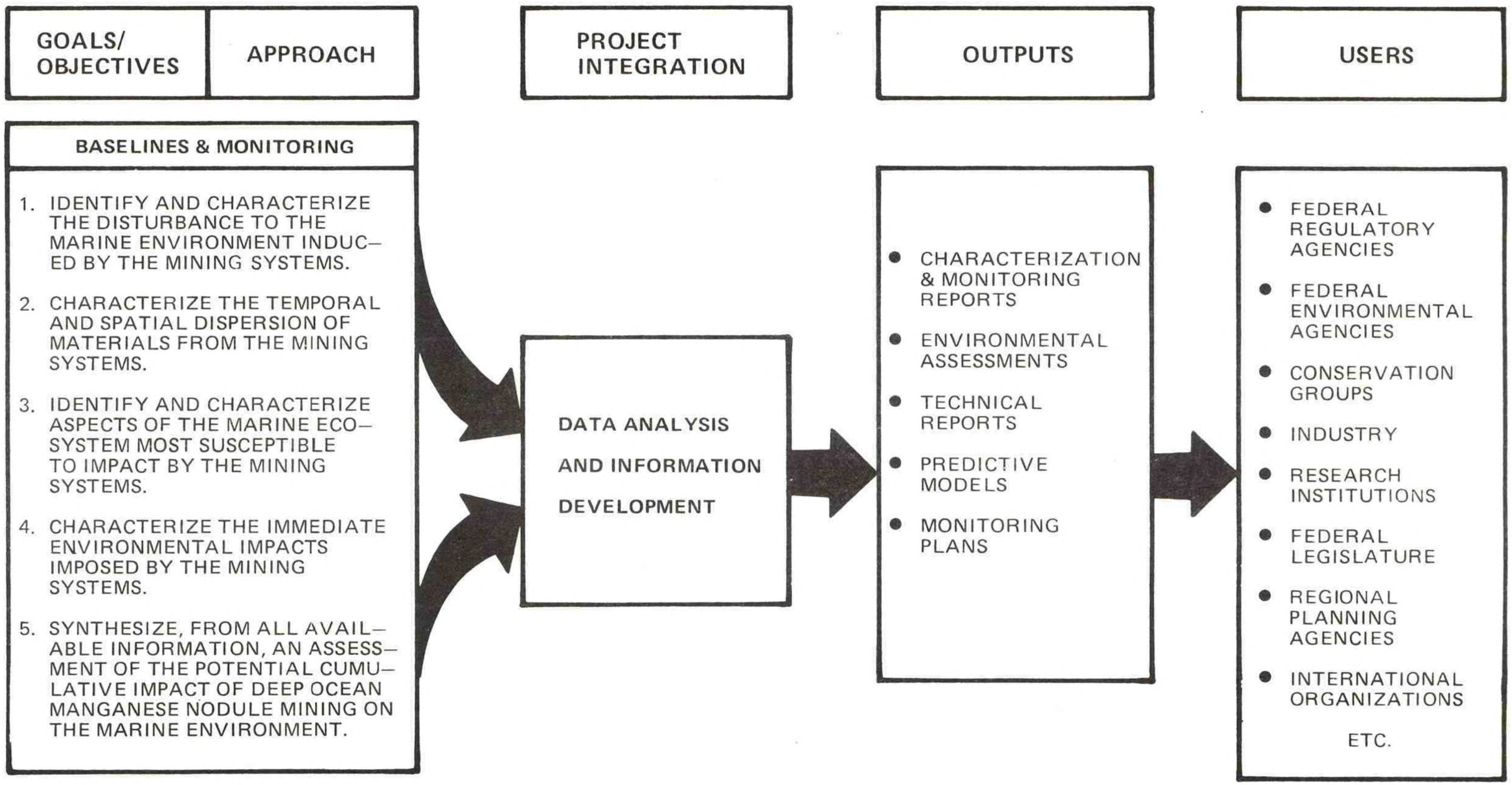

Figure 3.6 Interrelationship of Project Objectives and User Requirements

4. MANAGEMENT PLAN

4.1 MESA MANAGEMENT POLICY

The basic policy document for MESA management is the Management Plan for Marine Ecosystems Analysis (MESA) Program, March 14, 1977.

4.2 PROJECT MANAGEMENT

Overall responsibility for DOMES is assigned to the Project Manager. The Project Manager executes management functions within the authority granted by the NOAA/MESA Program Director. The basic responsibility of the Project Manager is to implement the Project so as to maximize scientific output in terms of quality, quantity, and user benefits, in a cost effective manner. It is also the responsibility of the Project Manager to keep the MESA Program Office informed of Project plans and progress in order that up-to-date management planning information can be provided to both the Program Office and Project participants.

The DOMES Project Manager will:

- Define responsibilities and lines of authority within the Project Office and define lines of communication with supporting agencies and organizations.
- Provide the planning and administrative framework for scientific activities.
- Control Project activities in accordance with the PDP and the Technical Development Plan (TDP) (see Section 4.3) and recommend changes in Project direction to the Program Office.

The Project Manager is supported by a staff which administers the scientific and technical program. In general, the Project staff does not engage directly in research. The scientific and technical program is largely accomplished by NOAA components and by universities and contractors on the basis of negotiated agreements with the Project Office. Responsibilities of the staff include technical planning, design direction and review, administration of basic agreements for research, and financial guidance. Figure 4.1 summarizes the functional responsibilities of the Project staff.

4.2.1 Scientific Support Function

Scientific support functions include:

- Development of recommendations for research plans, realignment of priorities, and modification of Project objectives.
- Technical evaluation of ongoing research to determine the need for redirection, expansion, or reduction.
- Evaluation and synthesis of completed research.
- Ensure maximum communication of scientific results to the user community.

4.2.2 Data Management and Information Exchange Function

Data management activities for the Project will be carried out in accordance with the "DOMES DATA MANAGEMENT PLAN" dated February 25, 1977.

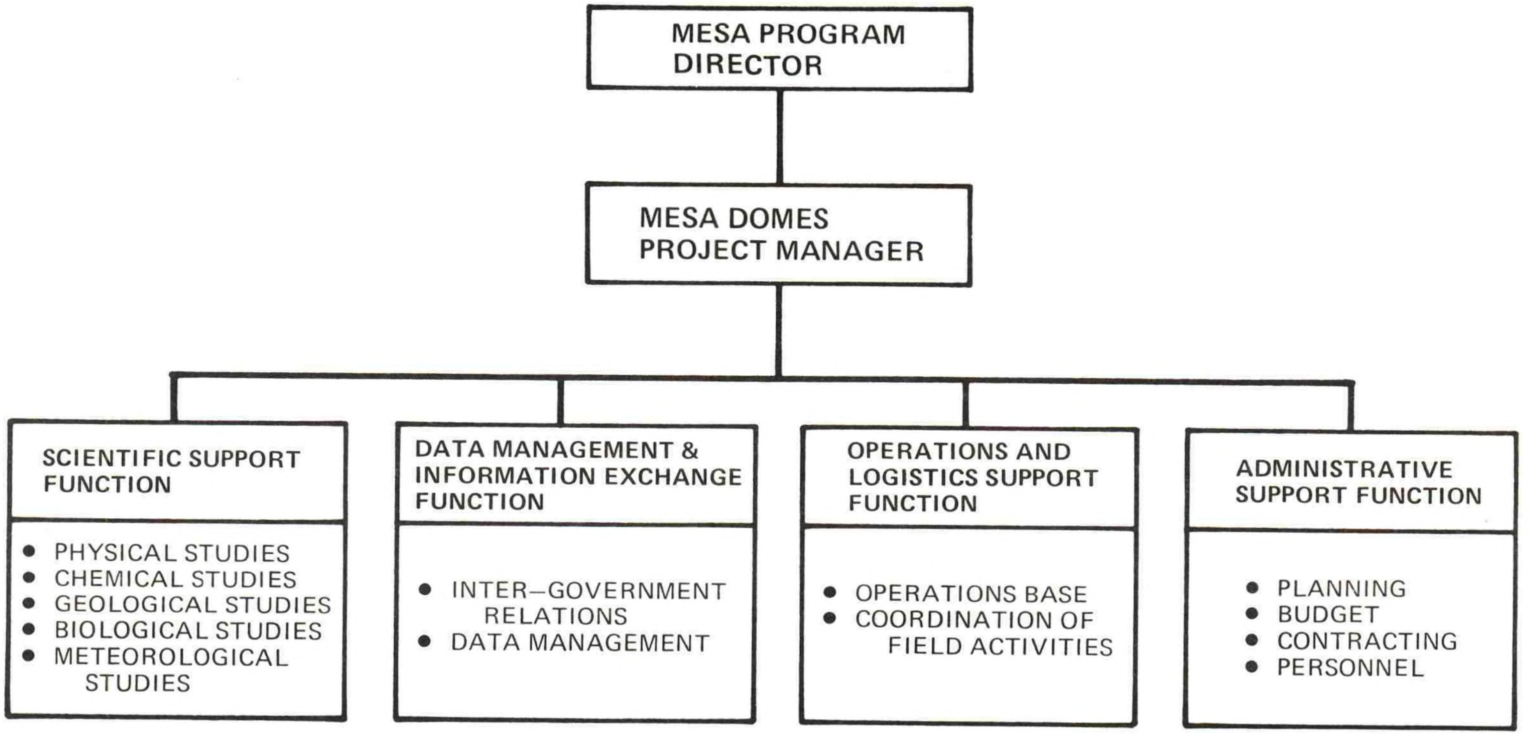

Figure 4.1. Functional Management Organization Chart

This plan documents Project data management standards and provides a framework for interdisciplinary usage of DOMES data. The plan will be updated as required, and provides an overview of DOMES data and information management schemes, and acquisition and processing procedures. Guidelines for NOAA Main Line Components regarding DOMES data and information management are included, and data and information storage and retrieval services are explained.

In order to aid in meeting Project objectives, rapid and effective exchange of information is required. There are a wide variety of Project participants, including private contractors, universities, scientific institutions, state and local government agencies, NOAA Main Line Components and other federal agencies. Information exchange between these organizations must be coordinated closely to effectively carry out planned activities.

Well-managed information exchange affords the best means to cope with problems of:

- accomplishing technical integration and scientific progress within authorized schedules;
- maintaining a user-directed, issue orientation within the basic plan;
- eliciting and maintaining participation by the many organizations having valuable contributions to make;
- controlling the actual Project activities; and
- eliciting adequate feedback from specific users and beneficiaries of the Project results.

4.2.3 Operational and Logistical Support Function

Operational activities will be planned in accordance with the NOAA Directives Manual. They include:

- Preparation and maintenance of the Project's Operations Plan and associated ship and other schedules.

- Coordination of field activities with NOAA facilities, universities, contractors and state and federal government agencies.

Operations and logistics support is coordinated from the DOMES Project Office located at Sand Point Naval Support Activity, Seattle, Washington. Specific operations and logistics support plans will be developed as required to support the forthcoming DOMES Phase II monitoring of test mining operations.

Three monitoring effects are presently scheduled with the timing dependent on the test schedules of the mining companies (see Section 5.3). DOMES Phase II will therefore be required to retain a high degree of flexibility with regard to logistics and operations planning of their monitoring studies. DOMES Phase II tests will be scheduled about three-fourths of the way through each industrial test period. It is expected that at the three-quarters point, the reliability of each prototype mining system will have been established. On this basis DOMES Phase II monitoring studies will be tentatively scheduled for January 1978, March 1978, and November 1978. Modifications to this schedule are anticipated as industrial tests take place.

The monitoring operations will involve both mining operations support ships and one or more NOAA research vessels. Detailed logistics support requirements and plans will be formulated for each of the three monitoring cruises.

Input to the Draft Project Instructions for all cruises listed in the operations plans must be submitted by Principal Investigators to the DOMES Project Manager. The Draft Project Instructions must be submitted four months in advance of the cruise starting date and as specified in NOAA Directive 17-17. These Project Instructions serve to coordinate Project activities with the National Ocean Survey for ship and operations support, provide for coordination among the various work tasks performed on NOAA and contract vessels, and provide detailed instructions to be followed by both ship operation and scientific personnel. Failure to comply with the NOAA Directive could result in cancellation of the specific cruise, and in potential violation of commitments or contracts with the MESA DOMES Project.

4.2.4 Administrative Support Function

The Administrative Support Function includes:

- Budget and Financial Management
- Contracts and Procurement
- Personnel
- Management Reporting

4.3 PROJECT IMPLEMENTATION AND CONTROL

The successful implementation of the DOMES PDP requires the preparation of an annual Technical Development Plan (TDP) that addresses the approach and methodology for achieving the Project objectives. Specifically, it addresses the control of the Project through examination of results, priorities, and funding level. The TDP is prepared annually by the Project Manager in response to guidance from the Program Office and precedes the solicitation of research proposals.

Contents of the TDP will include:

1. A Project Summary extracted from Chapter 1, 2, and 3 of the Project Development Plan (Introduction, Project Goal and Objectives, Overall Strategy and Research).

2. Description of research work units to be accomplished during the following fiscal year.

3. Project schedules, milestones and products.

4. Resource allocations reflecting personnel and budget needs.

5. Impact of proposed changes on accomplishment of Project objectives.

The TDP, as approved by the Program Director, provides the basis for preparation of research proposals for the following fiscal year. It is distributed in loose-leaf form by 31 May by the Project Office. Negotiations related to proposed efforts are to be concluded by 31 August. Excerpts from the proposals and negotiations to be funded by the Project will be combined with the TDP in loose-leaf form. These excerpts, combined with the TDP under appropriate research units, will provide a document describing, in some depth, endeavors to be undertaken during the fiscal year. This augmented TDP will be distributed by the Project Office to Principal Investigators and affected organizations by 1 October. The combined document will aid Principal Investigators and the organizations involved by coordinating and managing their efforts. The operations plans described in Section 4.2.3 will be keyed to the augmented TDP and distributed with it. Updates to this augmented TDP will be distributed as necessary.

4.4 REVIEW OF PROPOSALS

The MESA DOMES Project will review all proposals for research described in the TDP. All Requests for Proposals (RFP) for amounts greater than $5,000 will be reviewed by the Program Office prior to distribution. Guidance for the preparation, format, and content of these RFP's will be provided by a separate Program Office issuance.

Another separate Program Office issuance will provide general instructions to guide the preparation of proposals and to establish the format and content. Proposals are to be presented to the DOMES Project Office as briefly and concisely as possible using only this format. Appraisal, evaluation, and selection of prospective contractors, as well as any subsequent negotiations between the parties, will be based upon the information submitted in the proposal.

Proposals to be funded effective October 1 will be reviewed in accordance with the following schedule:

- May 31 - Distribution of new TDP (and RFP when applicable).
- Jun 30 - Last day to receive proposals.
- Jul 31 - Proposal review completed. Negotiations begun, if necessary.
- Aug 31 - Negotiations completed.
- Oct 1 - Funds to researchers.

A similar time schedule, but with dates shifted approximately, will be followed in reviewing proposals submitted at other times.

Proposals will be subject to review as follows;

- 0-$25,000 — DOMES Project Office
- $25,000-$75,000 — DOMES Project Office and MESA Program Office
- +$75,000 — DOMES Project Office plus 2 outside technical sources plus MESA Program Office.

Grants or other government agreements between the Project Office and a Principal Investigator will be subject to the same review schedule.

4.5 REVIEW AND REPORTING

4.5.1 Management Reports

The Project Manager will report progress, problems, and budgetary matters to the Program Office for subsequent reporting to ERL and NOAA headquarters. This reporting is accomplished through monthly reports, semi-annual reviews, and annual reports.

- Monthly Progress Reports - The report will be submitted to the Program Office by the 15th of each month and will include technical progress, accomplishments, impact of schedule deviations and other problems, budget status, and resource requirements. Each Principal Investigator and/or his parent organization will provide input to this report by the 7th of the month. A secondary purpose of this report is to keep Project participants appraised of Project status.

- Semi-Annual ERL Program Review - Every six months the MESA Program Director makes a comprehensive review of the MESA Projects. These reviews are conducted primarily to inform the Director of ERL of significant progress and research and budgetary plans. If requested, additional information will be provided by Principal Investigators and/or the Project Manager.

- Annual Technical Summary Report - The report documents significant Project achievements and technical progress during the preceding fiscal year. The format of this report will be such that it can be incorporated into ERL or NOAA Annual Reports.

  Information contained in this report may be utilized in the Annual Report to Congress which NOAA prepares under the provisions of the Marine Protection, Research, and Sanctuaries Act of 1972.

4.5.2 Technical Reporting

The reporting of research conducted by or for the DOMES Project adheres to the MESA Publication Policy and Guidelines (1977) which were established to insure that rapid, accurate, and adequate communications with users of Project data and information are maintained. Depending on the context, intended users, level of review, and the number of copies to be printed, the actual reporting of research results is performed through several types of reports as outlined below.

The preferred mode for publication is the open literature in order to reach the widest possible audience. Alternatives are the Technical Report, NOAA Journal, NOAA Professional Paper, or NOAA Atlas.

- Proceedings of Meetings, Journal publications, and similar publications in the "open literature" are the most desirable media for communication of research results. These types of publications are intended for a wide audience and are intended to be of highest quality. The standards and requirements for these media are normally controlled by a professional society or publisher.

* NOAA Journals, Professional Papers, or Atlases are high quality, editorially controlled, scientific or technical treatises that meet the standards of the designated organizations as described in the NOAA Directives Manual. All NOAA Professional Papers and Atlases must be published by the EDS Environmental Science and Information Center (ESIC).

* Technical Reports are to be treated as formal publications that could meet the high quality criteria of the preceding media, but which have other aspects making them unsuitable for journal articles or the more formal NOAA series. For example, they may be too lengthy, may encounter delay in processing, or may contain tables or data that do not conform to formal editorial requirements. These Technical Reports are to be reviewed so as to meet a desired professional quality of publication. Responsibility for obtaining reviews lies with the principal investigator, laboratory director, and/or Project Manager. The Program Director may request additional review through the Environmental Science Information Center, EDS. Editorial review will be provided by Publications Services, ERL.

* Technical Memorandums are informal publications that are required for other purposes. These include: documentation of work in progress, preliminary or status reports to sponsors, simple compilations of data, and descriptions of procedures and practices. The responsibility for scientific review of technical memoranda will ordinarily lie with the principal investigator and his laboratory director or Project Manager. Where more than one MLC is involved, the Project Manager is responsible. Editorial or scientific review of technical memoranda will be provided by ERL or the MESA Program Office only upon request by the Project Manager and approval by the Program Director.

- *Special Reports* can be published for any special purposes not covered by the preceding categories. They may vary in format, covers, etc., for required purposes. They are subject to the same review and quality control as Technical Reports.

- *Data Reports* in the form of microfiche are primarily used for the publication and dissemination of physical, chemical, and biological data. The responsibility for the review and accuracy of these reports lies with the Principal Investigators.

5. TECHNICAL APPROACH

5.1 INTRODUCTION

In the following sections, the general approach to the research that will be done in examination of the prototype mining tests is described. This is the work that will utilize the results of the DOMES Phase I baseline site studies described earlier (Sections 3.2.1 and 3.2.2). The tentative scheduling of the tests and of the major Project outputs is discussed, and the funding and manpower requirements for the Project are summarized. The DOMES Project Technical Development Plan (TDP), which will appear in a separate volume, contains detailed descriptions of the work planned to accomplish each of the Project objectives, the scheduling of the work, the funding breakdown by work unit, and the reports to be produced. The TDP will be updated annually to allow for revision of the research plans and will be distributed in loose-leaf form.

5.2 RESEARCH PROGRAM

5.2.1 Mining Test Monitoring Program

Because it is unlikely that the mining systems tests will be conducted at the exact location of the DOMES Phase I baseline sites (except possibly Site C), short duration (10 to 20 days) baseline confirmation studies will be conducted at the mining test sites during the month prior to the actual mining systems tests. These will be intensive studies of the sea bed and the water column to provide a comparison of the environmental parameters at the test site with those at the DOMES Phase I baseline sites.

In conjunction with the test site baseline study, a similar 2-day baseline confirmation study will be conducted at the nearby DOMES Phase I stations to serve as a control.

Because the technology for monitoring mining activities is at a developmental stage, NOAA intends to monitor only the surface plume during the first test and only the benthic plume and sea floor disturbance during the second test. This approach will facilitate evaluation of monitoring procedures and equipment performance. Both surface and benthic disturbances will be monitored simultaneously during the third test. The strategy for monitoring the fourth test, if such monitoring is done by NOAA (see Section 5.3), may be modified slightly, depending on the experience gained from the other three, and whether or not the test will be of a mechanical rather than hydraulic mining system.

The DOMES monitoring operations are summarized below in five major categories: Plume Tracking, Null Verification, Primary Productivity, Zooplankton, and Benthic Activities.

5.2.1.1 Plume Tracking

The plume tracking operations will have a number of components. The nature of the discharge will be examined on the mining ship. During generation of plume segments to be tracked, samples will be obtained periodically to measure the nitrate and silicate concentrations. Additional samples will be taken for use in measuring particle size, settling rate, and composition. The temperature of the discharge will be measured and recorded continuously. The mining consortiums have agreed to provide information such as nodule delivery rate, air injection rate, and surface discharge flow rate, and to provide samples of nodules recovered in order that studies of the correlation between variations in nodule type and in particulates in the surface discharge may be made.

Transects across the plume segment and into adjoining non-plume waters will be made at various plume ages. During a transect, measurements will be made of the temperature structure of the upper waters; and the distribution of suspended particulates, chlorophyll, zooplankton, and nekton will be measured.

5.2.1.2 Null Verification

The "Null Verification" experiment will be repeated two times and will test the validity of predictions that changes in temperature and salinity and in the concentrations of nitrate, silicate, and dissolved oxygen will not be detectable in the discharge plume immediately behind the mining ship.

During the null experiment the surface discharge will be sampled repetitively on the mining ship. Some samples will be processed and frozen for later analysis of nitrates and silicates, while others will be retained for analysis of salinity. Discharge temperature will be monitored continously.

5.2.1.3 Primary Productivity

An in-situ primary productivity experiment will be conducted two times. Each repetition will consist of a pair of experiments - one inside and the other outside the plume. The experiments, supported from a surface marker buoy, will be deployed before dawn and recovered after dark. During the daylight hours of the experiments, light levels in the water will be measured near each buoy to the 1% light depth. Water samples and light measurements for primary productivity studies will also be taken from the mining support vessel.

The primary productivity of phytoplankton in surface water that is mixed with varying amounts of the mining discharge will be measured through on-deck incubation experiments. Samples of the surface discharge will be transferred from the mining ship to the support vessel.

5.2.1.4 Zooplankton

Zooplankton will be sampled (from a mining support vessel when possible) using Bongo and Neuston nets. Samples will be taken in the upper 150 meters both day and night, and within and without the plume. They will be used to determine species distributions and to assess the rate of uptake of suspended particulate matter from the plume by planktonic organisms. The full set of observations will be repeated three times.

5.2.1.5 Benthic Studies

Prior to the mining test box cores, bottom photographs will be taken to document the conditions of the sea floor. On the post-mining cruises, these efforts will be replicated to determine the effect of mining operations on the sea floor. All photography will be done from the NOAA research vessel with a stereo camera system so that quantitative measurements can be made later as needed.

Deep near-bottom currents will be measured during the period of the mining test with a deep mooring containing several current meters located within 100 meters above bottom. Several deep CTD casts will be made to acquire data in support of the deep current studies.

5.2.2 Post Mining Test Studies

5.2.2.1 Post-Mining Site Recovery

Periodic visits to the sites to study recovery rates will be carried out after the completion of each of the prototype tests. Post-mining visits to a site will be coordinated with cruises to other sites for prototype test monitoring or post-mining studies.

5.2.2.2 Shore-Based Laboratory Experiments

Shore-based laboratory experiments will investigate the chronic and acute effects of mining effluents on selected indicator species. Experiments will focus on testing the tolerance of organisms to realistic concentrations of actual mining effluent and the behavioral changes that may occur. The design of the experiments will be closely integrated with the needs of the predictive modeling program.

5.2.2.3 Predictive Model Testing and Refinement

The predictive models developed through the combination of the DOMES Phase I baseline data and laboratory studies will be tested against the findings of the prototype mining system tests discussed above. The results should permit the modification or refinement of the models.

5.3 SCHEDULES

Five industrial organizations actively participating in the development of deep ocean mining systems have indicated tentative prototype testing schedules. The schedules are dependent on the success of their equipment planning and development activities, and as such, unforeseen delays in the test schedules may be anticipated. The tentative test periods are detailed for each organization in Table 5.1.

DOMES Project plans call for monitoring three tests. A fourth test may be monitored if available resources permit and if additional data is required by the Project. The first will be the Ocean Mining Associates test, scheduled to occur in January, 1978. The second will be the Ocean Management, Inc. test, scheduled for March, 1978. Specific Project plans for later tests are tentative, but will be resolved as consortium test plans become firm. The third test to be monitored will

Table 5.1. Prototype Mining System Test Schedule

Organization	Prototype Testing Period
Ocean Mining Associates	Winter 1977-78
Ocean Management, Inc.	Winter 1977-78
CLB Syndicate	Summer 1978
Lockheed Missiles and Space Co.	Fall 1978
Kennecott Copper Corp.	Spring 1980

Table 5.2. DOMES Milestones

Milestone	Date
Description of temporal and spatial dispersion of surface plume.	FY78*
Description of discharge effects on dissolved oxygen levels in the water column.	FY78*
Description of discharge effects on light attentuation.	FY79*
Description of discharge effects on phytoplankton and zooplankton populations.	FY79*
Description of discharge effects on primary production.	FY79*
Description of physical disturbance of the sea floor.	FY79**
Incorporation of heavy metals into marine organisms.	FY80**
Estimate of the effects of mining on mid and lower water column and benthic organisms.	FY80**
Description of recovery patterns of pelagic biota.	FY80+
Description of disturbance to benthic fauna.	FY80+
Description of recovery patterns of benthic fauna.	FY81+
Estimate of the cumulative ecological effects of marine mining.	FY81+
Monitoring plan for production mining.	FY81+

* Will require results from monitoring first test.
** Will require results from monitoring second test.
\+ Will require results from monitoring at least three tests.

possibly be the Lockheed test in the fall of 1978, or Kennecott system in early 1980.

DOMES will produce a number of major outputs in the course of the research. These "milestones" are listed in Table 5.2. Due dates are tentative depending on industry's test schedule, since completion requires specific test results as indicated in the Table.

5.4 RESOURCES

Resources information provided in this section is based upon best estimates as of February, 1977. Projected fundings for FY78-FY81 are not final and may be subject to change.

5.4.1 Manpower

The Project Office staff serves not only as a management group for the whole Project, but also provides for research planning and coordination of operations, Project progress, and expenditures. Project staffing requirements for the duration of the Project through FY81 are shown in Table 5.3.

5.4.2 Budget Summary

Table 5.4 shows the annual budget breakdown by expenditure category for the DOMES Project.

Table 5.5 shows the estimated annual cost for carrying out the Project.

Further breakout of the Project Office operating funds by budgetary categories through FY81 is shown in Table 5.6. The Phase II totals reflect the intent of monitoring only a single plume in each of the first two tests with FY77 and FY78 funds. The increased funding level in FY79 is needed in order to monitor both the surface and benthic plumes during the third test.

Table 5.3. Project Staffing Requirements

	FY77	FY78	FY79	FY80	FY81
Project Manager	1	1	1	1	1
Oceanographer	2	4	4	5	4
Administrative Officer	1	1	1	1	1
Electronics Technician	—	2	2	2	0
Clerk – Typist	1	1	1	1	1
NOAA Corps	3	3	3	3	3
Total	8	12	12	13	10

Table 5.4. Budget Breakdown for Each Fiscal Year During DOMES Phase I and II (in thousands)

Expenditure Category	Phase I	Phase II				
	1976 +T	1977	1978	1979	1980	1981
Field Operations	1250	333	250	601	394	394
Modeling	190	33	0	60	39	39
Laboratory Experiments	814	266	100	480	315	315
Equipment	280	234	275	422	276	276
Project Management	466	234	275	422	276	276
FISCAL YEAR TOTALS (Thousands of Dollars)	3000	1100	900	1985*	1300*	1300*
DOMES PROJECT TOTAL (Thousands of Dollars)	9585					

*Projected Funding.

Table 5.5. Cost by Major Elements (in thousands)

Expenditure Category	FY76 +T	FY77	FY78	FY79	FY80	FY81
Research Budget Based On Current Work Unit Projections						
Objective 1	38	60	70	130	60	0
Objective 2	258	293	120	368	219	39
Objective 3	1710	343	190	680	415	0
Objective 4	75	55	100	210	145	650
Objective 5	453	115	145	175	185	335
Sub-Total	2534	866	625	1563	1024	1024
Project Office Operating Budget	466	234	275	422	276	276
Totals	3000	1100	900	1985	1300	1300

Table 5.6. Estimated Project Office Operating Budget (in thousands)

Expenditure Category	FY77	FY78	FY79	FY80	FY81
Labor and Support	158	200	200	215	200
Travel	21	25	40	20	20
Miscellaneous Contracts	21	8	122	15	36
Supplies	15	15	20	10	10
Equipment	9	15	20	6	0
Vessel Operating Costs	4	12	20	10	10
Totals	234	275	422	276	276