UNIVERSITY OF CALIFORNIA INSTITUTE OF MARINE RESOURCES

SEA FLOOR WORK ECONOMICS

A PRELIMINARY REPORT
for
Marine Physical Laboratory
SCRIPPS INSTITUTION OF OCEANOGRAPHY

University of California
San Diego, California

Prepared by: Edward Dangler

for
SEA GRANT PROJECT R/E-2

AVAILABLE FROM:
UNIVERSITY OF CALIFORNIA
INSTITUTE OF MARINE RESOURCES
P.O. BOX 109
LA JOLLA, CALIFORNIA 92037

UC-IMR Reference No. 73-8
Sea Grant Publication No. 25

SEA FLOOR WORK ECONOMICS

A Preliminary Report

for

Marine Physical Laboratory
Scripps Institution of Oceanography
University of California
San Diego, California

Prepared by Edward Dangler
for
SEA GRANT PROJECT R/E-2

This work is a result of research sponsored by NOAA Office of Sea Grant, Department of Commerce, under Grant #USDC 2-35208 to the Institute of Marine Resources. The U.S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright notation that may appear hereon.

Available from:
University of California
Institute of Marine Resources
P. O. Box 109
La Jolla, California 92037

UC-IMR Reference No. 73-8
Sea Grant Publication No. 25

TABLE OF CONTENTS

LIST OF FIGURES

I. INTRODUCTION

As a supporting contractor to the Marine Physical Laboratory of the Scripps Institution of Oceanography Sea Grant Project R/E-2, Lockheed's role was defined in terms of professional services assistance during the first phase of the Sea Floor Work Economics Studies Program. The professional services were further defined into a consideration of those topics of economic analysis methodology selection and development of a work-task catalog which could have applicability to the second phase economic evaluation. The requirement of developing such a work-task catalog resulted in MPL organizing a seminar of major undersea work system organization representatives to jointly discuss sea floor task requirements. The seminar which was held 25 January 1972 at Scripps Institution had participants of government, university, and industry in an attempt to outline work system needs at the sea floor and its interface. The results of this seminar (Ref. Appendix A) provided a major input and impetus to the formulation of the sea floor task/performance matrix. In addition to the seminar participation, another major effort on the part of Lockheed in fulfilling their support role was the development of a bibliography which had specific application to sea floor work needs. The bibliography (Ref. Appendix B) represents a cross section of some of the current reports prepared by government agencies or their supporting contractors.

A somewhat unique approach in the formulation and selection of an evaluation methodology for sea floor economics was used. Traditionally, an evaluation methodology assumes that the capabilities of the candidate systems are well-defined and then proceeds to measure the relative effectiveness of each candidate accomplishing a specified task, e.g., the several manned and/or unmanned submersible vehicles would be compared from a cost effectiveness point of view as to their relative overall efficiency to locate, identify and retrieve a specified target at a given depth in a given location. The broader charter of the sea floor work economics study, however, purposely did not wish to have the evaluation methodology force fit into the mold of the existing capabilities of current configuration manned and unmanned systems. The approach conceived therefore, was to develop a range of sea floor tasks, establish measurable criteria for the tasks and allow the candidate systems to be compared on the relative cost-effectiveness merits of accomplishing the tasks. The difference of approach is mainly philosophical rather than methodological since the requirement for generating candidate system capabilities still exists. The use of tasks to determine systems capabilities, however, rather than systems capabilities to determine task is conceptually far-reaching and allows a broadening of sea floor system utilization, limited only by the imagination and innovation of the benthic R&D community. Selection of a cost element matrix required definition in broad terms of the types of operations one could expect of typical system configurations to accomplish the sea floor work tasks. Consideration was required to be given to manned and unmanned submersibles, remotely operated and/or supported manned and unmanned tracked vehicles, bathyscape vessels, surface controlled work systems and combinations thereof to assure the cost comparision accommodation of any potential system. A breakdown of major cost factors, i.e., development, capital investments and operations into their respective detail cost elements is provided in Section III of this report. A provision was allowed for incorporation of annual ROI, i.e., some fixed percentage, to account for the annual cost of capital. This latter feature would have applicability mainly in the cost-effectiveness evaluations of systems produced by industry where capital investment funds theoretically have an alternative means of earning interest. In the case of government owned or funded systems, a hypothetical discount rate could be applied when comparing relative cost effectiveness with competing system configurations.

Section IV of this report addresses the mechanics of determining the specific and relative cost-effectiveness of a system to perform a given task, or a generalized operational function. Budgetary restrictions did not allow for the development of specific models for each critical measure of performance effectiveness. The task of developing such models must be addressed during the initial effort of Phase 2 if the results of the economic analysis are to be meaningful. A sample of one such model formulation is shown for a functional parameter (search time) to illustrate the principles involved. Likewise, the question of need and amount of computer assistance for exercising the models over a range of tasks has not been addressed within the scope of this supporting contract. A review of existing computer programs which could be adapted to the sea floor work systems economic evaluation should be undertaken during the initial stages of Phase 2. A description of this task is included in the Phase 2 plan in Section V of this document. Also included within Section V are those tasks necessary to gather, organize, and structure cost and performance data in evaluation models for economic analysis of candidate sea floor systems.

II. TASK PERFORMANCE MATRIX

The application of technology to the ocean floor is a dynamic process and one dependent upon man's needs, desires, and willingness to push the frontiers of science within a set of budget priorities. Previous efforts in ocean engineering technology traditionally generated hardware items to perform certain functions. The scientific community's needs, desires, and requirements were then tailored to conform with the capabilities of the available hardware. As a consequence of this process, several basic requirements were left unfilled due to the urgency and/or more popular interest in some of the pragmatic applications of deep ocean technology. The need for filling these information voids nonetheless is still present and has impact upon the further application and expansion of technology to the sea floor. Knowledge concerning detailed topology and morphology of the bottom regime, creep, transport, erosion, and general physical properties are needed in order to fruitfully exploit the potential of undersea construction and resources development. Similarly, an increased body of information relating to the behavior, locomotion, and biological processes of benthic and pelagic organisms will not only add to the basic knowledge pool of marine biology but will further enhance man's quest for resources through applications of technology to aquaculture, maraculture, and sea life protection. One of the key missing factors in most sea floor work task catalogs is the identification of those tasks specifically defined in the area of in-situ measurements. The totality of measurement data relating to both the water column and the shelf and both bathyal and abyssal interfaces, is now receiving greater emphasis due to concern with pollution, coastal zone management, and ocean resources. The Stratton Commission in identifying ocean engineering needs listed the following areas as key requirements for the future:

- More effective methods and equipment for major shoreline modification and island building

- New pollution monitoring control and restoration systems
- Geographical characterization of the continental shelves with topographic and sub-bottom maps overprinted with gravimetric, magnetic, bottom type, and other information.

The tasks identified below would answer many of the data needs implied in the above future requirements statement. A systems approach to the problem of satisfying sea floor work requirements will result in a set of requirement specifications, for existing and future work systems. Various techniques for probing and sensing the sea floor are available and to certain degrees are capable of extensive on-site analysis in the fields of radiometry, magnetometry, resistivity, profiling spontaneous potential, head flow, neutron absorption, and geotechnique. These devices and methods can be supplanted with micro photography, recorders, side scanners, sub-bottom profilers, sampling and coring systems, and various imaging procedures. The packaging of these devices into a unit which can be readily handled by a surface or subsurface system seems technically feasible and may be economically justified for certain sea floor operations. What appears to be developing from the list of tasks however, is a need for a generation of multi-sensored profiling devices which may be remotely controlled, self-contained, and capable of transmitting real time data from in situ through the water column to a data receiving platform.

The matrix below (Fig. II-1) lists task along the "Y" axis and operational functions along the "X" axis. In utilizing a matrix such as this, one may examine the tasks and determine the functions needed to perform the tasks. With a list of required functions, one may then select from a grouping of candidate systems those which can at least minimally match the requirements. Carrying this procedure several steps further, the costing of the systems to a comparable level and application of the costs and performance criteria in a cost-effectiveness model, will allow one to select that system or systems which represent the cost/performance optimum of the candidates. The intersect of the task and requirement may be identified in terms of a condi-

Task \ Function	Navigate	Visual Observation	Remote Observation	Object Classifi-cation	Location Marking	Maintain Position	Manipulate Objects	Photograph	Coring	Data Sampling	Material Storage
In situ Observation											
Synoptic Survey											
Water Column Analysis											
Physical Properties Analysis											
Geological Characteristics											
Terrain Survey											
Micro-Topography											
Materials Extraction											
Object Location											
Object Emplacement											
Site Preparation											
Structures Erection											

Fig. II-1 Typical Sea Floor Task/Function Matrix tional as well as a positive requirement, i.e., the complexity of retrieving in the case of collection of sediment samples can be shown in a relative value scale.

III. COST MATRIX

A major step in analyzing the economics of sea floor work systems is generating a realistic cost analysis. The application of cost analysis to sea floor work systems poses problems because of a lack of historical data. In some cases, cost data must be developed from operating systems having similar or related characteristics to a specified sea floor system. It is also possible to supplant missing design point costs with parametrically developed cost estimating relationships (CER). An example of a typical CER is shown in Fig. III-1. In Phase 2 of the project, certain costs may be estimated by the CER technique when actual investment and operating costs are unavailable for the system being analyzed. To adequately perform the cost effectiveness evaluation (Ref. Section IV), a minimum cost data base will be needed for each new or proposed system undergoing evaluation. These costs are characteristically grouped into the following major categories:

- Capital Investment

  Fabrication and Procurement of Equipment
  Support Facilities Costs
  Initial Spares Equipage
  Technical Data Operating Manuals

- Operating Costs

  Depreciation and Interest
  Personnel and Related Costs
  Power Costs
  Maintenance and Repair
  Logistics Support

When it is desired to obtain a cost for a system which can then be used for cost-effectiveness model input, a format similar to Fig. III-2, Matrix for Measure of Cost Effectiveness (MOCE) costs, should be used. The values for

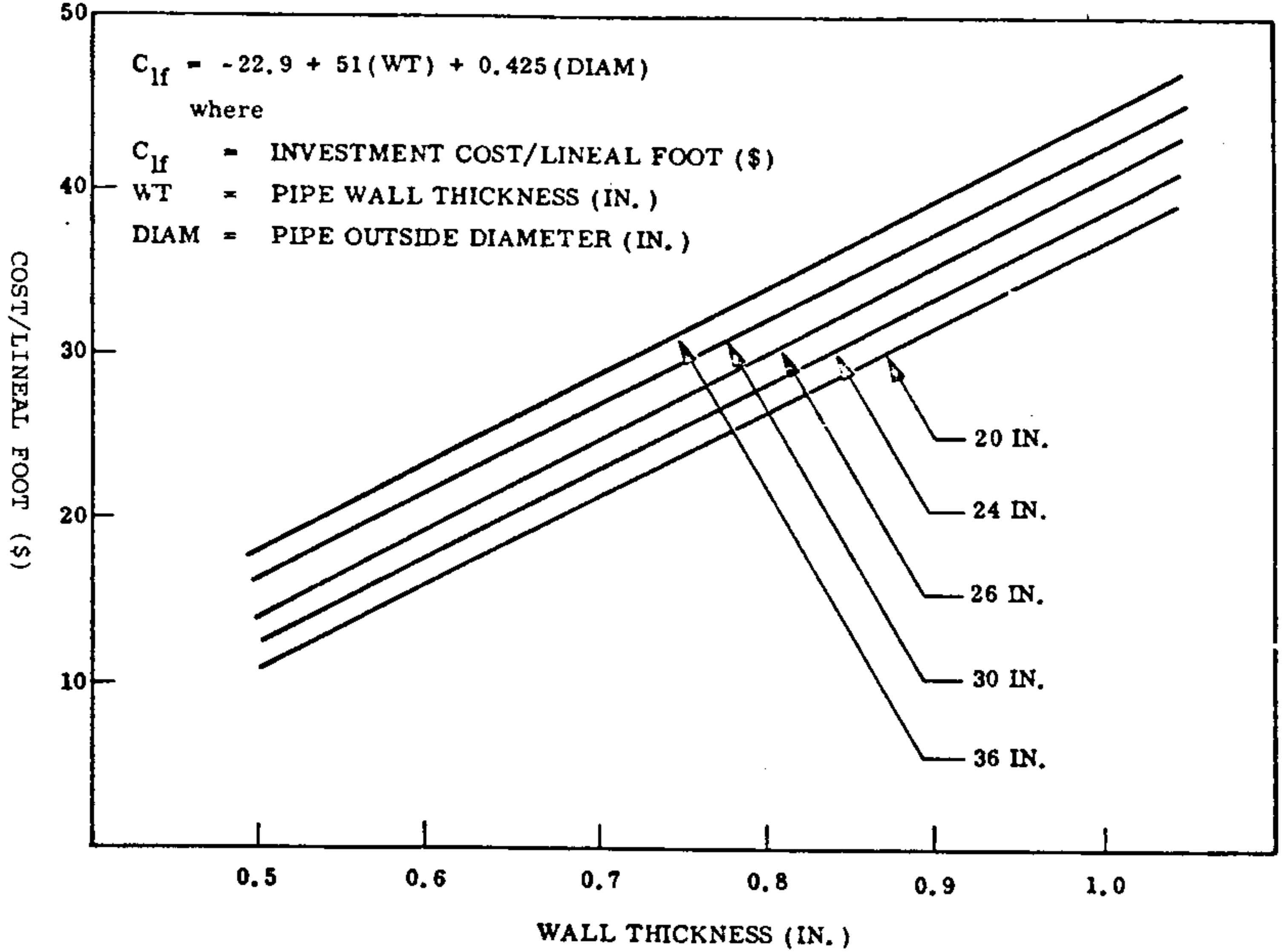

Fig. III-1 Typical Example of CER-Type Data

TASK: BIOLOGICAL IN SITU OBSERVATIONS

COST	CANDIDATE SYSTEMS			
	Manned Submersible (Free)	Manned Submersible (Tethered)	Unmanned Submersible (Tethered)	Remote Operated Work System
CAPITAL INVESTMENT				
ANNUAL COST OF CAPITAL				
ANNUAL OPERATING COSTS				
$\sum$ - COST				

Fig. III-2 Format Matrix for MOCE Costs

each cost heading above should be estimated for each system and for the same task requirement, to assure comparable and all inclusive data.

The capital cost can be expressed as an annual cost of capital by applying a projected return on investment (ROI) alternative factor, or amortizing the capital investment over a useful life span. The method of applying the ROI allows greater flexibility when comparing systems with varying useful life spans. The MOCE cost then can be expressed as

$$\sum \text{Cost} = K\ (\text{capital investment cost}) + \text{Annual Operating Cost}$$

IV. COST EFFECTIVENESS METHODOLOGY

An analytical tool which is proposed for evaluation of alternative systems in performance of a task or series of related tasks is the MOCE (Measure of Cost Effectiveness) method. The MOCE is based on a comparison of value received for dollar expended for each candidate system in a specified work-task environment. The method provides for accepting estimates of capital investment, development, and operational costs and combining them with effectiveness criteria. The criteria consist of quantitative as well as qualitative measures, the latter of which are converted into quantitative terms by means of rating the alternative system configurations with respect to one another on a given attribute. The criteria are then normalized by assigning a value of 1.0 to the candidate with the most desirable criterion measure or rating. Desirable criteria may be both maximum (e.g. speed, dwell time, etc.) and minimum (e.g. operators, weight, etc.). In either case the normalized values reflect relative desirability for that criterion.

The normalized effectiveness values then are summed for each candidate, resulting in a quantitative system performance measure,

$$\sum \text{Effectiveness}$$

The criteria may be assigned weighting factors to permit a more realistic assessment of candidate effectiveness, i.e., safety compliance may be predominant and weighted more favorably than datum reliability. The weighting factors to be applied will be established by knowledgeable analysts and engineers familiar with the relative performance of the systems. The costs for capital investment then will be amortized over the life of the system or converted to annual cost of capital and applied to operational annual costs to obtain the $\sum$cost (Ref. Fig. III-1).

The measure of cost-effectiveness index for each system under consideration then is expressed as

$$\text{MOCE index} = \frac{\sum \text{effectiveness}}{\sum \text{cost}}$$

This index provides a quantitative relative rating of system candidate alternatives in terms of systems effectiveness per dollar.

Fig. IV-1 illustrates a typical effectiveness criteria matrix for a set of alternative system candidates. Fig. IV-2 shows an actual example of a normalized unweighted criteria matrix used on another project. Fig. IV-3 is the same example with an illustration of weighting factors applied to specific criteria. The effects of weighting can be readily seen in the change to the $\sum$effectiveness values in each case. The MOCE index therefore establishes a priority of utility in terms of relative cost effectiveness. The examples shown in Figs. IV-1, -2, and -3 are presented to illustrate the format and method of cost effectiveness calculation and do not represent actual situations. In each case, criteria must be developed which relates to the work task to be evaluated.

Development of criteria for the effectiveness matrix is a critical function in that each proposed work task may impose different requirements on the same set of candidate systems. Each criteria selected must be expressed as either a quantitative function, i.e., knots, gals/min, tons/hour, or a qualitative value, as in the case of safety factors where a relative value can be applied to each system between the safest to the least safe. Wherever possible, if quantitative data is available it should be used. When certain criteria are not readily accessible through lack of operational records, a model of the function can be developed as a mathematical expression of related functions. In the case of elapsed search time for example, the criteria, "Mean Elapsed Search Time" (MEST), can be expressed as

$$\text{MEST} = \frac{Ts + Ti + N(T\ A/D)}{W} + (N-1)\ T_R + T_B + T_F$$

TASK: BIOLOGICAL IN-SITU OBSERVATION

Configuration / Criteria	CANDIDATE SYSTEMS			
	Manned Submersible (Free)	Manned Submersible (Tethered)	Unmanned Submersible (Tethered)	Remote Operated Work System
1. Personnel Requirements				
2. Vehicle Reliability (MTBF)				
3. Data Accuracy				
4. Data Quantity (OBS/Hr)				
5. Mean Elapsed Search Time				
6. Specimen Size Range				
7. Safety Factors				
8. On Station Dwell Time				
9. Data Handling Charact.				
10. Environmental Impact				
$\sum$ Effectiveness				
$\sum$ Cost				
MOCE index = $\frac{\text{Eff}}{\text{Cost}}$				

Fig. IV-1 Effectiveness Criteria Matrix

LIFT SYSTEMS UNWEIGHTED COST EFFECTIVENESS

Configurations / Criteria	"A"	"B"	"C"	"D"	"E"	"F"	"G"
Power	0.351	0.194	0.556	0.556	1.000	0.833	0.588
Weight	0.623	0.467	0.312	1.000	0.517	0.320	0.217
Crew Size	1.000	1.000	0.190	0.286	1.000	0.750	1.000
Compatibility – Bottom	0.500	0.250	0.333	0.333	0.333	1.000	1.000
– Surface	0.250	0.250	0.333	0.500	0.500	1.000	1.000
Development Required	0.333	0.333	1.000	1.000	0.333	0.333	0.500
Nodule Size Affected	1.000	1.000	1.000	1.000	1.000	0.500	0.500
Downtime	0.333	0.333	1.000	1.000	0.500	0.500	0.500
No. of Systems	1.000	1.000	0.167	0.250	1.000	1.000	1.000
Useful Life	1.000	1.000	1.000	1.000	1.000	0.500	0.500
$\sum$ Effectiveness$_u$	6.390	5.827	5.891	6.925	7.183	6.736	6.805
M.O.C.E. Index$_u$	.243	.168	.064	.140	.342	.557	.544
System Ranking	4	5	7	6	3	1	2

Fig. IV-2 MOCE Matrix - Unweighted

LIFT SYSTEMS WEIGHTED COST EFFECTIVENESS

Criteria	Weighting Factor	"A"	"B"	"C"	"D"	"E"	"F"	"G"
Power	2	0.720	0.388	1.112	1.112	2.000	1.666	1.176
Weight	1	0.623	0.467	0.312	1.000	0.517	0.320	0.217
Crew Size	1	1.000	1.000	0.190	0.286	1.000	0.750	1.000
Compatibility – Bottom	3	1.500	0.750	0.999	0.999	0.999	3.000	3.000
– Surface	2	0.500	0.500	0.666	1.000	1.000	2.000	2.000
Development Req.	2	0.666	0.666	2.000	2.000	0.666	0.666	1.000
Nodule Size	2	2.000	2.000	2.000	2.000	2.000	1.000	1.000
Downtime	3	0.999	0.999	3.000	3.000	1.500	1.500	1.500
No. of Systems	2	2.000	2.000	0.334	0.500	2.000	2.000	2.000
Useful Life	2	2.000	2.000	2.000	2.000	2.000	1.000	1.000
$\sum$ Effectiveness_w		11.990	10.770	12.613	13.897	13.682	13.902	13.893
M.O.C.E. Index_w		.456	.310	.136	.281	.652	1.149	1.111
System Ranking		4	5	7	6	3	1	2

Fig. IV-3 MOCE Matrix - Weighted

where

Ts = Search time

Ti = Inspection time

N = Number of descents to locate object

$T_{A/D}$ = Ascent, descent, mating, and unmating time

T_R = Replenishment time

T_B = Site survey and beacon deployment time

T_F = Time to repair failure

W = Fraction of time sea state allow operations

When the several criteria have been defined in terms of their function relationships, a computer program can be developed which will accept as input the characteristics data of the candidate systems. Selection of work-task requirements which have been incorporated into algorithms of criteria relationships will array the data and perform the necessary manipulations to generate the $\sum$ effectiveness function. Input of the MOCE cost data can be combined by the program to calculate the MOCE indices, in either a weighted or unweighted mode, for each candidate system.

Modeling of the criteria functions in terms of relationships of vehicle characteristics leads to an insight of sensitivity of individual factors to total mission accomplishment. In the case of Mean Elapsed Search Time, previous analyses indicate that the repair time component is most critical to the total mission time function. This is partially due to limited repairability at sea. The effect of vehicle MTBF, speed and transit time to accomplish repairs therefore will be significant in terms of task performance and system's cost effectiveness.

V. PHASE II TASKS

During Phase II of the sea floor work systems economics project, several key tasks must be accomplished to enable detail economic analysis of existing and potential sea floor systems. These tasks can be summarized as:

- o Acquisition of cost data for existing systems
- o Development of cost estimates and cost estimating relationships (CER) for new systems
- o Identification of performance criteria for each postulated sea floor work task and series of related tasks
- o Development of mathematical models for quantitative assessment of performance criteria
- o Review feasibility of computer program applications to individual criteria models and integrated cost-effectiveness model
- o Conduct cost effectiveness trade-offs for specified work tasks over a range of candidate systems

Each of the above tasks is composed of several subtasks. The cost data acquisition task requires the gathering of current cost profiles for each major work system. The data must be obtained from the vehicle operators or through extensive literature search. Development of CER data, which is necessary when estimating new or potential system designs requires the analysis of similar system costs and extrapolating from parametric values. The identification of performance criteria involves a functional analysis of the task and the assignment of the qualitative or quantitative values to the criteria. This latter need can be met through development of mathematical models which reflect relationships between the system's characteristics. While application of computers to generate the end results of cost-effectiveness effort may be helpful, it may not be necessary if the number of performance and cost variables can be easily handled in a manual mode. Prior to arriving at the decision for computer utilization, a review of existing programs and models should be undertaken to evaluate their application to the sea floor work system analysis task. The exercising of the MOCE method for several work tasks over a range of several candidate systems must be performed in conjunction with the evaluation of the task/function matrix data. It is anticipated that this latter task would be jointly performed by MPL and Lockheed personnel to assure completeness of the selection of candidate work systems.

APPENDICES

W. Crenshaw	15-54	150	1	31 Jan. 1972
Ed Dangler	52-50	204	2	45380

SEA FLOOR TASKS DEFINITION MEETING - SCRIPPS INST. - MPL

Contract: PO 72-C-40512-0 1/25/72

Attendees:

Vic Anderson	MPL Meeting Sponsor
Dan Gibson	Engineering Div. MPL - RUM Project
Lee Tomooka	UCSD - Oceanography - Grad studies
C. B. Momsen	GM - Delco Labs - Sta Barbara - Dir. Ocean Sci.
Maury Lebovitz	Engr. Mgr. Global Marine Co. San Diego
Andy Rechnitzer	Chief Scientist - CNO OP 23, Washington, D.C.
Al O'Neal	Dir. - Ocean Sci. & Technology ONR Wash., D. C.
Eric Barham	Ch. Marine Biology - NUC - San Diego
Ivor Lemaire	Dir. Adv. Systems - NUC - San Diego
Bob Breckenridge	NCEL Port Hueneme - Ch. Ocean Engr. Division
Tony Inderbitzen	Ocean Sciences - Lockheed - L.O.L. San Diego
Ed Dangler	Lockheed Research Laboratories - Palo Alto

The purpose of the meeting was to explore in a non-structured manner, the tasks which must be done at Sea Floor. The nature of tasks was to be independent of existing hardware systems. The goal established at the outset of the meeting was the compilation of those tasks which should be done, and the functions and necessary hardware capabilities would logically follow.

Considerable discussion (brainstorm type) ensued upon the issue as to whether an agenda and, if so, which items, should be included. The group was in agreement that basically all applications of sea floor work systems could be categorized under one of the following major subdivisions:

Fundamental Research
Construction
Operations

The research subdivision was itself broken into the following major fields which became the topics of discussion of the meeting:

Geology
Biology
Chemistry
Physics

Within each field there was a natural split between descriptive properties and processes (See Table 1). It was basically agreed that the area of operations falls into both the fundamental research and construction headings and therefore did not merit being carried along as a separate subdivision. Likewise, construction was expanded to include those application tasks on the sea floor, i.e., mining, emplacement, lifting objects, as well as those tasks generally associated with installation of structure on the ocean bottom.

As each of the primary research subdivisions was discussed, it soon became apparent that a fundamental need common to all areas of the ocean sciences (specifically, those related to the benthic interface zone) was the establishment of relationships between in situ and lab measurements. This topic appeared several times during the proceedings of the meeting as being one of the major requirements in ocean bottom work. The effects of measurements are wide-reaching in scope. Sampling devices which select and remove bottom substances from their in situ environs may be actually skewing the data due to changes in temperature, pressure, and sea floor interaction. Of particular import to the measurements relationships are the needs for improved knowledge regarding sedimentology and sea floor spreading, bottom rheology, biological interaction. From the table of sea floor measurement needs, one can develop several applied tasks which will impose work requirements upon undersea systems (either existing, improved, or new development hardware). Some of these tasks are:

- Subsurface benthic fauna - synoptic survey
- Developing environmental impact baseline (specific application for effect upon bottom due to chemical and ammunition dumps)
- Shift of fault lines, monitoring long term creep
- Effect of man made structures upon biological organism behavior
- Ion concentrate measurements in situ at bottom interface (1M depth)
- Recovery of benthic organisms in original temperature and pressure conditions
- Near bottom magnetics measurements
- Microthermal measurements at interface
- Bench calibration device development
- Optical measurements without disturbing optical properties

The above task list, while not exhaustive by any means, does cover those areas which reflect needs in fundamental research.

The topic of construction tasks elicited several direct applications of measurements, in that specific data prerequisites must be known prior to initiating sea floor operations. A sampling of these specific tasks and applications follows:

- Site Selection - Fine grain topography required - possible use of corings of 100' depth in close distribution pattern.
- Object Moving - Dynamics of vertical lift, possible application for underwater tug. Accuracy in object placement.
- Mining-Excavation - Detail survey over large bottom surface. Measurement of effects of water column fines. Application of detail scale navigation on bottom.
- Aquaculture - Study effects of fencing upon surrounding bottom and water column area.

It was agreed that some attempt at compiling a bibliography of undersea work tasks would be made by LMSC. The tapes of the meeting will be forwarded to LMSC in order to provide a record of the activities LMSC will further develop a format for the report and recommendations for cost effectiveness methodology. The format will be reviewed at MPL at a meeting (date TBD) with Dr. Anderson, Dan Gibson, Ed Dangler, Bill Crenshaw, and Dr. Inderbitzen. Additional contacts will be made between Ed Dangler and MPL as required.

Ed Dangler, P. E.
Operations Research Specialist

ED:t

cc: Dr. A. Inderbitzen - LOL

Attachment - Table I

TABLE I

FUNDAMENTAL RESEARCH

SEA FLOOR MEASUREMENT NEEDS

RESEARCH FIELD	DESCRIPTIVE PROPERTIES	PROCESSES
Geology	Topology Physical Properties	Deposition Erosion Settlement Transport Creep
Biology	Taxonomy Biomes	Behavior Locomotion Feeding
Chemistry	Composition	Temporal Changes Chemical Budgets
Physics	Magnetic Thermal Acoustics Hydrodynamics Optics	Interaction Energy Budgets

APPENDIX B

BIBLIOGRAPHY

B-1 Selected Bibliography

SEA FLOOR WORK SYSTEM RELATED

B-2 From DIALOG System Computer Printouts

UNDERSEA WORK SYSTEMS

B-3 From NTIS Subject Index

OCEAN FLOOR

SELECTED BIBLIOGRAPHY - (SEA FLOOR WORK SYSTEM RELATED)

Rather than research the typical set of standard bibliographies in underwater research and operations, such as are found in the several ocean engineering handbooks and civil engineering texts, the approach taken for development of the bibliography was to utilize information storage and retrieval techniques, both computer-assisted and manual, in generating the appropriate bibliographic searches. To determine some of the current literature in the field of ocean bottom physical and descriptive measurement needs, a thorough search of the Defense Documentation Center (DDC) recent (1970, 1971, 1972) technical abstract bulletins and the Department of Commerce National Technical Information Service's (NTIS) Research and Development Reports index was made. Those reports having sea floor work needs and/or task implications were selected and identified, and arranged in acquisition number sequence. Additionally, the Lockheed DIALOG (an interactive computer retrieval system) was used to search both the NASA STAR and PANDEX Data bases. Results of these searches, based upon boolean relationship of selected search terms are included in the computer printouts as part of Appendix B. A copy of the NTIS subject index is also included within Appendix B to illustrate the scope of literature being generated which may bear upon Sea Floor work system needs.

The following bibliography contains those references extracted from Defense Documentation Center's Technical Abstract Bulletins (unclassified) and the National Technical Information Services Research and Development Reports Index. References are grouped by acquisition number (AD, PB, etc.) to facilitate ordering from the Documentation Centers. In selection of references emphasis was placed on those items relating to collection of data and new techniques in the in-situ measurement of descriptive and physical properties.

Selected Bibliography

SEA FLOOR WORK SYSTEM RELATED

AD 417812L	A Bibliography of Contemporary Literature (Underwater Sound) Available March-May 1971. ONR-Arlington, Va.
AD 624677	Concepts For Drilling and Excavating in and Below the Ocean Bottom. NCEL-TR-725 - E.J. Beck et al.
AD 699098	A Marine Geotechnique Utilizing a Submersible. A Progress Report on the Geomechanical Study of the Sea Floor Independent Research Program. LMSC 694693 - A. Inderbitzen, F. Simpson.
AD 699099	A Comparison of the Test Results of Vane and Direct Shear Tests Made on Recent Marine Sediments. LMSC 694695 - A. Inderbitzen, F. Simpson.
AD 710348	Underwater Work Measurement Techniques - 1969 Studies. UCLA Eng - 7052 - Cont. N00014-69-A-0200-4025. G. Weltman, G. H. Egstrom et al.
AD 710720	The Submersible and Oceanography. Nav. PG School - Monterey - Thesis April '70 - J. F. King.
AD 710965	A Preliminary Study of Sea Floor Trafficability and Its Prediction. AEWES-TR-M-70-8. K. W. Wiendieck.
AD 712753	Site Surveying for Ocean Floor Construction, NCEL-TR-691 M. C. Hironaka, W. E. Hoffman.
AD 714-481	Light Scattering Measurements off San Diego Coast. NUC-TP-203, J. W. Reese, S. P. Tucker.
AD 715-618	Animal Undermining of Naval Seafloor Installations. NCEL-TN-1124. J. S. Muraoka.
AD 716051	A Comparison of In Situ and Laboratory Vane Shear Measurements. LMSC 681703 - A. Inderbitzen, F. Simpson.
AD 716754	Naval In-Place Seafloor Soil Test Equipment: A Performance Evaluation. NCEL-TN-1135, R. J. Taylor, K. R. Demars.
AD 717087	Feasibility of Detecting Objects Buried in the Sea Bottom With Love Waves. Sci. Res. Assoc. Inc. Rpt 70-1, Contr. N00014-70-C-0378. A Humidal.
AD 717638	An Investigation of Instrumentation and Techniques for Observing Turbulence in and above the Oceanic Bottom Boundary Layer. NYU-Bronx Geo Physic Lab. GSL-TR-70-16 Contr Nonr - 285 (57) - H. R. Fre6.

AD 720338	The Sea Floor Excavator - Vol I
AD 720339	" " " " Vol II
AD 720340	" " " " Vol III
AD 720344	" " " " Vol IV
	Northrup Ccrp - NORT-70Y137-NCEL-CR-71.003 Contr N62399-70-C-0006.
AD 720348	Final Report of Contract NONR-4029 including a History of the Contract and the Bibliography of Contributions Supported by Contract NONR 4092 at Woods Hole Oceanographic Institution - Sept. 1962 - Sept. 1969. Woodshole-WHOI-Ref 70-6Y, S.T. Knott, A. C. Vine.
AD 722259	Manned Submersibles and Underwater Surveying. NAVOCEANO-NOO-SP-153.
AD 724824	Geothermal Heat Flux Evaluated From Turbulent Fluctuations Above the Sea Floor. MPL-U-38/70. Contr. N00014-69-Z-0200-6002.
AD 726084	Shipboard and In Situ Electrical Resistivity Logging of Unconsolidated Marine Sediments. Texas A&M - OTC 1351 - Sea Grant NSF-GA-1296. A. H. Bouma, W. E. Sweet et al.
AD 728014	Sea Floor Foundations: Analysis of Case Histories. NCEL-TR-731 - D. G. Anderson, H. G. Herrmann.
AD 732637	Comparison of Pressure and Staff Wave Gauge Records. Army Coastal Engr. Res. Central - CERC Reprint 2-71.
AD 732-643	Bottom Boundary Shear Stresses on a Model Beach - CERC Reprint 3-71.
AD 732791	Quantitative Analysis of Cape Cog Bay Ecosystem - Woodshole Mass. Con. Nomr 3070 (03) N00014-70-A-0269.
AD 818754	Principles & Methods of Core Analysis at the SACLANT ASW Research Center. SACLANTEEN - TR-71. A. Kermabon, P. Blavier.
AD 859968	Underwater Laser Surveying System. TRW 12661-6001-T0-00, NCEL-CR 69.028. D. R. Borchardt.
AD 887431I	Use of Deep Tow to Survey a Submerged Wreckage (U). S10 Ref 71-14 - MPL-U-24/71.
AD 889087L	Sea Floor Pile Foundations State of Art, and Deep Ocean Emplacements (U) NCEL-N-1182.
PB 189109	A Critical Review of Manned Submersibles Used in Oceanographic Research. NYU - Grant NSF-GH-13. P. A. Lange

PB 189110	Ocean Environment and Design Considerations in a Pre-Reconnaissance Study of a California Undersea Aqueduct. Litton Systems - Cont. DI-14-06-D-6780. F. C. Lee.
PB 196605	Mechanics of Sea Floor Penetration by an Axisymmetric Tube: Static Penetration Studies. BuMines - BM-RI-7451. O. Terichow.
UCSD-3Y-P-127-12	Near Bottom Animal Population and Related Deep Circulation in the Ocean. J. D. Isaacs, R. A. Schwartzlose.

From DIALOG System Computer Printouts

UNDERSEA WORK SYSTEMS

NASI-5875	Study of Astronaut Capabilities to Perform Extra-vehicular Maintenance and Assembly Functions in Weightless Conditions. L. E. Browne, M. R. Gafvert, A. J. Macek, W. G. Robertson, W. H. Shreck, and E. C. Wortz. Airesearch Mfg. Co., Los Angeles, Calif., (AL629937), Washington, NASA, Sept. 1967, 431 p., Refs.
RE 298	Study of Underwater Low Frequency Electromagnetic Propagation. A. Crews and A. Morganstern. Grumman Aircraft Eng. Corp., Bethpage, N. Y., Research Dept., Aug. 1967. 35 p., Refs.
JPRS 40884	Description of Soviet Engineering Patents (Device for Computing Correlation Functions, Sound Field Analyzer, Method for Finding Envelopes of Correlation Functions, and Pendulum Device for Measuring Surface Slope of Underwater Structures). Joint Publications Research Service, Washington, D. C.
AD 647957	The Study of New Concepts in Solid State Transducers. R. M. Grant. Michigan University, Ann Arbor, Michigan. Sept. 1965 - Aug. 1966.
AD 647892	Timed Heat-Release Chemical System for Underwater Applications (Combination Chemical Heat Release and Fabric Insulation System for Preventing Excessive Loss of Body Heat of Downed Pilots in the Ocean). C. J. Crowell, Jr., and K. N. Tinklepaugh. Naval Missile Center, Point Mugu, California. 1967.
AD 644522	The **Deep Dip** Automatic Instrumented Diving Assembly: AIDA. F. G. Salton and A. Silverstein. Naval Ordnance Lab., White Oak, Md. (NR841909).
JPRS 39185	Translations on Communist China - Science and Technology, No. 356. (Communist-Chinese Studies on Underwater Sound Measuring Devices, Acoustics, Cavitation Bubble Motion, and Noise Transmission). Joint Publications Research Service. Washington, D. C., March 1966.

NAA-SR-5405, spcl. Preliminary Design of a Compact Nuclear Power Plant for Underwater Application. Atomics International, Canoga Park, California. 1960.

NASA-TM-X-57313 Underwater Location System (Active-Passive Sonar Device for Recovering Vehicle Components Underwater). R. W. Lovelady and J. C. McFall, Jr. NASA. Langley Research Center, Langley Station, Virginia. 1965.

AD 635211 An Investigation of the Effects of Hydrostatic Pressure on Cartridge Actuated Devices. T. J. Nock. Naval Weapons Lab., Dahlgren, Virginia. 1966.

PB 169444 Report of NRL Progress (Submarine Topside Coatings for Use in Damp, Cold weather and Betatron Storage Ring Development). W. M. Leak. Naval Research Lab., Washington, D. C., 1966.

Instrumentation Withstands Both Cannon Firings and Extreme Underwater Depths. A. V. Block and A. L. Kadis. in NTC/66, Proceedings of the 1966 National Telemetering Conference, Boston, Mass., May 10, 1966.

AD 609490 Manipulators and Special Devices (Special Devices for Operator-Manipulator Use in Deep Ocean Engineering Work). V. C. Anderson and H. A. O'Neal. Marine Physical Lab., University of California, San Diego. 1964.

A Review of Marine Propulsive Devices. (Reaction Screw-type Marine Propulsion Devices Including Hydrofoil Sections, Free and Ducted Propellers and Hydrojets). R. C. Amsler and S. Thurston. American Inst. of Aeronautics and Astronautics, 2nd Annual Meeting, San Francisco, California, July 1965. Paper 65-482. 55 p. 17 Refs.

AD 428934 An Experimental Investigation of Gas-Driven Underwater Sound Devices (Gas-actuated Sonal Pulser and Vortex Whistle - Underwater Acoustic Vibrations). R. D. Fulmer. Naval Ordnance Test Station, China Lake, California. Oct. 1963. 44 p., Refs.

From NTIS Subject Index

OCEAN FLOOR

Comments on Incentives for Ocean Mining. MTSJ-41. N. E. Taney.

Incentives for Ocean Mining - Case Study of Sand and Gravel. MTSJ-5-4-35. J. M. Davenport.

Prospects for and from Deep Ocean Mining. 71-MTSJ-5-2-5. F. LaQue.

Recent Developments in Deep Ocean Mining. 70-MTSJ-4-6-37. R. Kaufman and A. J. Rothstein.

Ocean Mining Begins to Compete with Land Sources. 71-UNTE-12-1-31. J. W. Padan.

AD 712722 Fifty Environmental Problems of Timely Importance. 70-USCHX. L. M. Libby.

PB 191947 Preliminary Engineering Studies to Characterize the Marine Mining Environment. 70-USCH. E. Corp.

AD 853893 Study of One - Atmosphere Manned Underwater Structures. Vol. I. Summary. 68-USCHX. H. Young.

AD 716051 A Comparison of In-Situ and Laboratory Vane Shear Measurements. 70-USCHX. A. L. Inderbitzen, F. Simpson and G. Goss.

AD 717140 Collected Reprints - 1969. Volume I. 70-USCHX.

JPRS 50791 Conquest of the Depths. 70-USCHX. M. N. Diomidov and A. N. Dmitriev.

AD 709495 Direct Mapping of the Sea Floor Using Side-Scanning Sonar and Transponder Navigation. 69-USCHX. J. D. Mudie, W. R. Normark, and E. Cray.

AD 710965 A Preliminary Study of Sea Floor Trafficability and Its Prediction. 70-USCHX. K. Wiendieck.

AD 853962 Study of One - Atmosphere Manned Underwater Structures. Volume III. Appendices. 68-USCHX. H. Youngs, B. Ciurlionis and H. Ruley.

AD 853894 Study of One - Atmosphere Manned Underwater Structures. Volume II. Technical. 68-USCHX. H. Youngs.

AD 808760 A Theoretical and Experimental Study of the Kinematics of a Coring Tube Accelerated in Water by Hydrostatic Pressure. 64-USCHX. A. Kermabon.

AD 492000 Underwater Visibility. 37-USCHX. L. H. Dawson.

AD 723812 Computer Generated Depth-Pressure conversion Tables. 71-USCHX. T. Berghage and H. Beatty.

AD 723202 An Illumination Ranging Technique for Improving Photographic Ranges from Manned Submersibles. 70-USCHX. L. Hawkins and J. Costin.

AD 723174 Saturation Dives, with Excursions, for the Development of a Decompression Schedule for Use During SeaLab III. 70-USCHX. J. Kulig and J. Summitt.

Intersecting Titanium Spheres for Deep Submersibles. 71-JMCE-97-3-981. G. F. Leon.

AD 722669 NCEL Ocean Engineering Program, FY 1971. 71-USCHX.

AD 722598 Bibliography of Technical Reports 1970. 70-USCHX. C. Fuglister.

AD 722315 Mark I Deep Dive System - Stress Analysis. 71-USCHX. S. B. Nosseir and S. K. Takahashi.

Evaluation of First Silver Zinc Batteries Used in Deep Submergence. 71-MTSJ-5-2-31. D. F. Momsen and J. C. Clerici.

AD 715103 Personnel and Training Requirements for the Deep Submergence Rescue Vehicle (DSRV). 70-USCHX. J. Noble.

AD 718856 Dental Support for Sea Lab III. 70-USCHX. W. Shiller.

AD 707723 Gravity Flow Past a Cylinder Moving Beneath a Free-Surface. 70-USCHX. G. Dagan.

AD 707662 Study of the Activity of Erythocyte Carbonic Anhydrase Exposed to a High Pressure Gas Environment. USCHX. R. Reinke and R. Wilson.

AD 709463 Bibliography of Maritime Search Theory and Background material on Operations Research. 70-USCHX. V. Banowetz.

AD 709393 1970 Annual Technical Symposium (7th). Mechanical Systems for Ocean Engineering. 70-USCHX. A. Southerland.

AD 709387 1970 Annual Technical Symposium (7th). A Closed Brayton Cycle Power Plant for Underwater Applications and Comparison with a Fuel Cell. 70-USCHX.

AD 709384 1969 Annual Technical Symposium (6th). Investigation of a Method to Provide Motion Synchronization During Submersible Retrieval. 69-USCHX. J. Buck and H. Stoll.

AD 708748 Research on Deep Submergence Diving Physiology and Decompression Technology Utilizing Swine: Evaluation of Swine as a Hyperbaric Analog to Man and Detection of Emboli by Use of the Ultrasonic Doppler Flowmeter. 70-USCHX. M. Gillis.

Fluid Power for Deep Submergence Applications. 70-SENR-23-2-15. W. E. Rouse.

Navigation of Deep Submersibles in Close Search. 70-NVGN-17-2-164. R. K. Worthington.

Use of Pulsed Doppler Sonar for Navigation of Manned Deep Submergence Vehicles. 70 17-2-136. T. A. Coulet.

AD 705524 Ducted Propellers - A Review and Description of Current Investigation. 70-USCHX. R. Weetman and D. Cromack.

AD 710720 The Submersible and Oceanography. 70-USCHX. J. King.

AD 704647 Gamma Aminobutyric Acid Levels in Brains of Mice Exposed to 20, 40, and 60 Atmospheres He-0_2 for 24 Hours. 69-USCH. T. Ritter, R. Vandrovec and R. Wilson.

AD 704646 Serum Alkaline Phosphatase, Serum Lactic Dehydrogenase, and Serum Glutamic Oxalacetic Transaminase in Mice Exposed to 1, 20, 40, or 60 Atmospheres of Helium-Oxygen at Physiologic Oxygen Partial Pressures. 69-USCH. T. Ritter, R. Reinke, R. Wilson.

AD 704485 Bibliography of Technical Reports 1969. 70-USCH. G. Fuglister.

AD 707363 Development of a Spherical Acrylic Plastic Pressure Hull for Hydrospace Application. 70-USCH. J. D. Stachiw.

A Deep Submergence Divers' Navigation System. 70-NVGN-17-1-76. B. Saltzer.

Early History of Deep Submergence Navigation Aboard Trieste. 70-NVGN-17-1-3. K. V. Mackenzie.

Weight Considerations for Deep Submersibles. 70-MART-7-2-196. E. H. Nickell.

Use of Mock-Ups in Design of a Deep Submergence Rescue Vehicle. 70-HUFA-12-63.