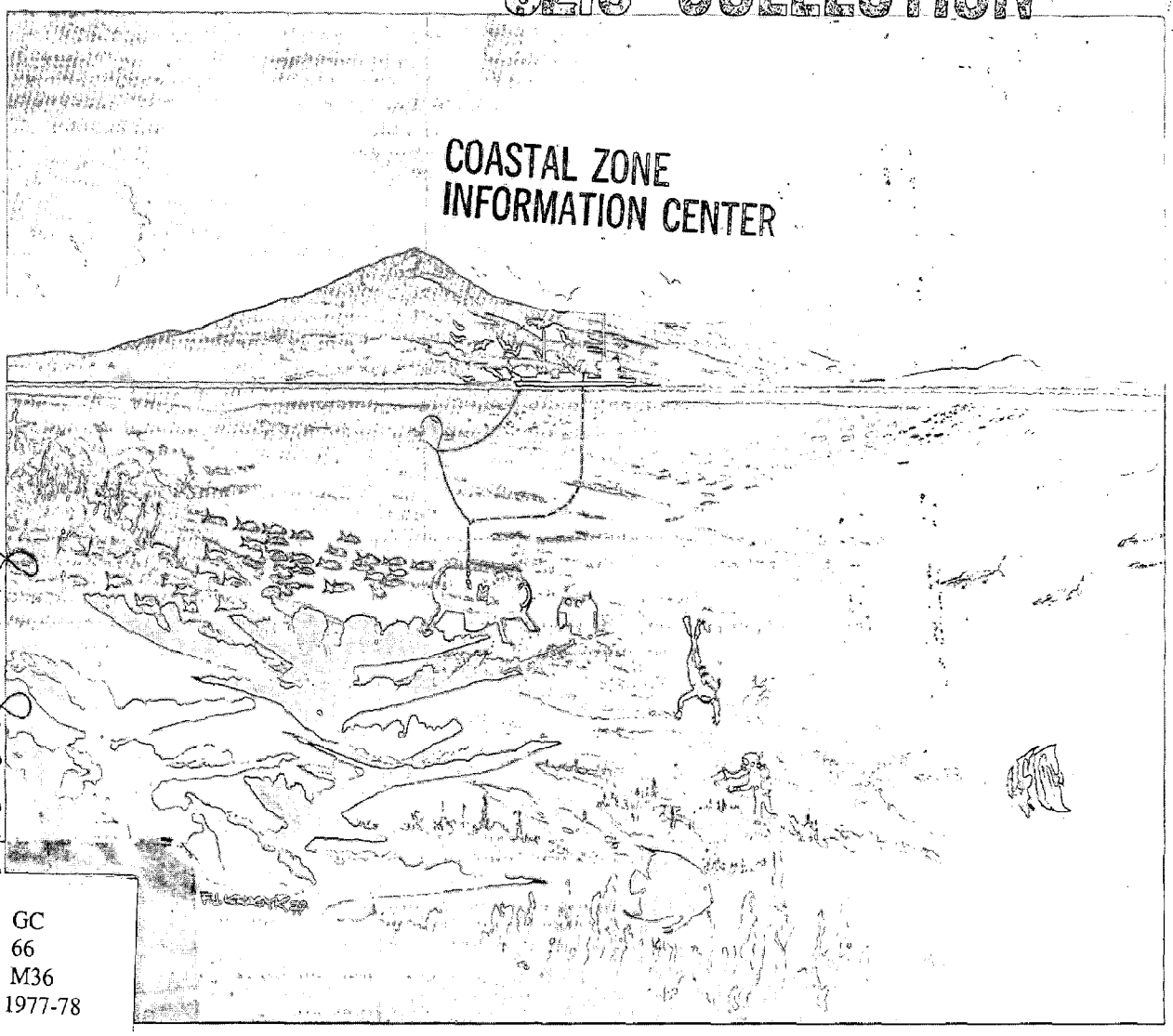
Manned Undersea Science and Technology Fiscal Years 1977 and 1978 Report

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Ocean Engineering



COVER: Artist's conception of *Hydro-Lab* habitat and surrounding terrain off St. Croix, U.S. Virgin Islands.

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Rockville, Md.
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U.S. DEPARTMENT OF COMMERCE
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National Oceanic and Atmospheric Administration
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Office of Ocean Engineering
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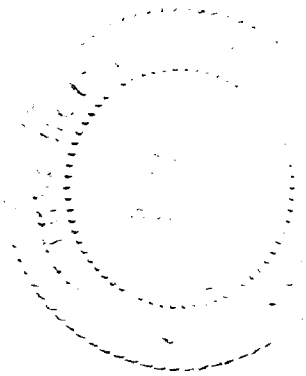

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CONTENTS

LIST OF ACRONYMS

ABS	American Bureau of Shipping
AOML	Atlantic Oceanographic and Meteorological Laboratory
BLM	Bureau of Land Management
CNCA	Council for National Cooperation in Aquatics
COE	Corps of Engineers (U.S. Army)
CSDL	Charles Stark Draper Laboratories
CZM	Coastal Zone Management
DOE	Department of Energy
DOI	Department of the Interior
DOL	Department of Labor
DSRV	Deep Sea Research Vehicle
DUMAND	Deep Undersea Muon and Neutrino Detector
EDIS	Environmental Data and Information Service
EMT	Emergency Medical Technician
EPA	Environmental Protection Agency
ERL	Environmental Research Laboratories
EUBS	European Underwater Biomedical Society
FDU	Fairleigh Dickinson University
FISSHH	First International Saturation Study of Herring and Hydroacoustics
FIT	Florida Institute of Technology
FY	Fiscal Year
GSFC	Goddard Space Flight Center
HEW	Department of Health, Education and Welfare
JAMSTEC	Japan Marine Science and Technology Center
JSL	*Johnson-Sea-Link*
MG&GL	Marine Geology and Geophysics Lab
MLC	Major Line Component
MPE	Main Program Element
MTS	Marine Technology Society
MURT	Manned Undersea Research and Technology
MUS&T	Manned Undersea Science and Technology
M/V	Merchant Vessel
NAE	National Academy of Engineering
NAS	National Academy of Science
NASA	National Aeronautics and Space Administration
NEFC	Northeast Fisheries Center
NIOSH	National Institute for Occupational Safety and Health
NMFS	National Marine Fisheries Service
NOS	National Ocean Survey
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NWAFC	Northwest Alaska Fisheries Center
OCS	Outer Continental Shelf
ONR	Office of Naval Research
OOE	Office of Ocean Engineering
PIRC	Portable Inflatable Recompression Chamber
RDL	Relative Day Length
RDT&E	Research, Development, Test, and Evaluation
ROV	Remotely Operated Vehicle
RTG	Radioisotope Thermoelectric Generator
R/V	Research Vessel
SAR	Search and Rescue
SEFC	Southeast Fisheries Center
SMU	Southern Massachusetts University
SWFC	Southwest Fisheries Center
UJNR	United States-Japan Cooperative Program in Natural Resources
UMS	Undersea Medical Society
UNCLE	Undersea Cosmic Lepton Experiments
UNH	University of New Hampshire
UNOLS	University National Oceanographic Laboratory System
URI	University of Rhode Island
USGS	United States Geological Survey
U of W/WWU	University of Washington/Western Washington University
WIL	West Indies Laboratory

INTRODUCTION AND SUMMARY

This report of the National Oceanic and Atmospheric Administration (NOAA) Manned Undersea Science and Technology (MUS&T) Program presents a general review of the Program's development and management, a summary of significant accomplishments, and a detailed description of new and ongoing activities in the period October 1976 through September 1978 (Fiscal Years 1977 and 1978). A bibliography documenting reports on MUS&T-supported activities not cited in the FY 1976 Report is also provided.

The purpose of the MUS&T Program is primarily to foster those manned underwater scientific investigations that meet the needs and requirements of NOAA and to encourage studies and activities that increase the safety, usefulness, and versatility of manned undersea operations. The program also conducts cooperative undersea programs with other Federal agencies and provides liaison, advice, and support to Federal, State, academic, and institutional bodies performing manned undersea work.

During the time period of this report (FY 1977 and 1978), interagency activities involved diver safety, underwater physics research, and the use of submersibles and a habitat for underwater biological, geological, scientific, and environmental studies. In response to a request initiated by Congress, requirements for improving manned underwater technology capabilities to support U.S. underwater scientific and engineering endeavors and missions were studied and a first cooperative national manned underwater laboratory regional program initiated at St. Croix, U.S. Virgin Islands. These latter endeavors were part of the Oceanlab Program, which is intended to focus on man-in-the-sea support of national and NOAA undersea scientific research and operations.

The Office of Ocean Engineering, through its MUS&T Office, continued to serve as the management focus for NOAA in a cost- and use-sharing arrangement for the support of the deep sea research submersible *Alvin*. This arrangement began in 1975 in partnership with the National Science Foundation and the U.S. Navy. The growth of NOAA's diving program and NOAA's increasing role in U.S. civil diving safety activities are reviewed. International cooperative man-in-the-sea programs have been continued.

Activities of FY 1977 and 1978 are described under the following categories: requirements and systems analyses; operational effectiveness and safety; applied technology and advanced concepts; marine science applications; and interagency and international activities.

BACKGROUND

The *MUS&T Program* was created to fulfill part of NOAA's responsibility for significantly increasing our knowledge of the ocean's resources and processes. Impetus for its formation came from recommendations by the National Marine Council, various advisory panels, and the Commission on Marine Science, Engineering, and Resources.

Although initial funds for the Program were not available until August 1971, staffing and planning began in December 1970. The MUS&T Program was assigned to the NOAA Associate Administrator for Science and Technology until September 1971, when it was transferred to the Associate Administrator for Marine Resources. At the beginning of FY 1977, the MUS&T Program became part of the Office of Ocean Engineering, now in the Office of Research and Development.

Funds appropriated to the MUS&T Program have been budgeted into broad functional categories: operational effectiveness, safety, and technical coordination; fisheries research support; environmental research support; submersible *Alvin* support; and other scientific research. Manned platforms have been leased through contracts and grants to universities and to operators of the platforms, based on competitive and sole-source procurement. Maximum cost effectiveness has been sought through the cooperative involvement and support of other agencies engaged in underwater research. Scientific and technical programs have been selected from unsolicited proposals and reviewed by members of the staff and outside reviewers. Selection of programs is based on national goals and needs, and the priorities recommended or suggested by appropriate review panels or individuals from the private sector and from government.

Scientific operations and missions support NOAA's MUS&T Program objectives in marine science, particularly the evaluation and development of our marine resources. Knowledge gained from these projects is also used to plan longer-range and more extensive marine endeavors and to solve day-to-day problems arising from competing interests in coastal and inland waters and the deep ocean.

OBJECTIVES

The basic objectives of the Manned Undersea Science and Technology (MUS&T) Program are to:

- Provide manned underwater and operational support to NOAA and other agencies investigating marine resources and environmental problems for which subsurface observations and collection of data by man are required.
- Develop, support, and manage a NOAA diving program to assure safe diving and more efficient operations for prolonged manned missions in coastal waters and on the continental shelf.
- Synthesize data from MUS&T-supported investigations and disseminate data to the user community to improve understanding of the nature and availability of marine resources.
- Foster and coordinate manned undersea science projects with Federal and State agencies, industry, institutions, and universities.
- Develop scientific and technical criteria for the design of civilian undersea facilities and platforms through experience gained by using available habitats and submersibles.
- Encourage and coordinate the transfer of undersea technology, including advances in diver technology and all civilian, military, and foreign undersea scientific and technological developments.

These objectives are being pursued by a small staff of technical personnel who are acquainted with Federal, industrial, and academic underwater programs and interests and whose standing in the marine science and technology community is well recognized. The staff's programming endeavors are guided by the advice of other NOAA components and by the suggestions and recommendations of such bodies as the National Academy of Science and National Academy of Engineering (NAS/NAE); joint task forces with other Federal agencies such as the U.S. Navy, National Science Foundation (NSF), Department of Energy (DOE), U.S. Coast Guard, and the National Institute for Occupational Safety and Health (NIOSH); and representatives from industrial and academic organizations and private institutions and foundations.

SUMMARY OF MUS&T ACTIVITIES FOR FISCAL YEARS 1977-1978

NOAA's Office of Ocean Engineering, through its Manned Undersea Science and Technology (MUS&T) Office in NOAA, has supported civilian operational capabilities for man to work under the sea in support of programs that aim to achieve a better understanding, assessment, and use of the marine environment and its resources.

Major efforts were expended on establishing, by means of user surveys and mission system analyses, the scientific and operational requirements for manned underwater activities. Federal agencies were again queried to establish those planned and potential marine civil programs which would benefit from the availability of manned underwater facilities. The first phases of the Oceanlab Program (which was redirected at the end of FY 1978) concluded with a complete mission analysis of both NOAA and other Federal civil marine programs as well as those research programs cited by the science community as ones which require manned underwater facility support. Although the Oceanlab concept of an autonomous, advanced capability, all-weather, manned mobile underwater laboratory facility was deferred, a program to consider cooperative national manned underwater laboratory regional programs using man-in-the-sea techniques was initiated.

MUS&T has continued to support NOAA investigations involving marine resources and environmental problems for which manned subsurface observations and data collection are required. In addition, the program has continued to assess the status of submersibles and habitats and to coordinate the use of available commercial and Navy assets for civilian Federal agencies' requirements. Included have been scientific projects jointly sponsored by NOAA and other Federal agencies, including the U.S. Army Corps of Engineers, Department of Energy, Environmental Protection Agency, National Aeronautics and Space Administration, and U.S. Geological Survey. Together with the U.S. Navy and National Science Foundation (NSF), NOAA has funded the operation of the deep sea research submersible *Alvin*, operated by the Woods Hole Oceanographic Laboratory System under a grant from NSF.

During fiscal years 1977 and 1978, MUS&T sponsored research missions using the deep-sea research submersible *Alvin* for seven missions; the Harbor Branch Foundation *Johnson-Sea-Link* research submersible for three missions; and shallow water research submersibles off Southeast Alaska, the eastern mid-Atlantic ocean coast, and off Hawaii for six missions. In addition, the *Hydro-Lab* habitat was purchased by NOAA and used to initiate a cooperative regional program at Fairleigh Dickinson University's West Indies Laboratory in St. Croix, U.S. Virgin Islands. During the first year of operation of the *Hydro-Lab* in Calendar 1978, a total of eight saturated science diving missions were conducted involving scientists from twelve United States and foreign universities.

The apportionment of the MUS&T funding for FY 1977 and 1978 is shown in Figure 1 for broad functional areas: operational effectiveness, safety, and technical coordination (including requirements and systems analyses); fisheries research support; environmental research support; and *Alvin* support provided to the Woods Hole Oceanographic Institution. Of the total funding available during this period, two-thirds has been spent out-of-house. This is shown in Figure 2, which presents the funding in five categories: submersible leases; habitat leases; research project support (all three outside MUS&T); systems studies; and salaries, travel, supplies, and equipment (MUS&T expenses).

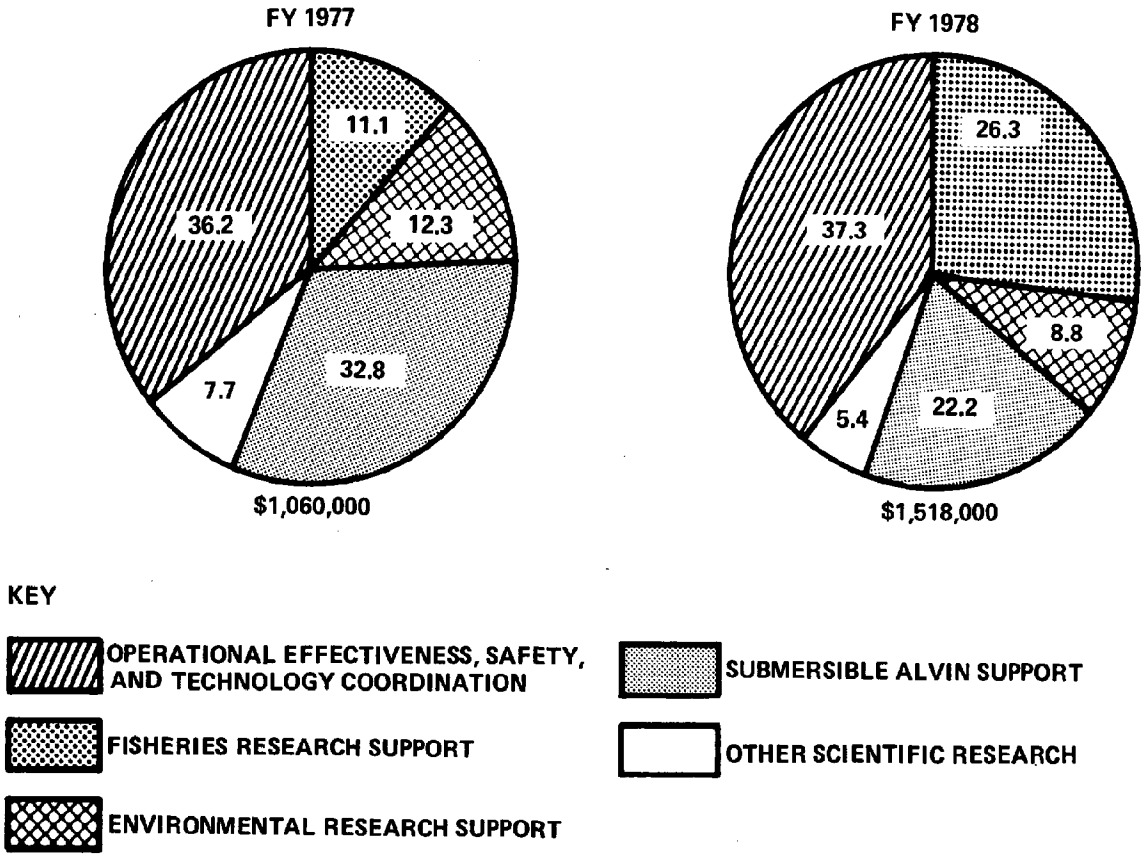


Figure 1.—MUS&T Funding by Broad Functional Areas, FY 1977 and 1978

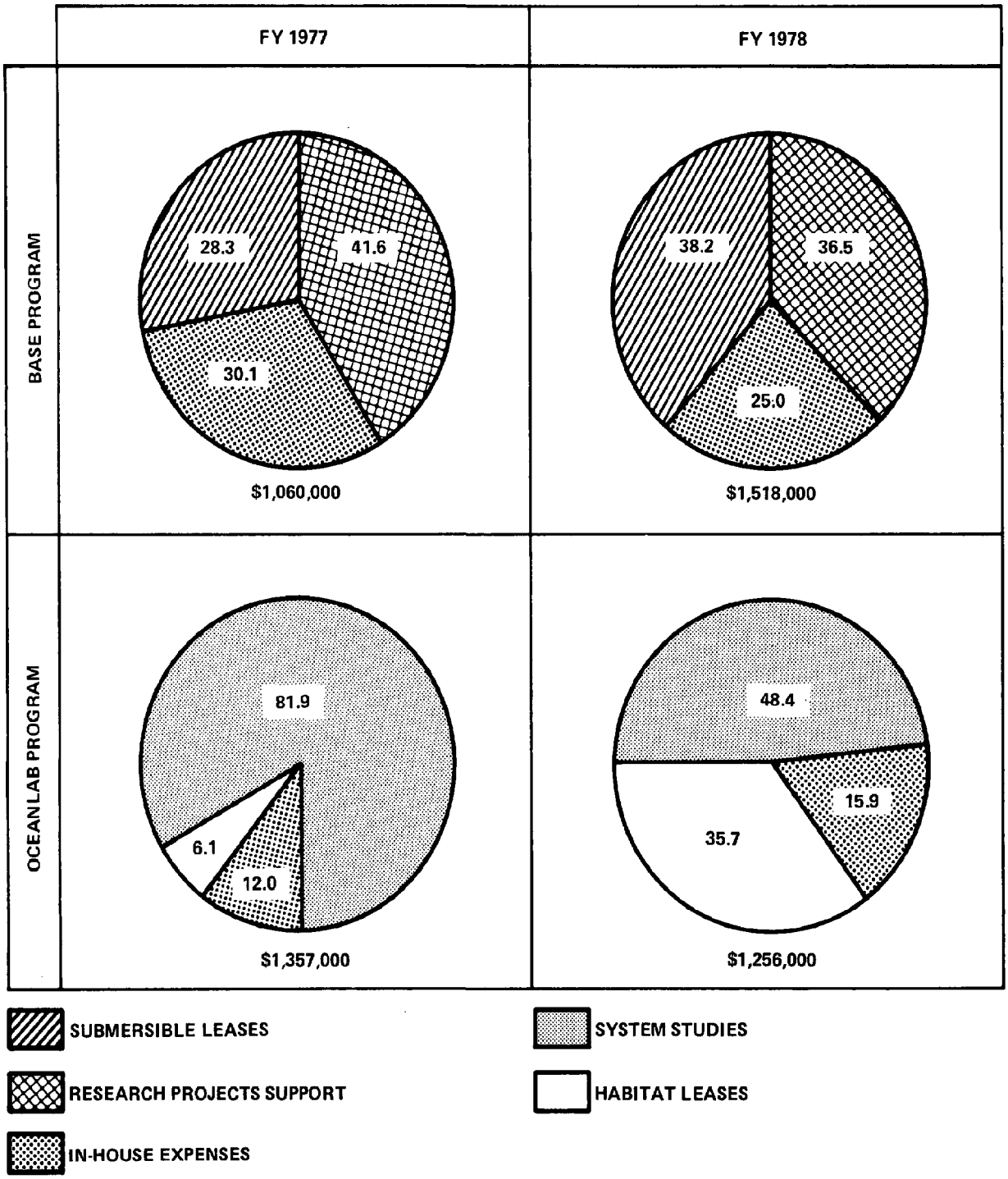


Figure 2.—MUS&T Funding for FY 1977 and 1978

REQUIREMENTS AND SYSTEMS ANALYSES

This section summarizes requirements and systems accomplished during FY 1977 and 1978. A fourth survey was conducted of civil Federal agencies to determine actual and potential marine programs involving the use of manned undersea facilities.* The utilization and status of manned undersea facilities is presented and trends in usage noted of both fiscal years. The initial systems analyses and engineering studies for the Oceanlab grant are summarized and the September 1978 redirection discussed.

These studies involved user surveys of NOAA operational and scientific mission requirements as well as surveys of the academic and private communities for research programs involving man-in-the-sea activities. The studies also analyzed the necessary manned underwater technology and facilities for both regional and national manned undersea science and technology programs.

USER SURVEYS OF MANNED UNDERWATER ACTIVITIES

During this reporting period, extensive surveys were conducted of Federal agency, civilian, and academic marine science and technology programs involving manned undersea facilities. The latter were included in the studies made in the Oceanlab program and are reported in a later section of this report. Summarized below is a survey of Federal agency actual and potential civilian marine programs requiring manned undersea facilities; a detailed listing of those programs is given in the Appendix. These results, as well as those from the Oceanlab efforts, will serve as guidelines to Federal and civilian research groups in establishing support for the use of existing facilities and for the development, construction, and utilization of future U.S. manned underwater systems.

The following information is based on a survey of present Federal agency utilization and future requirements which was performed during January and February 1978 and an international study of manned submersibles conducted under the auspices of the Oceanographer of the Navy, the U.S. Coast Guard, and NOAA, from September 1977 through June 1978.*

Eleven government agencies were surveyed, with current and planned civilian programs involving the use of manned undersea facilities identified and discussed in detail. In addition, those government programs that would use an underwater facility if supplied and operated at no cost to the individual program were also identified. Specific information sought included project purpose; facility requirements; geographic locations; operating water depth; scientific instrumentation requirements; and mode of facility operation including time frame, number of dives and repeat intervals, and funding levels.

Survey Summary

Of the eleven agencies contacted during this survey, nine identified some type of program which was using, or could use, manned undersea facilities to date. All the actual or potential programs are tabulated in the program summaries in categories which parallel previous studies, surveys, or analyses of mission requirements. This format was selected to afford continuity between present and past surveys and also to provide ease of entry of this information into other related manned undersea facility data tabulations.

Categories used for program summary presentation are:

Fisheries	General Oceanography
Geology	Oil Research Activity
Biology	Inspection
Pollution	Coral Harvest
Research, Development, Test & Evaluation (RDT&E)	Recreation/ Education

To provide comparisons with previous MUS&T user surveys, it was necessary to omit, add, or regroup some categories for accuracy of tabulation of data from this survey to the following:

Fisheries: Includes all fisheries and mariculture-related research.

*The previous surveys have been presented in prior MUS&T fiscal year reports.

*Both studies were conducted by R.F. Busby Associates under Department of Congress Contract No. MD-ADI-78-00-4077 and U.S. Navy Contract No. N62306-75-C-0049.

Pollution: Includes ocean spill and dumping, toxicity, and seabed waste research.

RDT&E: Includes diver safety, instrumentation, energy research, and ice-scoring programs.

General Oceanography: Includes all basic oceanographic research as well as environmental data collection and background studies.

Reported and potential programs are presented alphabetically by Federal department in the Appendix. Reported programs are those in which there was an immediate plan for funding of manned undersea facility utilization. Potential programs were those identified surveys or projects which could make use of a manned undersea facility if it were available. This latter group generally stipulated a free-of-charge availability. Not all the potential programs summarized in this report represent an official parent agency viewpoint, as each individual respondent was asked to present an opinion for potential facility utilization based on the objectives of his or her present program.

General responses of each of the Federal departments and agencies contacted during this survey are summarized below.

Department of Agriculture

No reported or potential programs.

Department of Commerce

Coastal Plains Regional Commission: Administratively, the Commission is under the aegis of the Department of Commerce, yet its funding comes directly from Congress and not from Commerce. Most, if not all, of its programs are conducted through grants to State agencies and universities. Three contacts were established within the Commission, and one potential vehicle utilization program was identified. This program involved evaluation of the fisheries economics of artificial reefs off the Carolina and Georgia coasts. The evaluation entails assessment of fish growth and stock replacement rates on the reefs. This program was not included in the program summaries of this report, nor were any university personnel contacted, as it was felt that the Commission would more properly fall into the academic arena.

National Oceanic and Atmospheric Administration: NOAA returned the most positive, detailed, and comprehensive responses related to requirements for manned undersea facility utilization in this survey, since NOAA personnel are constantly involved with oceanic problems and are more aware of the capabilities of undersea platforms than other potential Federal users. The NOAA responses were divided into four major disciplines: fisheries, geology, oceanography, and biology, with the majority of programs coming from fisheries components. Programs listed within these four NOAA categories are included in the program summary section within the ten overall categories listed above.

The degree of response generated within NOAA can be attributed also to the impetus for more extensive marine investigations brought about by the extension of U.S. offshore territorial limits to 200 miles and also because of required studies related to oil and natural gas exploration and exploitation on the Outer Continental Shelf.

Department of Energy (DOE)

Most of the reported and potential vehicle utilization programs were identified by personnel from outside laboratories receiving DOE funding. This is to be expected as DOE usually funds and then monitors outside organizations to meet their research objectives.

Battelle-Northwest is conducting the only reported DOE program utilizing submersibles. This program is involved with test and evaluation of a sediment pollution analyzer using X-ray fluorescence technique (see Applied Technology and Advanced Concepts). Battelle and Sandia Laboratory identified two RDT&E programs and one pollution program that could beneficially utilize a submersible. The sole potential program identified by in-house personnel concerned mariculture efforts and associated toxicity problems with upwelled water. This program is included in the fisheries category.

Department of Health, Education and Welfare (HEW)

HEW is not an in-house user of manned facilities. They rely mainly on data collected by others and therefore contract outside services to perform their research needs. The National Institute of Occupational Safety and Health (NIOSH) within HEW, however, is a user of diver and diving equipment safety data. The results of these data would best be reaffirmed through the utilization of undersea facilities, and NIOSH indicated a potential desire to pursue the use of available manned facilities for this reason.

Department of the Interior (DOI)

Other than NOAA programs, the greatest number of positive responses of reported and potential programs for manned undersea vehicle utilization came from DOI, particularly from the U.S. Geological Survey (USGS) and the Bureau of Land Management (BLM). The purpose of most of the programs reported by these two groups is to collect background data on which to base management decisions concerning oil leasing activities. Included in these efforts are studies of geological processes, bottom stability, geological hazards, the effect of drilling on the marine environment, and the delineation of unique features such as live bottom areas. In this context, it is not unusual for BLM to fund USGS laboratories to perform the at-sea research. Some overlapping of program types exists due to the regional responsibilities of these components.

The twenty-three potential programs reported by DOI cover a variety of disciplines from the basic sciences and RDT&E to recreational aspects of undersea facilities. These range from the practical to those that do not represent effective use of present facilities.

Department of Labor (DOL)

No reported or potential programs.

U.S. Coast Guard [Department of Transportation (DOT)]

While the Coast Guard plans no direct use of manned undersea facilities, they are responsible for an ongoing safety inspection program. They are also responsible for search and rescue (SAR) services and management of undersea communications frequency allocation.

Environmental Protection Agency (EPA)

EPA's interest in marine-related activities stems from their authority to promulgate guidelines and regulations, issue permits, and perform surveillance and analysis functions regarding the discharge of pollutants and toxic substances into the marine environment. These functions are based on laboratory and field research designed to determine the effect of these materials on marine life and the physical environment. They include some monitoring activities. At present, the major areas that utilize or could potentially utilize manned undersea vehicles center around the effects of ocean dumping (sludge, dredge spoils, and toxic substances such as low-level radioactive wastes) and the activities and by-products of oceanic petroleum exploitation and exploration.

Of the three reported programs within EPA, one project from the Office of Radiation Programs (involving the efficacy of dumping low-level radioactive wastes in the ocean) has funded submersible utilization in the past.

The remaining seven identified EPA projects considered as potential users of manned underwater facilities would totally rely on funding sources outside the parent agency. These projects typically concern regional desires to monitor and evaluate the effects of ocean dumping and petroleum activities but include the efficiency of studying artificial reefs at fish propagation sites and inspection of working rigs to ensure that proper blowout prevention devices have been installed. The latter two programs are outside the jurisdiction of EPA.

National Aeronautics and Space Administration (NASA)

Overall, NASA exhibited little interest in undersea facility utilization. No programs were identified that were directed to the transfer of space technology to underwater applications. The single program identified was an RDT&E effort involving a new "prompt effect" neutron gamma technique for use in pollution and mineral assessments and is discussed in the section entitled Applied Technology and Advanced Concepts.

Smithsonian Institution

The Institution does not customarily fund large, singular research endeavors. Therefore, interest in manned undersea facilities is typically with investigators pursuing individual research projects. The budget levels of these efforts preclude contracting manned facilities. However, one investigator has utilized submersibles by piggybacking on dives financed by other agencies or foundations.

Six contacts within the Smithsonian indicated desire to utilize or to continue utilizing a manned facility should one be made available. These investigations feel such facilities are required to complement and enhance their research efforts. The Smithsonian is viewed as having strong potential requirements for such facilities.

U.S. Army Corps of Engineers (COE)

In general, the interests of the COE lie in water depths too shallow (less than 20 m) for efficient utilization of submersibles. No interest was expressed for a habitat as their research efforts could be conducted using surface ship techniques and divers.

Three programs were identified that could potentially utilize a submersible and only one of these programs included prior submersible experience. The others have not, due to the lack of funds or the absence of a vehicle capability at the desired time and location. The desire to study the physical, biological, and chemical effects of dredge materials and spoil disposal was viewed within the COE as having a very remote potential for submersible utilization; however, investigator interest in one COE division was high. The Arctic Ice Scoring Project of the Cold Regions Research and Engineering Laboratory indicated a strong desire for under-ice submersible operations. Lack of funding and vehicle capability for under-ice operations were stated as the reasons for the absence of submersible activities in past and presently foreseeable years.

The program summary responses have been grouped by department or agency and are presented in Table 1. This table includes summaries from both reported and potential programs.

UTILIZATION AND STATUS OF RESEARCH SUBMERSIBLES AND HABITATS

U.S. Utilization Trends and Status, FY 1977 and 1978

Submersibles

In FY 1977, civilian submersibles (see Figure 3) were utilized a total of 676 dive days. These dive days represent

	Fisheries	Geology	Biology	Pollution	RDT&E	General Oceanography	Oil Activity Research	Inspection	Coral Harvest	Recreation/Education	Total	Percent
Dept. of Commerce (NOAA)	18	6	5			4					33	38
Dept. of Energy	1			1	3						5	6
Dept. of Health, Education and Welfare					1						1	1
Dept. of Interior	2	9	3		1	1	6	3	1	1	27	31
Dept. of Transportation (Coast Guard)								1			1	1
Environmental Protection Agency	1			5		1	3				10	12
National Atmospheric and Space Administration				1							1	1
Smithsonian Institution		1	5								6	7
U.S. Army Corps of Engineers				2	1						3	3
Total	22	16	13	8	7	6	9	4	1	1	87	
Percent	25	19	15	9	8	7	10	5	1	1		100

Table 1—Reported and Potential Programs: Department and Category

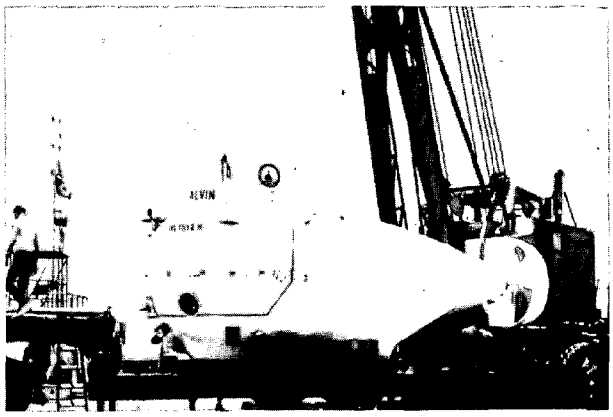


Figure 3.—Deep Sea Research Submersible *Alvin*

a total of 899 dives. In FY 1978, civilian submersibles were utilized a total of 510 dive days, representing a total of 915 dives. Groupings of dive days per type of mission are shown in Figure 4. For comparison, dive-day activities for FY 1976 are also shown.

The FY 1976 report used tabulations generated by giving a full dive or dive day to the proper mission category. In order to make the totals equal for all the tables and figures, the partial dive-day technique was adopted for the 1977 and 1978 data. The FY 1976 data for dive days was also reorganized and tabulated according to this scheme for ease of comparison between FY 1976, 1977, and 1978 data sets. Also, in cases where a dive was listed for two purposes (for example, geology and biology), each mission category was increased by one half dive and one half dive day. Data used to prepare Figure 4 are detailed by submersible and mission category in Tables 2 and 3.

An exact comparison between totals of dives and dive days from year to year could be misleading because each deep ocean dive generally requires one dive day while in shallow areas several dives could be made in a day. Thus the statistics are project-oriented, and the important relationship between successive sets of annual data are those trends reflected by mission category statistics. Submersible utilization trends between FY 1976, FY 1977, and FY 1978 are illustrated by percentages of sets of mission categories as shown in Table 4.

In Table 4, "Basic Research" includes dives made for research in biology, geology, fisheries, and pollution; "Commercial" includes oil industry, salvage, inspection, and coral harvest/survey operations.

These figures indicate an increase in the number of commercial or industrially oriented submersible diving operations during FY 1977. A similar trend is indicated by the tabulation of submersible activity funding sources (Table 5) which, when compared to FY 1976, shows an increase in private submersible activity funding from 28 to 55 percent and a decrease in government, academic, and foundation funding sources (per dive day) from 76 to 45 percent during the period. Some of the percentage

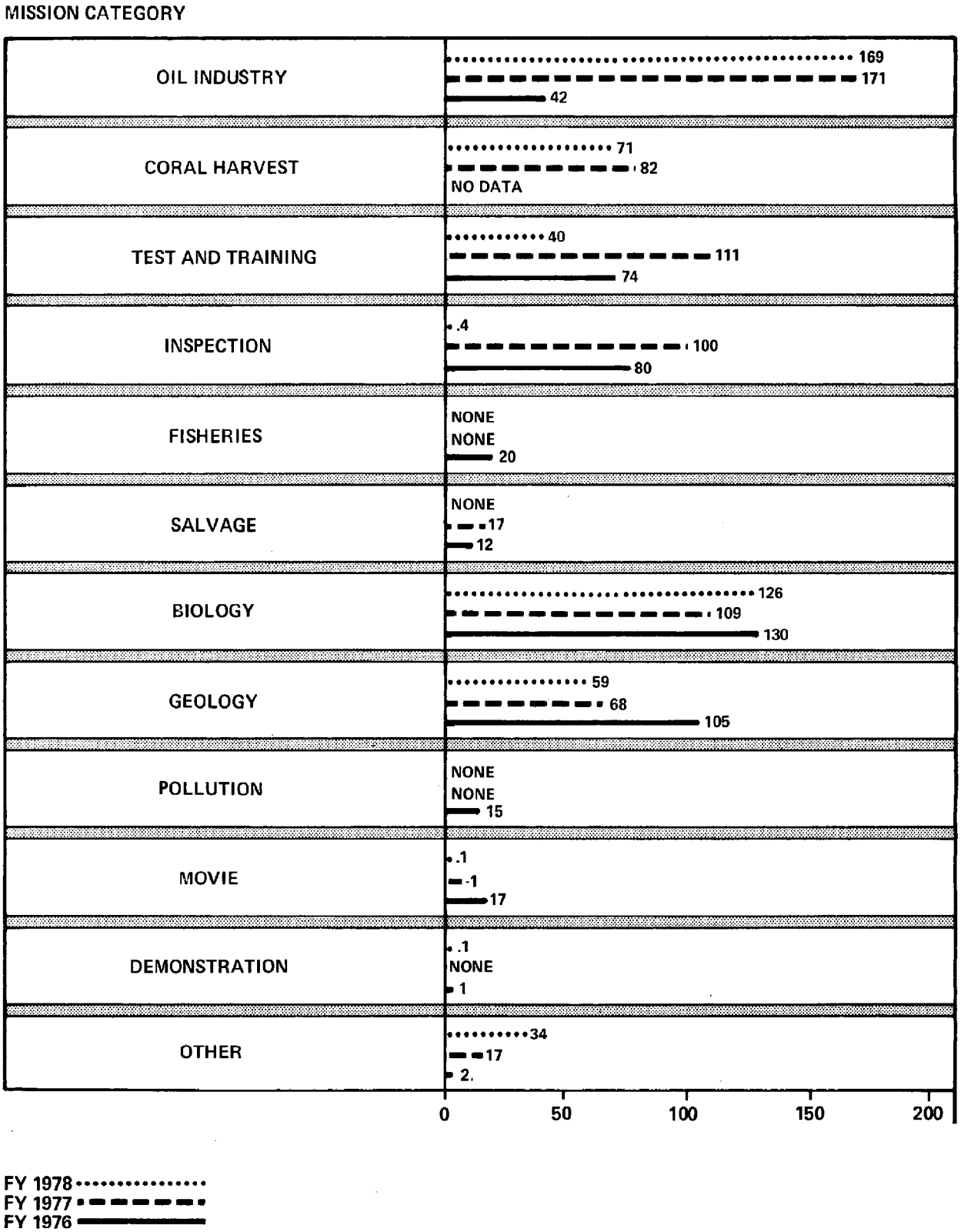


Figure 4.—U.S. Civilian Submersible Utilization by Number of Dives, FY 1976-1978.

Table 2—U.S. Civilian Submersible Mission Categories, FY 1977

	Alvin	*Aquarius**	*Deep Quest*	*Diaphus*	*Johnson-Sea-Link I*	*Johnson-Sea-Link II*	*Mermaid II*	*Nekton Alpha*	*Nekton Beta*	*Nekton Gamma*	*Neos I*	*PC-14-C-2*	*Sea Explorer*	*Snooper*	*Star II*	*Taurus**	Totals	Total Percentage of Dive Activities
Oil Industry		142 115						23 15		40 41							205 171	23 25
Coral Harvest															82 82		82 82	9 12
Test & Training	9 9		3 3		24 18	10 7	27 8	5 1	3 2		9 3					54 60	144 111	16 16
Inspection	6 4				28 17	20 14			5 2		12 5	38 35		62 23			171 100	19 15
Fisheries																		
Salvage									38 17								38 17	4 3
Biology	40 40			20 11	14 5	90 53											164 109	18 6
Geology	62 61			14 7													76 68	8 10
Pollution																		
Cable Bury																		
Movie														2 1			2 1	1 0
Demonstration																		
Other						17 17											17 17	2 3
Total Dives	117	142	3	34	66	120	44	28	46	40	21	38	0	64	87	54	899	100
Total Dive Days	114	115	3	18	40	74	25	16	21	41	8	35	0	24	82	60	676	100

*Canadian submersibles working in U.S. waters.

00 Dives (upper numbers)
00 Dive Days (lower numbers)

Table 3—U.S. Civilian Submersible Mission Categories, FY 1978

	Alvin	*Arms I*	*Deep Quest*	*Diaphus*	*Johnson-Sea-Link I*	*Johnson-Sea-Link II*	*Nekton Alpha*	*Nekton Beta*	*Nekton Gamma*	*Neos I*	*Snooper*	*Star II*	Totals	Total Percentage of Dive Activities
Oil Industry		13 12		25 25			110 62	117 66			13 4		278 169	30 33
Coral Harvest/Survey								14 4				72 67	86 71	9 13
Test & Training	2 2	2 2	2 2		37 13	7 5		59 11	3 2	5 3			117 40	12 7
Inspection											9 4		9 4	0 0
Fisheries														
Salvage														
Biology	9 9			45 16	88 40	73 40			63 21				278 126	30 24
Geology	29 29			43 25		11 5							83 59	9 11
Pollution	5 5												5 5	0 0
Movie		1 1											1 1	0 0
Demonstration				2 1									2 1	0 0
Other	5 5	3 3			19 10	18 10			4 1	7 5			56 34	6 6
Total Dives	50	19	2	115	144	109	110	190	70	12	22	72	915	100
Total Dive-days	50	18	2	67	63	60	62	81	24	8	8	67	510	100

00 Dives (upper numbers)
00 Dive Days (lower numbers)

Table 4—Percent of Total Dive Days (Major Categories)

Category	FY 1976	FY 1977	FY 1978
Basic Research	54%	26%	43%
Commercial Operations	27%	55%	46%
Test & Training	15%	16%	7%

increase in private submersible diving activity is due to a decrease of about 30 percent in nonprivate funding. This is reflected at the Federal level, which showed a decrease in funding of from 32 to 22 percent of dive days from FY 1976 to FY 1977. During the same period dive day funding increased in the private sector by nearly 100 percent.

The figures in Table 4 also indicate a decrease in the number of commercial or industrially oriented submersible diving operations during FY 1978. A similar trend is indicated by the tabulation of FY 1977 submersible activity funding sources (Table 6) which, when compared to FY 1976, shows a decrease in private submersible activity funding from 55 to 51 percent and an increase in government, academic, and foundation funding sources (per dive day) from 26 to 49 percent during the period. The percentage increase in Federal submersible diving activity is due to MUS&T's diving program of 1978; this program was not conducted in FY 1977.

Table 5—Submersible Utilization Funding Sources, FY 1977

Submersible	Federal		Foundation		State		Academic		Private	
	Dives	Dive Days	Dives	Dive Days	Dives	Dive Days	Dives	Dive Days	Dives	Dive Days
Alvin	117	114								
Aquarius									142	115
Deep Quest									3	3
Diaphus							34	18		
Johnson-Sea-Link I			66	40						
Johnson-Sea-Link II			120	74						
Mermaid II					17	17			27	8
Nekton Alpha									28	16
Nekton Beta									46	21
Nekton Gamma									40	41
Neos I									21	8
PC-14-C-2	38	35								
Sea Explorer										
Snooper									64	24
Star II									82	82
**Taurus*									54	60
Totals	155	149	186	114	17	17	34	18	507	378
Percent	17	22	21	17	2	3	4	3	56	55

*Canadian submersibles working in U.S. projects.

Table 6—Submersible Utilization Funding Sources, FY 1978

Submersible	Federal		Foundation		Private	
	Dives	Dive Days	Dives	Dive Days	Dives	Dive Days
Alvin	50	50				
Arms I					19	18
Deep Quest	2	2				
Diaphus	88	41			27	26
Johnson-Sea-Link I			144	63		
Johnson-Sea-Link II			109	60		
Nekton Alpha					110	62
Nekton Beta					190	81
Nekton Gamma	63	21			7	3
Neos I	12	8				
Snooper					22	8
Star II					72	67
Totals	215	122	253	123	447	265
Percent	23	24	27	25	48	51

Detailed activities of 14 U.S. submersibles whose dive programs have been reported for the time period October 1976 to September 1977 are listed in Table 7. Two Canadian submersibles, *Aquarius* and *Taurus*, which were utilized for U.S. projects or in U.S. waters, have also been included in the table. Of the 899 dives logged in FY 1977, 63 were lockout dives; all were performed by the Harbor Branch Foundation in *Johnson-Sea-Link I* and *Johnson-Sea-Link II*. Maximum lockout depth was 91.7 m. The private sector provided the main funding source (55 percent) in terms of dive days for FY 1976. Next was the Federal government, with 22 percent, foundations (Harbor Branch) with 17 percent, and State and academic at 3 percent each.

Detailed activities of 12 U.S. submersibles whose dive programs have been reported for the time period October

Table 7—Activities of U.S. Submersibles, FY 1977

Submersible	Date (Month, Day, Year)	Mission	Location of Mission	Total Number of Dives	Number of Days Diving	Depth (Meters)
Alvin	8/13/76–8/20/76	Biology	Offshore Mid-Atlantic States	6	6	3,650
	8/30/76	Test	Woods Hole, MA	1	1	15
	11/30/76	Test	Woods Hole, MA	1	1	2
	12/16/76	Test	Andros Harbor	1	1	20
	12/17/76–12/21/76	Test/Training Photo/Insp	Bahamas	5	5	2,086
	1/3/77	Training	Autec Harbor	1	1	30
	1/4/77–1/11/77	Biology	Bahamas	7	7	3,663
	1/12/77	Biology	Toto	1	1	2,133
	1/16/77–2/3/77	Geology/Insp	Caribbean	12	9	3,661
	2/17/77–3/19/77	Geology	W. Coast S. America	24	24	2,763
	4/7/77–4/13/77	Geology	Caribbean Sea	6	6	3,676
	4/25/77–6/1/77	Geology/Biology	Bahamas	22	22	3,638
	6/12/77–9/28/77	Geology/Biology	Offshore Mid-Atlantic States	30	30	3,648
Deep Quest	12/76	Precertification Test Dives	San Diego, CA	2	2	89/700
	1/77	Precertification Test Dives	San Diego, CA	1	1	1,549
Diaphus	2/77	Biological—near oil rigs	Tanner Bank, CA	7	3	100
	9/77	Biological/Geological Physical	N.W. Gulf of Mexico	27	15	200
Johnson-Sea-Link I	11/76	Pilot Training	Ft. Pierce, FL	9	9	9-70
	12/76	Science, Algae	W. Palm Beach, FL	14	5	30-120
	1/77	Science, Reconnaissance	Ft. Pierce, FL	1	1	20
	6/77	Training, Checkout	Ft. Pierce, FL	1	1	8
	7/77	Science, Training	W. Palm Beach, FL	5	4	30-70
	7/77	Training, Lockout	Ft. Pierce, FL	7	3	10-12
	7/77	Science, Support	Monitor Marine Sanctuary, NC	3	2	70
	8/77	Science, Support	Monitor Marine Sanctuary, NC	2	2	70
	8/77	Science, Transects	Sebastian, FL	11	7	60-300
	8/77	Tests, Evaluation	Ft. Pierce, FL	2	1	30-300
	9/77	Science	W. Palm Beach, FL	11	5	35-100
Johnson-Sea-Link II	10/76	Algae	W. Palm Beach, FL	17	10	30-134
	11/76	Invertebrates	Ft. Pierce, FL	2	2	45-120
	1/77	Science, Current meters	Ft. Pierce, FL	3	2	40-131
	1/77	Science, Reconnaissance	Ft. Pierce, FL	2	2	24-90
	1/77	Science, Meter trees	Ft. Pierce, FL	5	3	38-135
	2/77	Benthic Ecology	Ft. Pierce, FL	6	6	36-82
	2/77	Icthyology	Ft. Pierce, FL	3	2	82
	3/77	Macro plankton	Grand Bahama Island	7	4	305
	3/77	Training, Algae	W. Palm Beach, FL	3	2	5-41
	3/77	Benthic Ecology	Ft. Pierce, FL	4	3	24-80
	4/77	Invertebrates	Ft. Pierce, FL	5	3	81
	5/77	Algae	W. Palm Beach, FL	9	4	38-88
	5/77	Benthic Ecology	Ft. Pierce, FL	4	4	40-110
	5/77	Macro Plankton	Abaco Island, Bahamas	9	4	305

Table 7—Activities of U.S. Submersibles, FY 1977—Continued

Submersible	Date Month, Day, Year	Mission	Location of Mission	Total Number of Dives	Number of Days Diving	Depth (Meters)
	6/77	Tethyology	Ft. Pierce, FL	18	8	26-79
	6/77	Invertebrates	Ft. Pierce, FL	6	3	28-79
	7/77	Photogrametry	Monitor Marine Sanctuary, NC	10	7	67
	7/77	Tests and Evaluation	Ft. Pierce, FL	4	2	35
	8/77	Test Evaluation Training	Ft. Pierce, FL	3	3	27
Mermaid II	5/76	Pilot Training	Long Island Sound	12	3	32
	5/76–6/76	Body Search	Round Valley Reservoir, NJ	17	17	70
	7/76	Pilot Training	Long Island Sound	15	5	45
Nekton Alpha	10/76	Platform work for Exxon	Santa Barbara, CA	7	7	252
	12/76	Sonar Test	San Diego, CA	5	1	280
	6/77	Pipeline survey	Gulf of Mexico	16	8	109
Nekton Beta	3/77	Trim and Sonar Test	Santa Barbara, CA	3	2	9
	4/77	Recover BOP stack	Santa Barbara, CA	31	13	162
	5/77	Dam Inspection	Oroville, CA	5	2	41
	7/77	Base Removal	San Diego, CA	7	4	212
Nekton Gamma	10/76	Pipeline Inspection	Gulf of Mexico	3	3	110
	6/77	Exxon Platform	Santa Barbara, CA	2	1	69
	7/77	Pipeline Inspection	Gulf of Mexico	35	37	88
Neos I	11/4/76	Photographic/ Observation	Newburyport, MA	3	1	0-30
	4/6/77	Pilot Qualification	Boston, MA	4	1	0-30
	4/15/77	Pilot Qualification	Boston, MA	5	2	0-70
	5/18/77	Photographic/ Sampling	Boston, MA	3	1	20-40
	5/27/77	Photographic	Boston, MA	1	1	20
	8/10/77	New Instrumentation Tests	Boston, MA	2	1	30
	9/18/77	Piling Inpection (visual)	Boston, MA	3	1	15-20
PC-14-C-2	10/1/76–9/30/77	Search, Inspection, Observations	Marshall Island	38	35	50-60
Sea Explorer		No Dives				
Snooper	12/76–9/77	Outfall Inspection, Bouy Inspection	Palos Verdes, CA	19	8	67
	6/77	Outfall Inspection	Avalon, CA	2	1	84
	1/77–2/77	Sonar Array Inspection	Palos Verdes, CA	9	2	106
	7/77	T.V. Series	Catalina, CA	2	1	7.5
	7/77–8/77	Pipeline Inspection, T.V. and Electronic	Santa Barbara, CA	32	12	68
Aquarius	11/76	Pipeline Inspection	Morgan City, LA	15	10	65
	1/77	Pipeline Inspection	Morgan City, LA	19	15	65
	5/77–9/77	Pipeline Inspection	Port Arthur, TX	108	90	125
Taurus	5/77–7/77	Dry Transfer Trials	Catalina Island	54	60	350

Table 7—Activities of U.S. Submersibles, FY 1977—Continued

Submersible	Date Month, Day, Year	Mission	Location of Mission	Total Number of Dives	Number of Days Diving	Depth (Meters)
Star II	10/76	Coral Harvest	Hawaii	2	2	400
	11/76	Coral Harvest	Hawaii	8	8	400
	12/76	Coral Harvest	Hawaii	7	7	400
	1/77	Coral Harvest	Hawaii	11	11	400
	2/77	Coral Harvest	Hawaii	9	9	400
	3/77	Coral Harvest	Hawaii	2	2	400
	4/77	Coral Harvest	Hawaii	5	5	400
	5/77	Coral Harvest	Hawaii	7	7	400
	6/77	Coral Harvest	Hawaii	12	12	400
	7/77	Coral Harvest	Hawaii	7	7	400
	8/77	Coral Harvest	Hawaii	9	9	400
	9/77	Coral Harvest	Hawaii	3	3	400

1977 to September 1978 are listed in Table 8. The two Canadian submersibles, *Aquarius* and *Taurus*, which were utilized for U.S. projects or in U.S. waters in FY 1977, have not been included in FY 1978 data. The private sector provided the main funding source (45 percent) in terms of dive days for FY 1977 and 1978. The Federal government and the Harbor Branch Foundation both contributed 27 percent to the total.

Fixed Habitats

Two fixed habitats are known to be operational: *Helgoland* (Federal Republic of West Germany) and NOAA's *Hydro-Lab*. A third habitat, *Aegir* (U. of Hawaii), is reportedly capable of operating within short notice. A fourth, *La Chalupa,* was used for research off Puerto Rico, but is now inactive in Florida. A fifth habitat, *Tektite*, was last used at St. John, U.S. Virgin Islands, in 1970 and is presently being refurbished for operation off the coast of California. All these units are towed or transported to the dive site and lowered to the bottom, where they remain immobile until the specific operation is over. The occupants live at ambient pressure for the duration of the dive and can exit and enter at their discretion. All work tools and instruments are carried in or on the habitat. If additional supplies are required, they can be obtained from the surface support facilities. Electrical power is derived from the surface, as are additional life support supplies and components. Observations can be made of the surrounding environment through viewports, and limited laboratory experiments can be conducted within the habitat confines. Briefly, the capabilities of the four habitats listed above are shown in Table 9.

The fixed habitat offers long-term, continuous, in-situ observation and experimentation. Similar to the lockout submersible, it can deploy the best manipulation system to date: the human being. Limitations are found in its virtual lack of mobility, limited depth, and the extensive transport/support facilities required for deployment and maintenance. The *Hydro-Lab* approach simplifies many the above problems, but lack of mobility and limited depth are severe obstacles.

Remotely Operated Vehicles

In concert with the growing presence of remotely operated vehicles (ROV's) in offshore oil and natural gas operations, a survey of U.S. civilian ROV operators was made to ascertain the utilization of these vehicles during the FY 1978 period (see Figure 6). In FY 1978, civilian ROV's were utilized a total of 2,007 dive days. Total number of dives was not attainable, since ROV operators do not normally keep such records.

U.S. civilian operators of ROV's during FY 1978 are shown in Table 10. The 11 operators listed represent a total of 27 ROV's of varying depth and performance capabilities. Table 11 lists the activities of three operators (the Harbor Branch Foundation's CORD underwent sea trials and tests during this period); the remaining operators elected not to respond to queries.

All civilian utilization of ROV's in FY 1978 in the United States was funded by private industry. Offshore oil and gas exploration is the primary use of ROV's. The civil segment of the federal government has not utilized this burgeoning capability in any of its scientific or research programs. Relative to manned submersibles, remotely operated vehicles are experiencing an unprecedented surge in offshore utilization. Their work involves observation and video tape documentation. The impact of ROV utilization appears to fall most heavily on one-atmosphere (non-diver lockout) manned submersibles and the ambient pressure diving community.

Facility Status

The status of the three general types of facilities discussed in the preceding pages—manned submersibles, habitats, and remotely operated vehicles—is shown in Tables 12 and 13 for FY 1977 and FY 1978, respectively. The status of current U.S. submersibles as of mid-1978 is shown in Table 14.

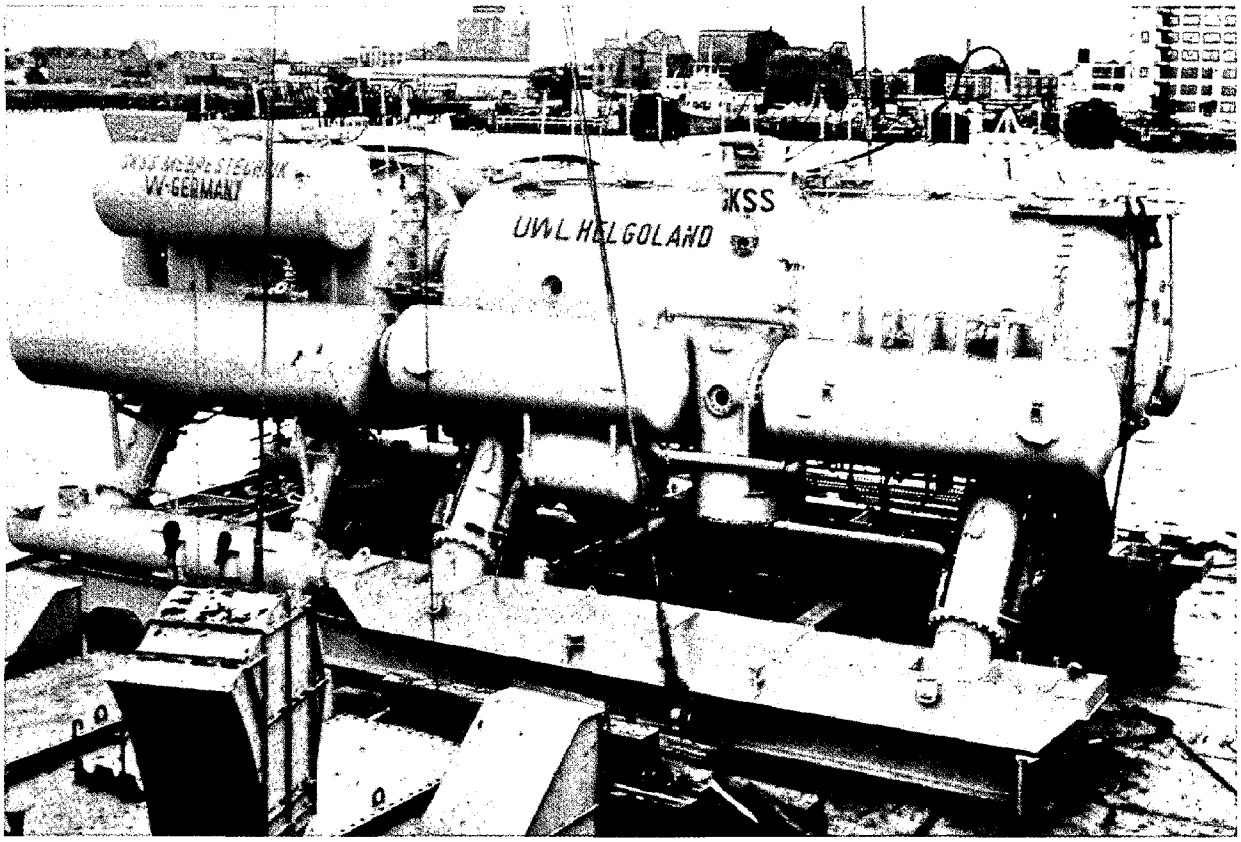


Figure 5.—West German Habitat GKSS *Helgoland*

Table 8—Activities of U.S. Submersibles, FY 1978

Submersible	Date Month, Day, Year	Mission	Location of Mission	Total Number of Dives	Number of Days Diving	Depth (Meters)
Alvin	10/3/77	Test	Woods Hole, MA	1	1	4
	5/2/78	Test	Woods Hole, MA	1	1	2
	5/16/78–5/22/78	Certification	Bahamas	5	5	4,007
	5/29/78–6/13/78	Geology	Offshore Mid-Atlantic States	10	10	2,334
	6/23/78–6/27/78	Radioactive Waste	Offshore Mid-Atlantic States	5	5	3,983
	6/29/78	Biology	Offshore Mid-Atlantic States	1	1	3,635
	7/30/78–8/26/78	Geology/ Geophysics	Mid-Atlantic Ridge	15	15	2,670
	9/17/78–9/30/78	Biology	Offshore Mid-Atlantic States	8	8	3,635
	10/28/78	Geology	Northern Bahamas	1	1	1,433
	10/31/78–11/2/78	Geology	Florida Straits	3	3	961
Arms I	7/23/78–7/26/78	Test	Halifax, N.S.	2	2	No data
	7/31/78	Photography	Halifax, N.S.	1	1	24
	8/1/78	Certification	Halifax, N.S.	1	1	No data
	8/2/78, 8/3/78	Certification	Offshore Halifax, N.S.	2	2	866
	8/11/78–9/11/78	Drilling Support		13	12	547
Deep Quest	9/20/78–9/23/78	Fuel Cell Test	Offshore San Diego	2	2	186

Table 8—Activities of U.S. Submersibles, FY 1978—Continued

Submersible	Date Month, Day, Year	Mission	Location of Mission	Total Number of Dives	Number of Days Diving	Depth (Meters)
Diaphus	9/77–5/78	Inspection	Gulf of Mexico	25	25	366
	6/18/78	Demonstration	Gulf of Maine	2	1	99
	6/20/78–6/30/78	Biology	Gulf of Maine	27	10	58
	7/9/78–7/14/78	Biology/Geology	Wilmington Canyon	7	4	338
	7/15/78	Biology/Geology	Baltimore Canyon	3	1	366
	7/16/78–7/17/78	Biology/Geology	Washington Canyon	4	2	366
	7/18/78	Biology/Geology	Wilmington Canyon	1	1	274
	7/30/78–8/7/78	Geological	Northeast Atlantic	24	9	366
	8/15/78–8/19/78	Geology/Biology	Georgia Bight	22	5	180
Johnson-Sea-Link I	3/78	Test	Ft. Pierce, FL	2	1	20-177
	4/78	Training	Grand Bahama Island	19	6	10-30
	5/78	Training/Plankton Studies	Grand Bahama Island	33	12	20-333
	6/78	Algae Collection/ Radiation Meas.	Grand Bahama Island	24	10	15-110
	7/78	Current Study/Coral Growth	Ft. Pierce, FL	14	10	75-200
	8/78	Biology	Bahamas/Florida	40	16	30-333
	9/78	Biology	Ft. Pierce, FL	12	8	100
Johnson-Sea-Link II	10/77	Radiation/Biology/ Training	Bahama Islands	28	15	20-333
	11/77	Biology	Ft. Pierce, FL	14	8	30-110
	12/77	Biology	Bahama Islands	13	7	333
	1/78	Biology	Ft. Pierce, FL	4	3	27-83
	2/78	Biology	Ft. Pierce, FL/ Bahama Islands	14	7	77-333
	3/78	Radiation/Biology	Bahama Islands	18	9	333
	4/78	Biology/Geology	W. Palm Beach & Sebastian, FL	23	9	30-110
	9/78	Radiation	Bahama Islands	2	1	333
Nekton Alpha	10/77-6/78	Pipeline Inspection	Morgan City, LA	110	62	107
Nekton Beta	12/77	Pipeline Route Survey	Bahamas	7	4	305
	3/78	Training	San Diego, CA	55	10	71
	3/78	Coral Survey	San Diego, CA	12	3	293
	4/78	Coral Survey	San Diego, CA	2	1	107
	5/78	Certification/Test	San Diego, CA	4	1	305
Nekton Gamma	7/78	Certification/Testing	San Diego, CA	3	2	293
	7/78–8/78	Biology	Southeast AL	63	21	305
	8/78	Environmental	Boca de Quadra, AL	4	1	168
Neos I	8/3/78–8/9/78	Test	Boston, MA	4	2	15
	8/27/78–8/31/78	Equipment Monitoring	Lake Winnepesaukee, NH	7	5	15
	9/12/78	Test	Boston, MA	1	1	12
Snooper	10/77	Pipeline Inspection	Santa Barbara Channel, CA	5	2	57
	12/77	Bottom Sampling	Catalina, CA	8	2	91
	4/78–9/78	Outfall Inspection	Palos Verde Peninsula	9	4	67
Star II	10/77–9/78	Coral Harvest	Makopuu Pt., Hawaii	72	67	366

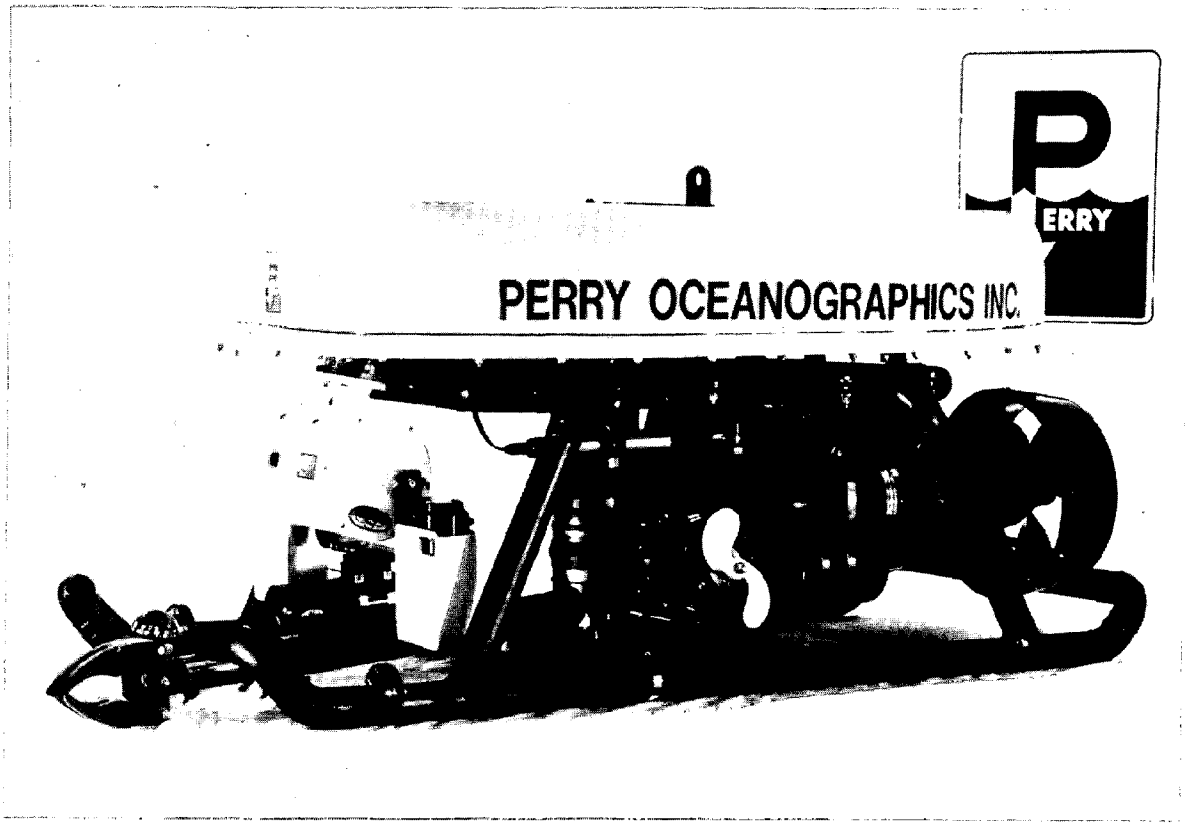


Figure 6.—Remotely Operated Vehicle (ROV) (Courtesy of Perry Oceanographics)

Table 9—Fixed Habitat Capabilities

Habitat	Depth	Divers	Weight (dry tons)	Max Mission Duration (days)*	Status
Aegir	180.5 m (550 ft)	6	224	14	Inactive, last used in 1971
Helgoland	328 m (100 ft)	4	110	14	Operational, Baltic Sea
Hydro-Lab	164 m (50 ft)	3-4	60	7	Operational, St. Croix, V.I.
La Chalupa	328 m (100 ft)	5	133	14	Inactive, last used in 1975
Tektite	328 m (100 ft)	4-5	70	60	Inactive, since 1970

*Without replenishment.

Table 10—U.S. Civilian Remotely Operated Vehicle Operators, FY 1978

Operator	Vehicle	Depth (ft/m)	Builder	Status
Ametek Straza El Cajon, CA	*Scorpio*	3,000/914	Same as Operator	Operational
AT&T Longlines Bedminster, NY	*Scarab I & II*	6,000/1,829	Ametek Straza El Cajon, CA	Trials
Harbor Branch Fnd. Ft. Pierce, FL	*Cord*	1,500/457	Same as Operator	Trials
J. Ray McDermott Co. Harvey, LA	*Trov S-3*	1,200/366	International Submarine Engineering Ltd. (ISE), Port Moody, BC	Operational
Kraft Tank Co. Kansas City, MO	*EV-1*	1,500/457	Same as Operator	Trials
Martech International Houston, TX	*RCV-225* (3 ea)	6,600/2,012*	Hydro Products San Diego, CA	Operational
	Trec (4 ea)	1,200/366	ISE, Ltd. Port Moody, BC	Operational
Oceaneering International Santa Barbara, CA	*RCV-225*	6,600/2,012	Hydro Products San Diego, CA	Operational
	Orca	6,000/1,820	Saab-Scania Linkoping, Sweden	Operational
Rebikoff Underwater Products Ft. Lauderdale, FL	*Sea Inspector* (2 ea)	3,280/1,000	Same as Operator	Operational
Remote Ocean Systems San Diego, CA	*Telesub-1000*	2,000/610	Same as Operator	Operational
Solus Ocean Systems Int. Houston, TX	*Trec*	1,200/366	ISE, Ltd. Port Moody, BC	Operational
	Trov S-4	3,000/914	ISE, Ltd. Port Moody, BC	Operational
Taylor Diving and Salvage Co. Belle Chasse, LA	*RCV-225* (7 ea)	6,600/2,012	Hydro Products San Diego, CA	Operational

*Operational depth of the RCV-225 is as stated, however, as of October 1978 no RCV-225 had been sold with a cable longer than 1,312 ft (400 m).

Table 11—Activities of U.S. Remotely Operated Vehicles, FY 1978

Operator	ROV	Date Month/Day/Year	Mission	Location of Mission	Number of Diving Days	Max. Depth (Meters)
Martech International	*RCV-225* (2ea)	10/77–11/77	Inspection	Gulf of Mexico		61-152
	RCV-225 (2ea)	12/77–9/78	Inspection	Offshore Brazil		61-152
	RCV-225	3/78–9/78	Inspection	Gulf of Mexico	1,220*	61-152
	Trec	4/78–9/78	Inspection	Gulf of Mexico		61-152
	Trec (2ea)	5/78–9/78	Inspection	Gulf of Mexico		61-152
	Trec	6/78–9/78	Inspection	Gulf of Mexico		61-152
Rebikoff Underwater Products	*Sea Inspector* (DR 330-2)	1/77–9/78	Training	Ft. Lauderdale, FL	16	50
	Sea Inspector (DR 330-3)	8/77–9/78	Training/ Demonstration	Cannes, France	6	70
Taylor Diving and Salvage	*RCV-225* (#3)	11/77	Inspection	Gulf of Mexico	2	116
	RCV-225 (#3)	1/78–3/78	Inspection	North Sea	60	320
	RCV-225 (#3)	6/78–9/78	Monitoring	North Sea	94	156
	RCV-225 (#4)	5/78–9/78	Monitoring	Tasman Sea	150	140
	RCV-225 (#5)	4/78–9/78	Monitoring	Gulf of Mexico	153	314
	RCV-225 (#6)	6/78–9/78	Monitoring	Gulf of Mexico	84	314
	RCV-225 (#7)	7/78–9/78	Inspection	North Sea	67	152
	RCV-225 (#9)	10/77	Inspection	Gulf of Mexico	9	314
	RCV-225 (#10)	12/77–5/78	Monitoring	Tasman Sea	146	140

*This is the cumulative number of dive days for all Martech vehicles over the 12 month period.

Table 12—Facility Status*, FY 1977

	Operational	Construction	Inactive	Refit	Design
Manned Submersibles:					
1-ATM Untethered	33	4	6	2	
1-ATM Tethered	3		1		
1-ATM Bell	4	2	2		
Lockout Untethered	13	2		1	
Lockout Tethered	2				
ADS Self-powered	20		1		1
ADS Powered	2				
Habitats:					
Fixed	2		1		
Mobile	1		2		4
Remotely Operated Vehicles:					
Tethered, free swimming	47	6			
Tethered, bottom crawling	3				
Untethered, free swimming		1	3		1
Towed	4		1		

*Not including military systems or USSR systems.

Table 13—Facility Status*, FY 1978

	Operational	Construction	Inactive	Refit	Design
Manned Submersibles:					
1-atm Untethered	33	4	7	2	
1-atm Tethered	3		1		
1-atm Bell	4	2	2		
Lockout Untethered	13	2		1	
Lockout Tethered	2				
ADS Self-powered	20		1		1
ADS Powered	2				
Habitats:					
Fixed	2		1		
Mobile	1		2		4
Remotely Operated Vehicles:					
Tethered, free swimming	47	6			
Tethered, bottom crawling	14	1	3		
Untethered, free swimming	3	4	1		1
Towed	15		1	1	

*Not including military systems or USSR systems.

Table 14—Status of Contemporary U.S. Manned Submersibles

Name	Depth (ft/m)	Builder	Operator	Status
Alvin	12,000/3,658	Litton Ind. Minneapolis, MN	WHOI Woods Hole, MA	Operational
*Arms**	3,000/914	Oceaneering Int. Houston, TX	Oceaneering Int. Houston, TX	Operational
Beaver†	2,700/823	North American Rockwell Seal Beach, CA	Unt. Underwater Contr. City Island, NY	Refit
Deep Quest	8,000/2,438	Lockheed Missile & Space Sunnyvale, CA	Lockheed Ocn. Lab. San Diego, CA	Operational
Deep View	1,500/457	NUC San Diego, CA	Southwest Res. Inst. San Antonio, TX	Inactive
Diaphus	1,200/366	Perry Sub. Bldrs. Riviera Beach, FL	Martech International Houston, TX	Operational
Dowb	4,500/1,372	General Motors Santa Barbara, CA	Southwest Res. Inst. San Antonio, TX	Inactive
DSRV 1 & 2 (Mystic & Avalon)	5,000/1,524	Lockheed Missiles & Space Sunnyvale, CA	U.S. Navy San Diego, CA	Operational
*Curry**	1,000/305	Sun Shipbuilding & Dry Dock, Chester, PA	Sun Shipbuilding & Dry Dock, Chester, PA	Inactive
Johnson-Sea-Link I & II	1,000/305	Harbor Branch Foundation Ft. Pierce, FL	Harbor Branch Foundation Ft. Pierce, FL	Operational
Mermaid II	1,200/366	Bruker-Physik AG Karlsruhe, West Germany	Int. Underwater Contr. City Island, NY	Operational
Nekton A, B, C	1,000/305	General Oceanographics San Diego, CA	General Oceanographics San Diego, CA	Operational
Nemo	1,000/305	Naval Civil Eng. Lab. Port Hueneme, CA	Southwest Res. Inst. San Antonio, TX	Inactive
Neos	150/46	New England Ocean Services Boston, MA	New England Ocean Services Boston, MA	Operational
NR-1	NA	General Dynamics Groton, CT	U.S. Navy	Operational
*Opsub**	1,000/305	Perry Sub. Bldrs. Riviera Beach, FL	Ocean Systems Reston, VA	Inactive
PC-14 C-2	600/183	Perry Sub. Bldrs. Riviera Beach, FL	Kentron, Kawaii Huntsville, AL	Operational
PRV-2†	1,000/305	Pierce Submersibles Bayshore, NY	Seahawk Oceanics Inc. Arlington, TX	Inactive
Sea Cliff	6,500/1,981	General Dynamics Groton, CT	U.S. Navy San Diego, CA	Operational
Sea Explorer	600/183	Sea-Line, Inc. Brier, WA	Sea-Line, Inc. Brier, WA	Inactive
Sea Ranger	600/183	Verne Engineering, Inc. Fraser, MI	Verne Engineering, Inc. Houston, TX	Inactive
Snooper	1,000/305	Undersea Graphics, Inc. Torrance, CA	Undersea Graphics, Inc. Torrance, CA	Operational
Star II	1,200/366	General Dynamics Groton, CT	Deepwater Explorations, Ltd. Honolulu, Hawaii	Operational
Trieste II	20,000/6,096	U.S. Navy	U.S. Navy San Diego, CA	Operational
Turtle	6,500/1,981	General Dynamics Groton, CT	U.S. Navy San Diego, CA	Operational

*Tethered
†Lockout

Summary

There is a wide range of existing U.S. facilities (platforms) capable of use in underwater research. However, because of costs, commitment to commercial use, or unsuitability, most of these facilities have not been available for use by scientists working in the oceans.

The undersea facilities available can be conveniently categorized as follows:

a. Manned Submersibles
   (1) 1-atm submersibles, with depth capability varying from 200 to 3658 m (46 in all; 510 dive days in United States in 1978).
   (2) 1-atm tethered submersibles (three, nonactive).
   (3) 1-atm tethered bell systems, with crew of two, viewing, manipulation, etc.
   (4) Diver lockout submersibles, with depth and lockout capability up to 914 m (3000 ft), (16).
b. Remotely Operated Vehicles
   (1) Tethered swimming vehicles, of size varying from 68 kg (150 lb) to 5 tons, depth capability generally in 610-915 m (2000-3000 ft) range, or deeper, cost $150,000 to $1.2 million (at least 120).
   (2) Bottom crawlers, wheeled or tracked (18).
   (3) Towed vehicles, towed at various speeds, generally 1 to 1½ knots, at deep depths, up to 6000 m (19 in all).
c. Habitats
   (1) Fixed habitats (six, but only two—*Hydro-Lab* and the German *Helgoland*—operational).
d. Diving Systems
   (1) 1-atm diving systems (e.g., JIM), self-powered, tethered; depth 437 m (1442 ft).

Available to scientists, in general, are:

(1) *Hydro-Lab*
(2) *Alvin*
(3) Small submersibles on lease (e.g., *Nekton, Star II*). Many (such as *Aluminaut, Deep Star*) are laid up.
(4) To a limited extent only, Navy research submersibles, e.g., *Sea Cliff* and *Turtle*.
(5) The lockout submersibles *Johnson-Sea-Link I* and *II* are used for scientific purposes by the Harbor Branch Foundation, but are not generally available to the scientific community. They have, however, been used on a cooperative basis by NOAA in studies of underwater physics research and marine science.

OCEANLAB PROGRAM

In the fall of 1975, NOAA conducted some of the first extended underwater research off the coast of New England using the German habitat *Helgoland.* This research was part of an international effort to determine ecological factors effecting survival of the North Atlantic herring.* Congressional interest in this as well as in Project SCORE, conducted earlier that year in the Bahamas using the Perry Foundation habitat *Hydro-Lab,* led to support for Oceanlab Program initiative. This program's objective is to provide the technology needed to improve the effectiveness of manned underwater investigations for ocean science. A basic premise is that diving, whether by scientists or skilled workers, is essential to making progress toward a full understanding and proper utilization of the oceans—to provide the first-hand knowledge of the sea impossible to acquire through conventional techniques.

Workshops and detailed surveys were conducted nationally of prospective user groups and organizations. These groups included the scientific and academic community, commercial industrial groups, and recreational groups. With the cooperation of the NOAA Sea Grant Office, user workshops were conducted and potential missions and preliminary operating requirements with system characteristics were identified.

During Phase I—preliminary system design, cost, and schedule study—lasting from September 1976 to March 1977, the information obtained from the earlier workshops and surveys was used to develop performance requirements and characteristics as well as mission classes with their respective objectives and needs. Preliminary trade-off analyses and technical evaluations resulted in three recommended systems: autonomous submersible, carried system, and towed habitat, each acting as an underwater laboratory.

With the Phase I results available, NOAA, through the Department of Commerce, held a competitive procurement for Phase II, "System Program Definition." However, prior to this Phase II effort in September 1977, NOAA decided to interact further with the user community on user requirements and unique needs. This included leaders in the oceanographic science community and various laboratories and groups within NOAA. NOAA's Environmental Data and Information Service (EDIS) also provided meteorological and oceanographic data on potential operational sites for Oceanlab to be used in developing operational system constraints.

All this additional information and data were made available to the Phase II contractor and published in a summary mission analysis report.† With the Phase I results, the contractor began the development of system performance requirements and system technical specifications. The most viable systems from Phase I were evaluated and conceptual systems designs made for each.

*This international marine science program was named Project FISSHH: First International Saturation Study of Herring and Hydroacoustics, and it is discussed in detail in the Fiscal Year 1976 MUS&T Annual Report.

†General Electric Document No. 775DR2291-Oceanlab, Phase II System Program Definition, Mission Analyses, Department of Commerce Contract 7-35252; Revision B, 24 February 1978.

The Charles Stark Draper Laboratories (CSDL) provided technical support with the system design areas and the user mission-related work.

In December 1977, the contract efforts were directed to reevaluate and update the Phase I study in response to congressional and Department of Commerce queries.

Based on surveys made by NOAA and CSDL on scientific user requirements, scale models of the Oceanlab laboratory facilities were made and minimum laboratory size and configuration requirements identified, and a baseline laboratory developed. Optimum system configurations were developed and compared, one being a surface-support independent autonomous submersible and the other a surface-supported undersea mobile habitat.

Using these improved configurations, detailed comparative cost analysis and mission effectiveness studies were done with respect to the various capabilities and design parameters.* In July 1978 NOAA began a review of the entire Oceanlab Program. As a result of this review, it was decided that NOAA should continue a program of development and use of various technological means for supporting undersea research.

In order to provide for the widest scientific community interest and use, it was decided not to implement a single undersea system, but instead to support and stimulate "man-in-the-sea" technology for ocean research. The program was redirected in September 1978 to include:

- Continuing examination of manned undersea facility requirements with close interactions with the science community.
- Analyses of existing U.S. undersea facilities and systems.
- Developments of requirements for advanced-capability systems and technologies.
- Expansion of NOAA's cooperative underwater laboratory program on a regional basis using a number of different systems.

These items will comprise a 2-year effort resulting in the identification of undersea technological program areas requiring new capabilities and facilities. From here, either existing systems can be modified and updated or new ones implemented to meet the scientific requirements.

Cooperative National Manned Underwater Laboratory Regional Program

In the House of Representatives Appropriations Committee report of May 1977, which discussed the FY 1978 appropriation of $3,750,000 to NOAA for the continuation of the Oceanlab Project, it was stated that the funds were also to be used for "cooperative habitat programs." The corresponding Senate report of June 1977 stated that the funds were also for "cooperative undersea programs, including habitats in shallow and intermediate depths necessary to develop safety and expertise in future Oceanlab operations."

Therefore, NOAA initiated a cooperative national manned underwater laboratory regional program in 1977. The purpose of this program is to provide manned underwater facilities and research support to investigations of U.S. coastal marine environmental, biological, geological, and ecological problems. Initial program emphasis is on the provision of sea-floor laboratories and the advanced technology needed for safe science saturation diving operations.

The overall goals of the programs include:

1. Acquire basic scientific information about the marine ecology and environment applicable to conditions existing in U.S. coastal areas.
2. Provide solutions to marine environmental problems through the support of research efforts requiring advanced underwater laboratories and saturation diving operations.
3. Demonstrate that safe manned underwater operations can greatly enhance researchers' ability to successfully complete selected types of tasks, and that certain classical land-based laboratory scientific methods can successfully be extended to the sea floor.
4. Provide a mechanism to ensure continuity of effort and long-range funding for otherwise unfeasible in-situ research efforts.
5. Provide the training and facilities to develop a cadre of scientific personnel proficient in the use of underwater laboratory systems and advanced underwater research techniques.

Hydro-Lab Regional Program

The first phase of the cooperative regional programs took place in St. Croix, U.S. Virgin Islands, using the former *Hydro-Lab* as the first undersea habitat facility.

In 1977 NOAA purchased *Hydro-Lab* from its builder, Perry Oceanographics, Inc. After a thorough refurbishing, it was placed on the ocean floor at St. Croix, U.S. Virgin Islands, off the north central coast as the head of Salt River submarine canyon (Figure 7).

Hydro-Lab, 4.88 m (16 ft) long and 2.44 m (8 ft) in diameter, sits on the ocean floor and is equipped (in its refurbished state) to support four divers for as long as 14 days. Its key advantages over surface-supported diving and other research techniques are:

- Its fixed location allows for laying out a permanent grid of study areas, an especially important factor in statistical analyses of population densities.
- Less time and energy are wasted in surfacing and diving during limited research time.

*The final results were published under Department of Commerce Contract No. 7-35252, Oceanlab Comparative Concept, Cost and Effectiveness Studies of Alternate Oceanlab Systems, 31 July 1978, based on General Electric Document No. 78SDR2243 dated 30 June 1978.

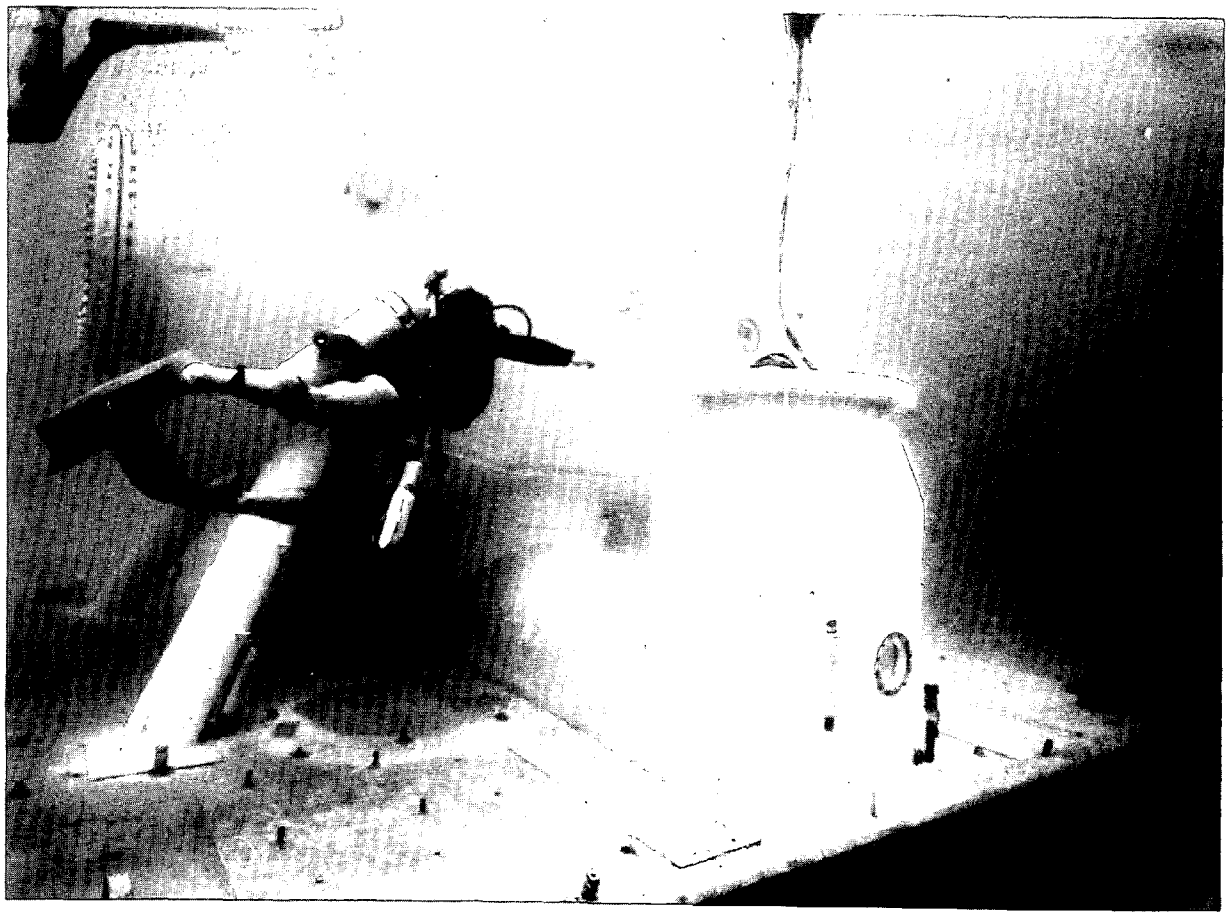


Figure 7.—*Hydro-Lab* on Ocean Bottom off St. Croix, U.S. Virgin Islands

The specific goals of the *Hydro-Lab* system program are to:

- Acquire, via in-situ study, scientific information about the marine environment of U.S. coastal and tropical marine environments.
- Provide a national underwater facility for preliminary and advanced training of marine scientists in underwater research techniques and saturation diving.
- Develop new and improved underwater scientific research and engineering techniques, oceanographic instrumentation, and diving equipment.
- Provide a facility for the open-sea test and evaluation of underwater biomedical and diving procedures tested in shore-base hyperbaric laboratories.

The MUS&T Office is responsible for overall management of the *Hydro-Lab* program. These responsibilities include:

- Final review and approval of all safety and operational aspects of the program.
- Coordination and integration of the scientific program.

Fairleigh Dickinson University's (FDU) West Indies Laboratory (WIL), acting under NOAA Grant No. 04-8-1401-6, is responsible for the operation and maintenance of the underwater laboratory system and associated shore support facilities as well as the development of safety and operating procedures to meet NOAA requirements.

A discussion of the science mission projects accomplished using *Hydro-Lab* is given in the Marine Science Applications section of this report. Development of the second phase of the program began in April 1978 with the solicitation for "letters of interest," from over 400 academic institutions in a second regional cooperative manned undersea research program. Fifteen responses were received which in turn were evaluated by a screening group. Nine were selected as viable candidates and were asked to develop detailed feasibility studies. These final feasibility studies will be completed in FY 1979. They will in turn be evaluated by a panel of scientists and engineers experienced in undersea marine research. Further development of the next regional cooperative underwater research programs is planned to begin in FY 1980.

OPERATIONAL EFFECTIVENESS AND SAFETY

NOAA DIVING PROGRAM

Administrative Structure

During FY 1977 and 1978 the NOAA Diving Program has been managed, from a policy standpoint, by the Associate Administrator for Research and Development and the Director of the Office of Ocean Engineering (OOE) through the Director and Deputy Director of MUS&T. The management of the diving safety, training, and certification program is the responsibility of the NOAA Diving Coordinator and his assistants.

The Diving Coordinator is responsible for the training, safety, and certification of all NOAA divers and for working closely with the NOAA Diving Safety Board and NOAA Diving Medical Review Board, which develop and oversee training and operational policies, medical qualifications, and reporting requirements.

The NOAA Diving Safety Board is the policy-formulating body in the administrative structure. Its recommendations, based on reviews of operating policies, training needs, and operational procedures, shape the direction of the diving program as it continually changes and expands to meet NOAA's diving needs.

The NOAA Diving Medical Review Board, established by a NOAA Directive on March 8, 1974, is responsible for reviewing the medical qualifications of NOAA divers and diver candidates. The Board is made up of experts in hyperbaric and occupational medicine. As new knowledge of diving physiology is gained, the Medical Review Board assesses this knowledge to update diving medical evaluation criteria.

Diving operations in NOAA are carried out to support the missions of NOAA's Major Line Components (MLC's) and Main Program Elements (MPE's). Each of NOAA's three MPE's that actively use diving as an operational tool have an MPE Diving Officer who represents the MPE on the Diving Safety Board, and who interacts with the Diving Coordinator by planning, programming, directing, and reviewing the diving activities within the MPE to ensure compliance with overall NOAA policies on underwater operations.

The responsibility for the operation rests with the Unit Diving Office (UDO) within each of the MPE's individual units that have diving operations. The UDO has direct control of all individual diving operations. The use of the NOAA divers for NOAA missions, and the safety and operational efficiency of the dive, depend on the judgment and expertise of the UDO.

The administrative structure of the NOAA diving program is presented graphically in Figure 8.

NOAA Divers

NOAA divers are certified at one of three levels: trainee, limited, or unlimited. About one-half of NOAA divers are in either the NOAA Corps or the National Marine Fisheries Service (NMFS).

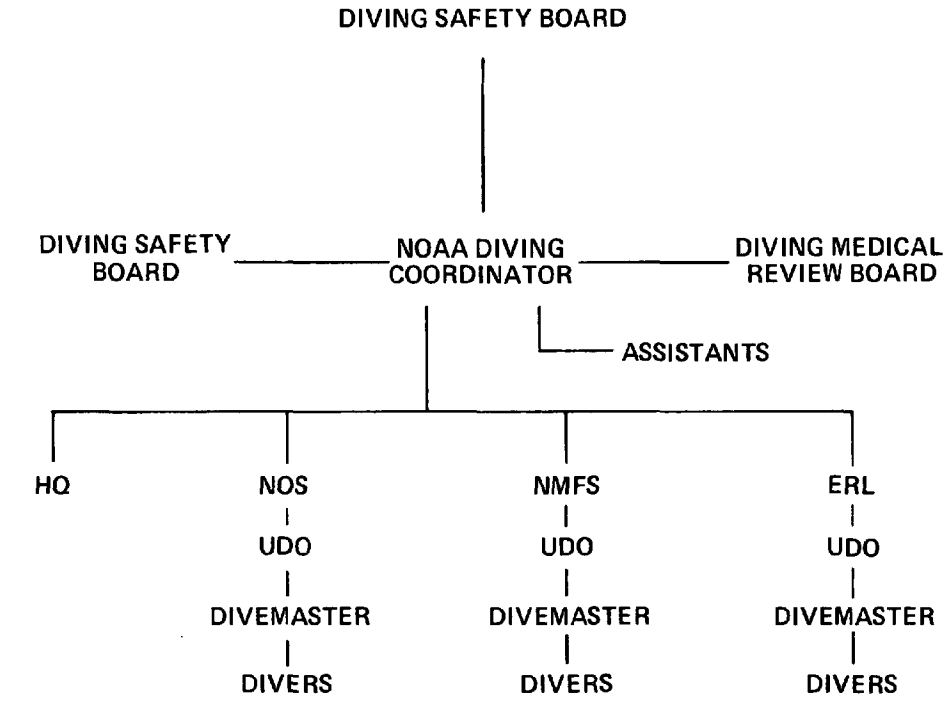
Most diving activities relate to resource ecology, fisheries management, coastal zone and estuarine studies, ecosystems investigations, environmental conservation and assessment, hydrographic and oceanographic surveying, and vessel and installation maintenance. NOAA divers also assist other Federal agencies such as the Coast Guard and National Transportation Safety Board in search, rescue, and recovery operations.

The majority of NOAA diving activities are in U.S. maritime areas, including Alaska, Hawaii, and the Great Lakes. Most NOAA fleet vessels have a complement of divers (officers or crew), and many National Marine Fisheries Service (NMFS) centers, laboratories, and field stations have resident divers. Diving is a collateral voluntary duty in NOAA, generally performed by qualified individuals whose primary occupation is enhanced by such duty. Since 1972 the number of certified divers in NOAA has grown from the approximate 100 absorbed from the Bureau of Commercial Fisheries to approximately 400, of which about 250 are considered an active diving resource pool.

Table 15 summarizes the myriad of activity in which NOAA divers are involved. Because the diving activities of OOE/MUS&T are significantly different from those of the other organizations, they are summarized separately in Table 16.

Tables 17, 18, and 19 present statistical data associated with NOAA diving for FY 1977 and 1978.

In addition to supporting ongoing NOAA missions, numerous advanced diving programs have been carried out for the purpose of improving our ability to operate effectively under the sea. Such operations have involved



LEGEND

UDO – UNIT DIVING OFFICER
NOS – NATIONAL OCEAN SURVEY
NMFS – NATIONAL MARINE FISHERIES SERVICE
ERL – ENVIRONMENTAL RESEARCH LABORATORIES
HQ – HEADQUARTERS

Figure 8.—Administrative Structure of NOAA Diving Program

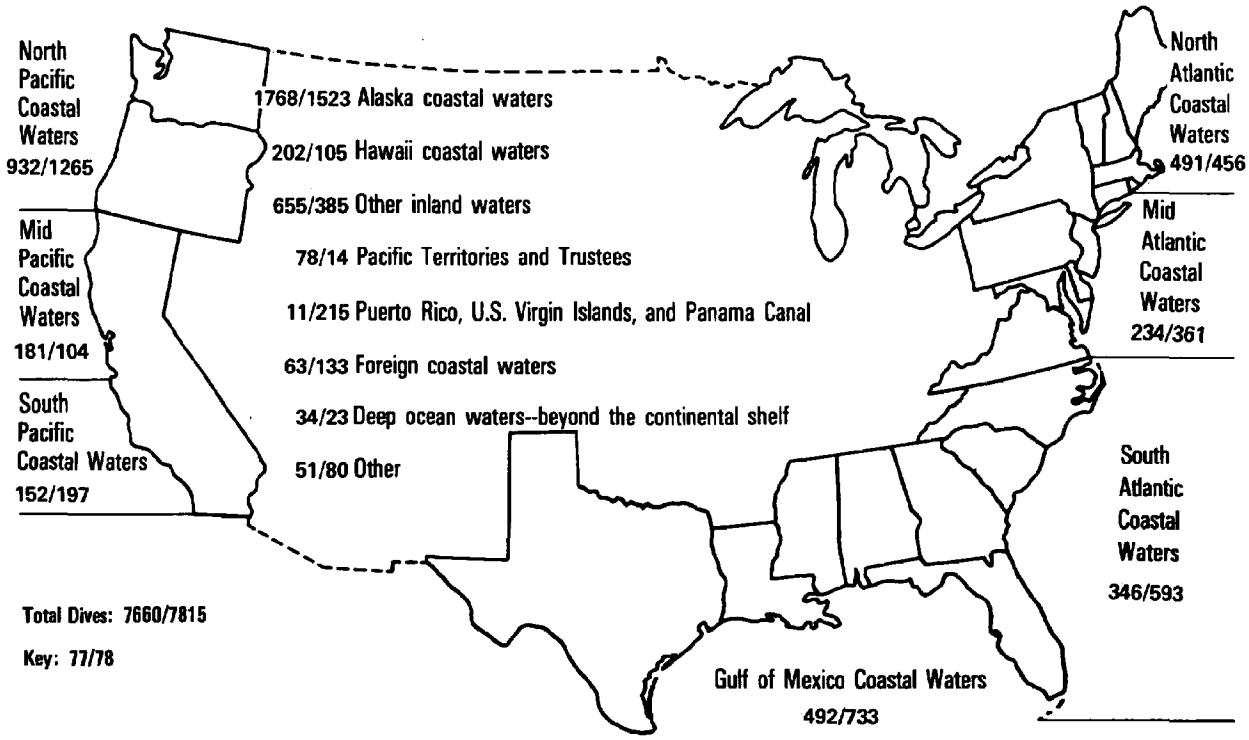


Figure 9.—NOAA Dives in U.S. and Foreign Waters, FY 1977 and 1978

underwater habitats, submersibles, support ships, and shore-based facilities. Geographical locations of NOAA diving activities are shown in Figure 9.

Diving programs in NOAA include:

- Diver training courses
- Recompression and training facilities
- Equipment acquisitions
- Physiology and medicine
- Diving technology
- Advanced diving operation
- Compilation, documentation, and dissemination of diving information

Many of these programs are described on the following pages.

Revision of *NOAA Diving Manual*

A special achievement of the NOAA Diving Program was the development and publication in 1975 of the *NOAA Diving Manual.* The manual is an authoritative reference for NOAA's scientists and working divers. It also has broad appeal for non-NOAA divers and has been accepted by the entire diving community. It contains basic information and data on applied diving technology, including that needed to carry out scientific investigations and the many other tasks of the working diver. During FY 1978 the first major revision of the *NOAA Diving Manual* began with publication planned before the end of calendar year 1979.

The manual provides NOAA and non-NOAA scientists and working divers with the latest advances in

Table 15—NOAA Diving Activities

Environmental Assessment	In-Situ Observation	Surveys
Assess reef damage by oil spill	Herring egg bed dynamics	Fisheries resource assessment
Observe marine flora and fauna around offshore oil platforms	Pray/ predator relationships between baitfish and tuna	Baitfish resources and concentrations
Effects of thermal discharge from power plants	Octopus den occupancy	Tridacnid clam survey and collection
Effects of nuclear testing on benthic communities	Long-term observation and studies using ocean-floor habitats	Pearl oyster surveys
Inshore marine effect of discharge from sugar mills, sewer outfalls, tuna canneries, and storm drains	Ground truth observations for aircraft and satellite overflights	Damage by "Crown of Thorns" starfish
Effects of filling, dredging, and construction	Search and delineation of submerged obstructions	Sample subtidal testing on benthic communities
Baseline data collection	Analysis of sediment flux by observing movement of dyed sand	Juvenile salmon behavior and net reaction
Baseline studies for proposed NOAA center at former Sandpoint Naval Air Station	Repeated observation of artificial reefs	Sediment and water sampling
Determine effects of clams and other resource development on fish migration and survival	Attraction of pelagic fish to artificial structures	Determining least depths for hydrography
Analyzing wrecks for damage to the marine environment by cargo		Wire drag operations
Study effects of changes in river ecology on salmonids		

Table 15—NOAA Diving Activities (Continued)

Equipment Installation and Retrieval	Equipment Evaluation	Vessel Inspection Maintenance and Repair
Fish trap emplacement	Observe midwater trawls using towed sleds	Clean propellors, viewing ports, sonar, sea strainers, etc.
Install, inspect, and service current and temperature sensors and tide gauges	Observe harvesting gear dynamics leading to new design concept	Monitor bottom paint and corrosion rates
Install cyclesonde and boundary experiments in New York Bight	Observe performance of electric shrimp trawl	Untangle nets and wire from propellors
Install plankton nets in reef and sea grass areas	Evaluate fishing nets and analyze fouling problems	Emergency repairs
Install, clean, and maintain salmon bypass systems at Washington and Oregon dams	Evaluate trap effectiveness	
Install and repair salt water pumps	Observe behavior of animals inside capture gear; i.e., King and Dungeness Crabs, flat and round fish, etc.	
Install instrument package for tsunami research	Capture and cage fish for acoustical studies	
Install anchors and docks and inspect deep-sea buoys	Monitor underwater pyranometer while underway	
Installation of underwater targets for aircraft and satellite sensing	Evaluation of hydroacoustic systems	
Interagency cooperation in search and recovery of items such as downed aircraft and sunken boats	Acoustic sensing of pelagic fish schools	
Search and recovery of lost gear	Experimental submerged salmon egg incubators	
	Test diving equipment	
	Photographic and communications	

Table 16—OOE/MUS&T Diving-Related Activities

Maintenance of records on each NOAA diver including: medical examination, training, certification, diving logs, waivers, and participation in special projects.
Arrangements for training of NOAA divers.
Preparation and distribution of a quarterly Technical Services Publication.
Maintenance of NOAA diving library.
Revision of NOAA Diving Manual.
Preparation of project operational plans.
Cooperation with other agencies toward the development of national standards and regulations related to diving.
Maintain liaison with other federal agencies and national diving organizations.
Represent NOAA on national and professional committees related to diving technology and diving physiology.
Direct participation in advanced diving programs involving ocean-floor laboratories and submersibles.
Development and open-sea testing of advanced diving technology.
Monitor diving fatality study at the University of Rhode Island.
Maintenance of MUS&T diving equipment.

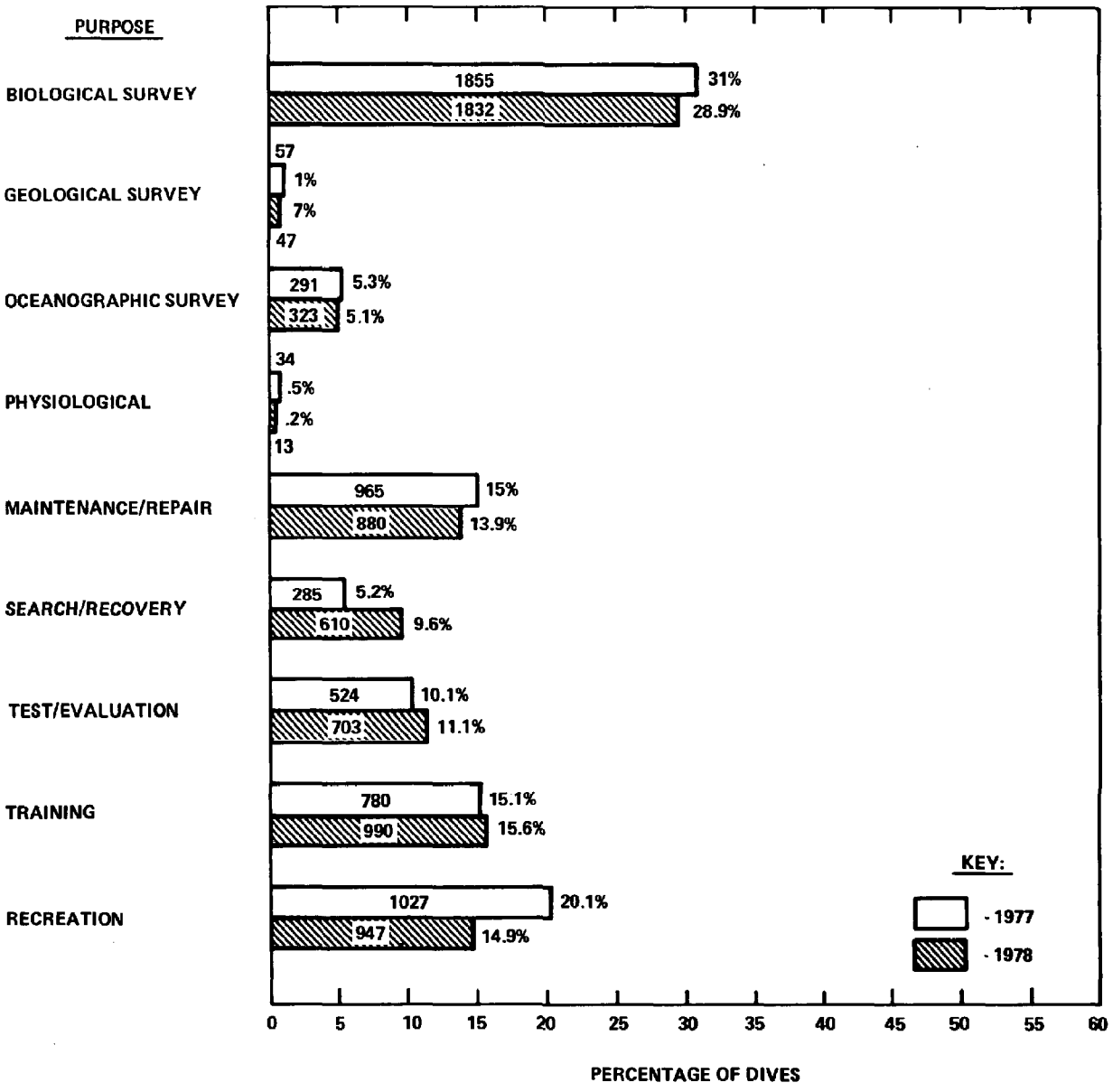
Table 17—Diving Activity by NMFS, NOS, and ERL (1977 and 1978)

Major Line Components	Dives and Bottom Time					
	Number of Dives		Percent of Total		Bottom Time (Hrs.)	
	1977	1978	1977	1978	1977	1978
NMFS	4073	3342	70%	57.6%	1657	1746
NOS	1571	2483	27%	38.8%	882	1183
ERL	175	223	3%	3.6%	134	95
Totals	5918	6058	—	—	2673	3024

Table 18—Depth Ranges of Dives

0–10 m (0–33 ft)		10–20 m (34–66 ft)		20–30 m (67–99 ft)		30 m or more (100 ft)	
1977	1978	1977	1978	1977	1978	1977	1978
45%	48.2%	37%	36.6%	14%	11.5%	4%	3.7%

Table 19—NOAA Diving by Purpose, FY 1977 and 1978



diving physiology, hyperbaric medicine, underwater scientific methodology, and information on newly developed equipment and operational techniques. It is used, with the *Navy Diving Manual*, as a reference in the OSHA Standard for Diving Operations, which is now Federal law for the diving industry. The manual is concerned mainly with shallow water diving[surface to 51 m (130 ft)].

The new manual, prepared and edited with the assistance of approximately 90 contributors throughout the diving community, is a major revision. Much new information has been added and the information contained in the first addition updated. A new chapter has been added on diving accident management. Changes also have been made in the saturation diving chapter based on additional experience gained during NOAA missions and recent research in diving medicine. Over 24,000 copies of the first edition have been sold, and a commercial edition is in its second printing. The manual currently is used as a standard text by many organizations and government agencies both in the United States and internationally.

Diving Program Computer Data Base

A recently implemented monthly update system has been established which allows the immediate retrieval and printout of current certification levels, diving physical due dates, qualifying dive requirements, and the physical location and number of active NOAA divers. This computer data base is vital to the effectiveness of the NOAA Diving Program, as divers are required to meet certification requirements by NOAA Directive in order to remain active NOAA divers. The location, certification level, and status of divers likewise is important when specific projects require diving support. The data base is being expanded to permit ready analysis of NOAA diving activities, including parameters such as type of dive, depth, duration, diving conditions, and location.

TRAINING AND SAFETY

Recompression Chamber Operator Course

The curriculum and maintenance of recompression chambers is a vital part of the NOAA diving program. In order to ensure that all NOAA personnel operating recompression chambers are properly trained and certified, the MUS&T office has initiated a series of courses for recompression chamber operators.

The curriculum for the training program is as follows:

- Introduction to recompression chambers
- Chamber setup and subsystems
- Recordkeeping
- Introduction to the physics of pressure
- Decompression theory and calculation of decompression tables
- Barotrauma
- Examination and handling of victims
- Emergency management of decompression sickness and air embolism
- Inside tending procedures
- Chamber medical kit contents
- Review of case histories
- Hands-on experience with simulated treatments
- Review of chamber operation procedures

The training courses, which are given to NOAA diving personnel and other divers working on NOAA missions, are held on an as-needed basis. The first of the week-long courses was held at Woods Hole in the winter of 1977. Subsequent courses have been conducted in Seattle (under contract to Virginia Mason Research Center) and in St. Croix, U.S. Virgin Islands. Because the requirement for recompression chambers is increasing, the training of chamber operators is taking an important place in NOAA's overall emergency handling capability.

Workshop on Scuba Lifesaving and Accident Management

NOAA and the Council for National Cooperation in Aquatics (CNCA) sponsored a workshop, held from November 27 to December 3, 1977, for the purpose of developing procedures for scuba lifesaving and accident management. This workshop was conducted at the National YMCA Center for Diving Activities in Key West, Florida, under the supervision of the Director, Robert W. Smith.

The Workshop dealt with the special problems associated with rescue and revival of personnel using self-contained compressed air in swimming pools or open water. The apparatus used by these underwater swimmers and the physiological aspects of compressed-air breathing present unique problems for would-be rescuers. The challenge extends beyond physical retrieval and resuscitation of the distressed diver to a myriad of additional activities including unique and sophisticated first aid procedures, as well as communications, transportation, and other factors associated with eventual recompression or other special emergency treatment.

The affected population for this project includes over 2 million persons engaged in scuba diving in the United States today, as well as lifeguards, other maritime personnel, and the general public, who may have the responsibility and/or opportunity to render lifesaving assistance to these individuals.

The need for guidance in this important area is great. The technology of rescue and accident management has been inadequately, and in some cases, inaccurately, documented in the available literature.

At the Workshop, experts presented information representing the latest on scuba lifesaving procedures and valuable new technology. Almost a dozen agencies in the United States and Canada with an interest in scuba lifesaving were represented.

The results of the Workshop were published as a manual of scuba lifesaving and accident management.* It also served as the basis for a new chapter on accident management in the revised edition of the NOAA Diving Manual.

Training of Physicians in Hyperbaric Medicine

In 1976 the Undersea Medical Society published a *National Plan for the Safety and Health of Divers in their Quest for Subsea Energy.*† The development of this plan was supported by the National Institute for Occupational Safety and Health (NIOSH) and NOAA. One of the recommended top-priority requirements identified in this plan was the need for additional physicians trained to treat diving casualties.

With financial support from the Department of Energy (DOE), NOAA developed a course in hyperbaric medicine in response to this need in 1976. Since that time, four hyperbaric medical training courses have been given:

1. February 21 to March 11, 1977
2. October 24 to November 18, 1977
3. September 11 to October 6, 1978
4. May 21 to June 9, 1979

The response has been extremely favorable from both the diving medical community in general and the attendees in particular. The first three courses were given in cooperation with the U.S. Naval School of Diving and Salvage, Washington D.C., where 3 of the 4 weeks were spent. The fourth week was at the NOAA diving facility in Miami, Florida. Thus far, about 42 physicians have been trained.

A fourth course was conducted entirely at the NOAA diving facility in Miami. NOAA now has three types of recompression chambers located there, which allow the physician students to gain wider experience in chamber operation.

This course is producing a nucleus of knowledgeable diving-oriented physicians who will be located near centers of diving activity. These physicians will be available to treat decompression sickness, diagnose causes and effect cures for diving accidents, and generally be involved with the overall health and safety of divers. The results of training for the initial group will determine the size and curriculum for future groups.

NOAA plans to continue this program, as the applications continue to exceed the number of students that can be accepted by a ratio of 4 to 1. It is anticipated that this level of interest will continue.

Free Ascent Training Workshop

The Free Ascent Training Workshop was sponsored by NOAA through the auspices of the Undersea Medical Society, and it took place December 10-11, 1977, in Bethesda, Maryland.

The purpose was to review the many factors involved in conducting free ascent training as part of scuba diving instruction. The basic question considered was whether the potential risks to a student diver exposed to free ascent training outweigh the benefits to be gained by practicing the proper procedures of a technique which one day might prevent a serious accident or death. The proceedings of the workshop are in preparation.

The workshop was chaired jointly by Ronald Samson, M.D. (U. of Maine School of Medicine) and James W. Miller, Deputy Director of MUS&T. It was attended by 33 persons representing the medical profession, diving training organizations, the academic community, and the Federal Government. In general, after 2 days of discussion it was concluded that there is no medical or statistical basis for discontinuing free ascent training that is carried out properly. Details of the proper procedures were discussed and will appear in proceedings of the meeting.

Commercial Diver Training Program at the Florida Institute of Technology (FIT)

An Underwater Technology Program was established in FY 1977 to assist in the development of the National Plan for the Safety and Health of Divers in Their Quest for Subsea Energy (referred to earlier). This effort is supported with reimbursable funds from the Department of Energy (DOE). The program director is Mr. James W. Woodberry of FIT.

The purposes of the Underwater Technology Program are to:

- Provide the diving industry with trained underwater technicians who have completed a 2-year Associate of Science degree in underwater technology
- Serve as a model program for other institutions
- Provide students with a high employment probability program

The Associate of Science degree in underwater technology was implemented as a joint venture between a small private university, industry, and government. FIT contributed technical expertise and equipment, and the Office of Sea Grant contributed technical information,

SLAM: Scuba Lifesaving and Accident Management, National YMCA Center for Underwater Activities, May 1978.

†Charles W. Shilling, *National Plan for the Safety and Health of Divers in their Quest for Subsea Energy,* Undersea Medical Society, Bethesda, MD, Jan. 1979

funds for additional personnel, facility modifications, and equipment. In spite of the initial help from these sources, the program was still deficient due to the lack of an adequate surface-supply diving platform. NOAA then provided funds to FIT for the conversion of a U.S. Navy-donated LCM6 into a suitable surface-supply diving vessel (Figure 10).

The LCM6 was transported to FIT from Virginia, refurbished, and converted to a surface-supply diving platform. A double lock chamber and four 42.5 m^3 (1500 ft^3) high-pressure air flasks were installed in the hold, and an upper deck was then welded in place. On this upper deck, four diver support consoles were added, two diesel-powered, low-pressure air compressors and their associated volume tanks. A flying bridge was built housing engine controls and steering gear. General crew quarters were also added.

In the present configuration, the LCM6 can carry a complement of sixteen students, four instructors, and two crew members. The vessel has the capacity to support four air or mixed-gas divers simultaneously, plus operate the recompression chamber with either primary or backup air and oxygen.

Complete field-type medical capacity, plus trained on-board emergency medical technicians (EMT's) (or equivalent), ensures that an accident casualty receives competent emergency care. The three-point mooring systems, overboard ladders, and hydraulic davits with diving stages were installed, the design thus permitting four methods of entering or leaving the water (two ladders and two stages). The LCM6 carries sufficient fuel for 24 hours constant cruise at 8 knots, and normally is at sea from dawn to dusk, 5 days per week.

To date, two classes have graduated (50 students), and positive feedback is being received on the quality of training of these students. The vessel has been, and will continue to be, one of the most important assets to the Associate of Science degree program in underwater technology conducted at FIT.

PHYSIOLOGY AND MEDICINE

High-Altitude Diving Tables

From June to September 1978 a series of experiments was conducted at the University of California-Davis, and Lake Tahoe, California, to test altitude no-compression limits calculated from extrapolation of the U.S. Navy safety criteria.

The principal investigator was Dr. Richard L. Bell, Chairman, Department of Chemical Engineering, UC-Davis.

The purpose of this program was to develop safe, effective procedures for diving at altitudes greater than sea level. A series of experiments was conducted at sea level and at an elevation of 1890 m (6200 ft). The dives were performed using a hyperbaric chamber and in open water. Physiological monitoring of the experimental subjects was conducted in all phases of the program. The output of this effort was a report containing diving profiles for use at altitude in tabular form based on the analysis of previously developed systems and the test data collected during this program.

The subjects were given a series of tests in the Human Performance Laboratory (University of California) to determine their state of fitness, body composition, maximum ventilatory capacity, heart rate, and other physiological variables. The purpose of these tests was to provide baseline data which would yield correlates in the event certain of the subjects experienced decompression sickness during the tests.

Each subject was required to complete the 12.2-, 21.4-, and 48.8-m (40-, 70-, and 160-ft) exposures under dry resting conditions in a hyperbaric chamber on the UC-Davis campus [elevation 19.5 m (65 ft)] before they were allowed to participate in the altitude exposures. The purpose of this was to determine which, if any, of the subjects were sufficiently susceptible to decompression sickness that they could not safely complete a standard U.S. Navy no-decompression schedule at sea level. All subjects completed the schedules at sea level without symptoms. The baseline studies were completed by July 22, 1978, and the laboratory was moved to Lake Tahoe [elevation 1,889.8 m (6,200 ft)].

A total of 168 exposures were completed. There were no cases of decompression sickness. No precordial bubbles were detected.

Based on these results, it appears that the safety criteria derived from the extrapolation of the U.S. Navy data provide no-decompression limits which are safe. Dr. Bell used the results of previous experiments and the results of these studies to prepare a new section on altitude diving for the revised edition of the *NOAA Diving Manual.*

NOAA Nitrox I

NOAA Nitrox I is a standard breathing gas mixture of 32 percent oxygen (± 1 percent); the balance of the gas (68

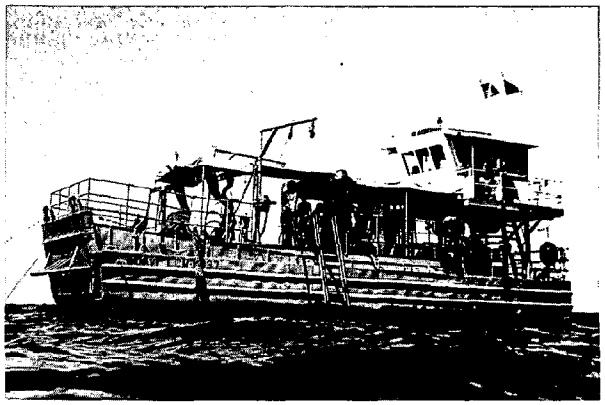


Figure 10.—Florida Institute of Technology Surface Support Vessel (Converted U.S. Navy LCM6)

percent) is nitrogen. Use of the gas mixture significantly increases the amount of time a diver can spend at depth without decompression, and it may be used in routine diving operations where it is advantageous. All oxygen partial pressure time combinations for use with this mixture are within the normal exposure limits of the U.S. Navy Oxygen Partial Pressure Limits Table.

Decompression tables and repetitive dive tables for a gas mixture of 32 percent oxygen/68 percent nitrogen were calculated, approved by the NOAA Diving Safety Board and NOAA Diving Medical Review Board, and tested in recompression chambers and in field experiments. It was used during September and October 1978 for a training program and in the Ocean Pulse Program (see "Marine Science Applications").

The following limitations have been placed on the use of NOAA Nitrox I:

- Both gases must be of breathing quality. NOAA Nitrox I gas may be used only in standard open-circuit breathing equipment. High-pressure storage cylinders, scuba tanks, and all high-pressure gas transfer equipment must be cleaned and maintained for oxygen service.
- The normal depth limit for use of this mixture shall be 39.6 m (130 ft) of seawater for dives that do not require decompression.

The NOAA Nitrox I diving tables have been included in the revised edition of the NOAA Diving Manual.

Operational Evaluation of Bubble Detectors

The level of nitrogen bubbles in the bloodstream in Nitrox I tests is determined by use of the Doppler ultrasonic monitor. The Doppler probe is placed on the left side of the diver's chest between the third and fourth ribs. The diver is instructed to go through a specific set of exercises and activities. As the number of nitrogen bubbles in the bloodstream increases, the "noise" level transmitted increases. Signals monitored by the investigators are recorded on a scale of zero to 4, along with heart rate and cardiac period (systolic or diastolic). These recordings are then analyzed in the laboratory, and comparisons of these signal rates are made between divers using air and those using Nitrox I.

Recorded gas bubble levels taken in the open sea appear to be higher than those taken in the diving chambers. This could be caused by the stress of open-water dives and post-dive activity on shipdeck. The investigators suggest that monitoring techniques can be improved and result in more accurate bubble-detector evaluation of Nitrox I.

Microbial Hazards Associated with Diving in Polluted Water

NOAA personnel, particularly divers, frequently are exposed to some degree of water pollution during the performance of their official duties. Of particular concern is pollution from bacterial and viral pathogens as a result of sewage disposal practices. In 1977 the MUS&T Office, in response to a NOAA field office inquiry, implemented a research project to study these concerns. The purpose of this project is to assess the health hazards to divers from polluted water and develop techniques which will minimize any inherent dangers associated with this type of occupational exposure.

The principal investigating institutions, in addition to NOAA, are the University of Maryland and the Naval Medical Research Institute. Other cooperating agencies in the program are the U.S. Coast Guard and the Veterans Administration.

During the first year, experimental protocols were established to maximize the use of personnel talents and laboratory capabilities. Two additional first-year milestones completed were the development of an appropriate epidemiological survey and design of special techniques for use in anaerobic pathogen studies.

Several sampling periods have been completed in both the New York Bight and the Anacostia River. Characterization of the microflora at both sites and their abundance and spatial distributions is nearing completion, with essentially only the seasonal fluctuations remaining to be quantified. A number of significant findings have already been obtained.

Anacostia River Site

Three strains of *Salmonella* were isolated and biochemically confirmed using API strips, which are rapid diagnostic tests for the identification of enteric bacteria. Two strains were isolated from a 250-ml volume of surface water. The third strain was isolated from 50 g of sediment.

Fecal coliform counts were close to or exceeded 1000/100 ml, a concentration indicating sufficiently high numbers to restrict contact/recreational activities in the water. Of great significance for human health considerations is the presence of *Vibrio cholerae* and *Aeromonas* species. The counts of *V. cholerae* were low. However, the recent outbreak of cholera in Louisiana makes it necessary to evaluate seriously the presence of this organism in water used for diver training.

During the course of this project, the investigators learned that a U.S. Navy diver developed an infection and tissue abscess as a result of a puncture wound obtained while operating in the Anacostia River. Cultures obtained from this diver identified the causative agents as *Aeromonas hydrophila* and *Aeromonas sobria*. These isolates are being tested for toxin production and mouse lethality. Similar organisms are penicillin-resistant and are often misdiagnosed.

Thus, the divers were obviously colonized with *Aeromonas*, at least transiently, following exposure to polluted water. The opportunity therefore exists for infection of sores or abrasions received by the divers.

The occurrence of the diver injury followed by infection

of the wound with *Aeromonas* poses a genuine health hazard.

New York Bight Apex

On April 28-29, 1978, a shakedown cruise was made in the New York Bight aboard the R/V *Johnson*. Due to inclement weather and mechanical problems, only surface water samples were collected; *Pseudomonas* and *Streptococcus* species were tentatively identified.

It is anticipated that the program will continue due to the nature of the findings, plus the fact that it is the only program currently underway in the U.S. designed to provide an inoculation and decontamination regime for divers operating in polluted waters.

DIVING TECHNOLOGY

Digital Decompression Computer

A digital decompression computer to be worn on a diver's wrist has been developed by the Naval Undersea Center's Hawaii Laboratory under a grant from NOAA (see Figure 11). The computer monitors the diver's depth and dive time and gives a continual display of decompression status. A prototype was demonstrated early in FY 1975.

The decompression computer (Decometer) comprises four principal electronic subsystems: a pressure transducer, an electronic "clock," a programmable read-only memory (PROM) storage, and a digital information display. The pressure transducer measures the diver's depth while the electronic clock monitors the diver's time. The two signals are used as inputs to the PROM, which is programmed with a mathematical model for inert gas absorption. The computer uses the time and depth inputs to calculate the diver's decompression status continuously, even in multidepth or repetitive dives not covered by the standard decompression tables. The readout on the computer consists of two digital light-emitting diode displays. One tells the diver the depth and the other the safe-ascent depth (the depth to which he can safely return without decompression). The unit can be converted for mixed gas diving using a PROM that is programmed for the gas mixture used.

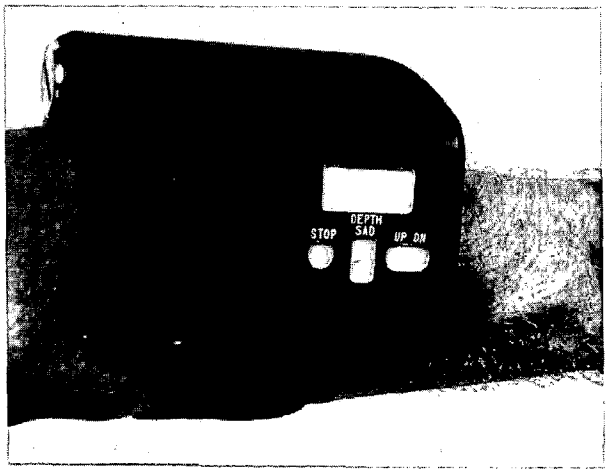


Figure 11.—Diving Decompression Meter (Decometer)

The computer can easily compute the gas absorption of seven different tissues, compared with present decompression meters that use three tissues for computation. These present meters work by measuring the pressure of the gas as it diffuses through a tissue-simulating membrane. They are subject to error, especially if poorly maintained or roughly handled. The wrist-worn digital decompression computer was demonstrated in October 1974 to the Navy's Experimental Diving Unit and to MUS&T. Several simulated decompression dives were found to match exactly the standard decompression tables. The unit also was used to run a simulated 3-day saturation mission, using excursions that were encountered during Project SCORE of the Bahama Banks Research Program in 1975.

The program was accelerated during FY 1977 after nearly a year of delays due to fabrication problems. The circuit boards have now been delivered; the fabrication problems have been attributed to the high-density configuration required and to changes resulting from design review (February 1977).

Two prototype diver decompression computers were completed and are now being programmed with data from NOAA-approved decompression schedules. Similar units are being produced for evaluation by the U.S. Navy Experimental Diving Unit with specific mission-oriented decompression schedules.

The Decometer was developed for a specific Navy mission, but also offers great potential for use in nitrogen-based saturation-excursion diving. It should substantially increase the effective working time of downward excursions by permitting the use of controlled ascent back to habitat depth (i.e., use of decompression stops). This method will facilitate access to the depth range extending to 76 m (250 ft), without the use of helium.

Several commercial diving companies have begun to use nitrogen and air saturation-excursion techniques; such operations could be significantly improved by real-time computation of inert gas absorption and elimination. This adaptation of the Decometer to saturation-excursion diving will yield an efficient and cost-effective tool for NOAA diving operations. Because of this additional application, a contract was awarded during FY 1978 to prepare a revised matrix appropriate for Decometer-controlled excursions from a nitrogen-oxygen-based habitat. The new matrix is a modification of the original NOAA matrix, based on diving experience that has become a available since the original NOAA OPS program.* The constraints are intended to be such that the Decometer can be used directly for excursions at

*See J.W. Miller (ed.), *Vertical Excursions Breathing Air from Nitrogen-Oxygen or Air Saturation Exposures*, NOAA, Rockville, MD, May 1976.

"face value" without the need for further conservatism factors. The work leading to Decometer suitable for habitat operations has continued through FY 1978 in a cooperative program involving the Naval Undersea Center at Hawaii and Hamilton Research, Ltd. Matrices are being developed, tested, and modified, and it is anticipated that a working system should be forthcoming within about 2 years.

The following tasks have been completed to date:

- Documentation Survey
- Mathematical Model Software
- Documentation (Completed Program)
- Incorporate NOAA Parametric Indices ("M" Values)*

The following tasks remain uncompleted:

- Documentation Package (projected completion June 1979)
- Production Package
- Maintenance and Operation Manual

Complete construction and preliminary testing of two excursion saturation diving Decometers (projected completion August 1979).

*The maximum value of the partial pressure of dissolved gas which can be tolerated in a specific compartment of the body and still permit the diver to ascend safely to the next stop.

Portable Inflatable Recompression Chamber (PIRC)

The portable inflatable recompression chamber (PIRC) provides on-site recompression of divers suffering from hyperbaric distress and allows patients to be transported to more complete medical facilities.

Cost, weight, and bulk have prevented their wider use by divers in difficult or remote diving locations. The Naval Undersea Center has built a prototype of a small, inexpensive, lightweight PIRC with support from NOAA.

The PIRC is a cylindrical body manufactured from a Kevlar fiber-rubber composite (see Figure 12). Kevlar is a new high-strength organic compound that has been used

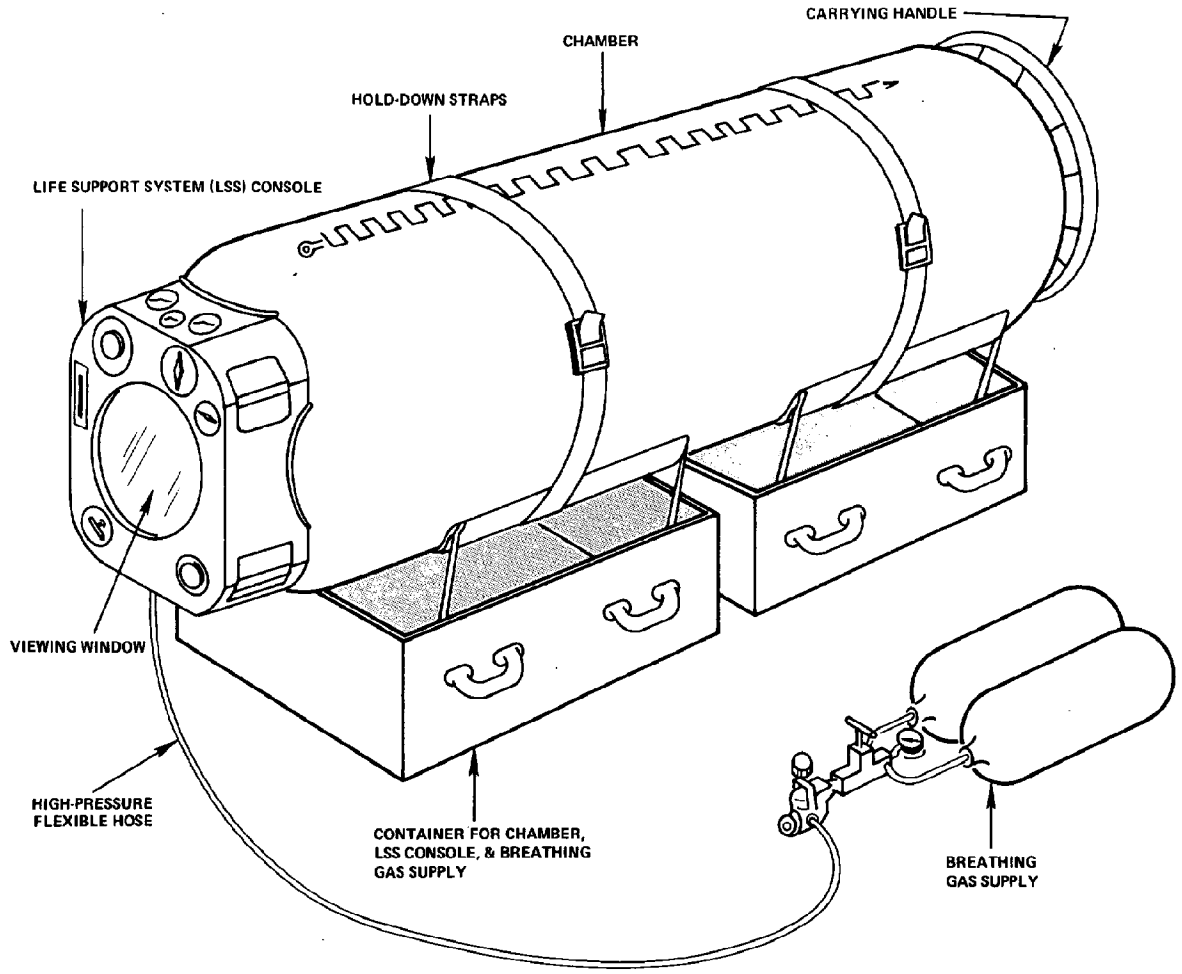


Figure 12.—Portable Inflatable Recompression Chamber (PIRC)

for cables and bulletproof vests. The door of the chamber is a specially designed leakproof "zipper." The chamber will withstand an internal pressure equivalent to 50.3 m (165 ft) of seawater. When inflated it is 76.2 cm (30 in) in diameter and 228.6 cm (90 in) long, which allows it to hold the patient and a medical attendant. The entire chamber can pass through standard double-lock recompression chamber doors so the patient can be transferred directly to a larger, more complete facility. When not in use, the chamber can be collapsed to fit into a 20 by 20-cm (36 by 8 by 8-in) carrying container. The chamber weighs about 23 kg (50 lb), and uses standard scuba tanks for its pressurization and life support. A high-efficiency recirculating device circulates the chamber air through a CO_2 scrubber, allowing a single 2.04-m^3 (72-ft^3) scuba tank to provide life support for about 1 hour.

The specifications are given in Table 20.

Table 20—PIRC Specifications

Manufacturer	B.F. Goodrich
Chamber Capacity	2 divers
Chamber Size	228.6 cm long x 76.2 cm (90 in x 30 in)
Chamber Weight	43 kg (95 lb)
System Weight	113.4 kg (250 lb)
Packaged Volume	0.57 m^3 (20 ft^3)
Chamber Material	Rubber-Covered Kevlar Cord
Design Depth, Operating	50.3 m (165 ft)
Zipper Opening	13.8 cm (54 in)
Viewport Size (2)	(10.75 ft^3) (Two 5000 psig composite alloy and fiberglass air bottles)
Oxygen Rebreather Capability:	
Chamber Leakage @ 18.29 m (60 ft) of Seawater	0.55 scfm*
Chamber Leakage @ 50 m (164 ft) of Seawater	0.45 scfm
CO_2 Scrubber Absorbent	Soda-Lime
CO_2 Scrubber Capacity [1.36 kg (3 lb)]	3 hr

*Standard cubic feet (of air) per minute ("standard" meaning at 1 atm pressure).

This lightweight, portable system can be easily deployed on demand. After a single use or the lapse of a predetermined period of time (1 to 2 years nonuse) it can be exchanged for a freshly packaged system. This method of packaging and single use should minimize failure of the system which might otherwise result from misuse and/or excessive environmental exposure.

Significant progress has been made by the Navy toward completion of the prototype system, including assembly of the life support system fabrication of twin lightweight air supply containers, preliminary design of a carrying container, and the completion of materials documentation and operations manual.

One-Atmosphere (JIM) Suit Evaluation

The one-atmosphere suit (JIM) is a system that permits an operator (usually but not necessarily a diver) to spend long periods of time underwater at depths up to 1500 feet with no increase in ambient pressure (see Figure 13).

The overall height of JIM is 1.98 m (6 ft 6 in), and its empty weight is 408 kg (910 lb) in air and approximately 498 kg (1100 lb) with an operator. In the water it has about 27 kg (60 lb) negative buoyancy, depending on the exact weight of the operator. Ballast weights, which are positionally adjustable, are mounted at the front and rear. The plexiglass ports afford excellent visibility.

The life support system for JIM consists of two independent systems which are designed to maintain a constant partial pressure of oxygen inside the suit. An oral-nasal mask (see Figure 14) is used for breathing. When the suit is sealed, the atmospheric pressure inside is equivalent to that at the surface. Oxygen is provided through a redundant system from a dual set of cylinders contained in a backpack, and the exhaled CO_2 is absorbed by soda-lime contained in a canister. The oxygen makeup system is automatic so that the internal pressure is always maintained at one atmosphere.

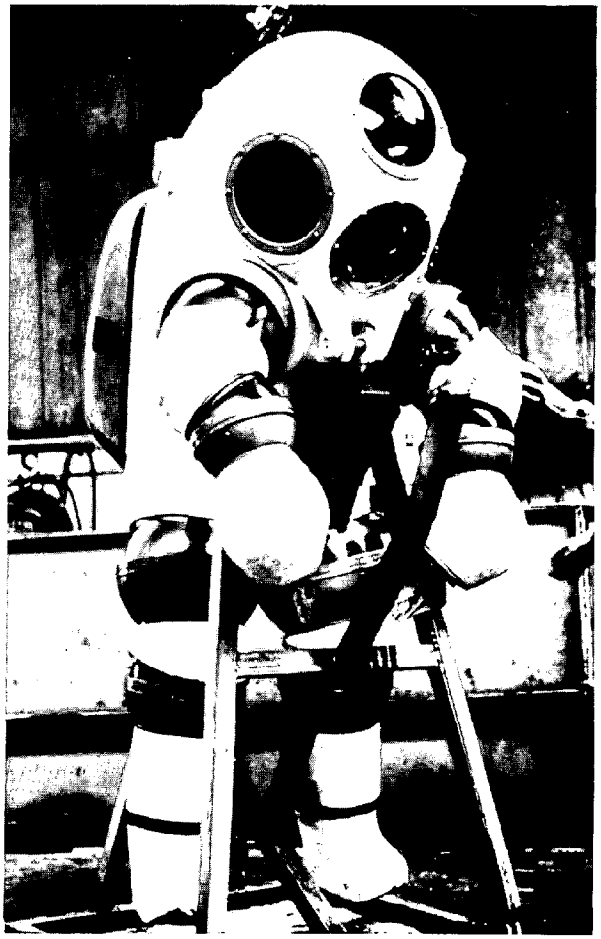


Figure 13.—One-Atmosphere (JIM) Suit

Figure 14.—Diver Donning JIM Suit Regulator

Such a system enables an operator to work for hours at a time limited only by workload, and to surface directly without having to undergo decompression. Tasks are accomplished using simple manipulators, such as those shown in Figure 13, which can be modified on the job site to suit specific requirements.

In October 1977 the Naval Medical Research Institute of Bethesda, Maryland, initiated a program to evaluate the physiological and human performance capabilities of JIM. NOAA was invited to participate in the planning and implementation of this program.

Following the initial planning and preliminary trials by the Navy, personnel from the National Marine Fisheries Service (Woods Hole, Massachusetts) participated as subjects and JIM operators during 1- to 2-year program of testing. The objective of this participation was to determine whether the JIM suit would be suitable for marine science exploration and development. Following a series of performance tests on mobility, manual dexterity, and life support function in Navy deepwater tanks and pools, an open-water evaluation was conducted on the Isle of Shoals in the Gulf of Maine during August 14-18, 1978.

The open-water testing involved personnel from the Naval Medical Research Institute, OOE's MUS&T Office and Northeast Fisheries Center (NEFC), the Shoals Marine Laboratory, the Admiralty Marine Technology Establishment-Physiological Laboratory (U.K.), and the University of New Hampshire. These tests were the first open sea trials of the JIM system made by personnel from the U.S. Navy and/or governmental and educational institutions. The objectives included the gathering of physiological data, testing of system capabilities (specific scientific tasks), and training of personnel.

The overall objectives were accomplished, and a number of tasks were performed to depths of 33 m (100 ft). In addition to the evaluation of the system, a NOAA diving technician from the Northeast Fisheries Laboratory has now been fully trained in the use of the JIM. This is part of a program to take advantage of new technology to safely increase underwater work time of NOAA dives and allow the exploration of previously unavailable areas.

It is anticipated that NOAA will continue to participate in the further testing of the JIM and will be able to conduct marine scientific studies utilizing this new technology.

DIVING INFORMATION

The *NOAA Diver*

The *NOAA Diver* is a periodic newsletter designed to inform NOAA divers about new technical developments, legislation, diving procedures, and other general information which is of interest and could enhance their effectiveness and operational safety. It is prepared in the MUS&T office by the Assistant to the NOAA Diving Coordinator. This technical services publication has been well received and is considered an important function of the diving program. The first *NOAA Diver* was published in October 1974, and seven issues have been published since that time. It is anticipated that approximately four to five issues will be published annually in the future.

Diving Accident Network

With financial support from DOE, NOAA is funding a project by the Undersea Medical Society (UMS) to establish a diving accident network. The objective of this network is to coordinate existing facilities and manpower to effect a rapid, efficient response to diving accidents, including the provision of medical advice, activating appropriate recompression facilities, and arranging transport of diving casualties to these facilities.

A meeting of the Advisory group was held in November 1977 to begin planning. The U.S. and its territories were divided into seven regions:

Northeast	Northwest
Southeast	Southwest
Midwest	Pacific Oceanic
Gulf Area	

Each region would have a Director and a Co-Director. The responsibilities of the regional Directors were outlined at this meeting.

Through follow-up correspondence, a checklist was developed to be used in evaluating the network's proposed centers. Following are the most important of these criteria:

- Personnel available (particularly physicians), whether the personnel at each center would be well suited to the team concept, and how much additional training would be required.
- Pressure chamber type and location (further engineering studies were required to detail this factor).
- Transportation
- Availability of emergency treatment facilities (high priority given to those centers that are associated with a hospital and those that have demonstrated ability in treating hyperbaric accidents).
- Physical characteristics (type of recompression chambers, location, ancillary services).

A group of hyperbaric chamber specialists met at the NOAA/Miami recompression chamber to develop a specific checklist for chamber inspection.

Visits are being made to the proposed centers by two-person teams consisting of a physician and an engineer. A plan for operating the proposed network is being developed in consultation with communications engineers. A meeting of individuals tentatively selected to be center coordinators has been called to discuss operating procedures and other details necessary to setting up the network. UMS will then turn over the final program, with recommendations, to NOAA for implementation.

Bibliography of Diving and Submarine Medicine

Since 1969 the Undersea Medical Society has been under contract with the Office of Naval Research to prepare and disseminate selective bibliographic material related to diving and submarine medicine. NOAA became a joint partner in this endeavor in FY 1977. UMS surveys all literature published in the field, annotates the appropriate articles, and prints them in hardbound volumes. An average of 110 abstracts are prepared each month. Abstracts are available to subscribers through a computerized information retrieval system. Almost 200 organizations and individuals routinely use this service. The small fee charged to subscribers helps to defray the cost of the system, which has proven to be an invaluable aid in the field of diving medicine.

Glossary of Hyperbaric and Diving Terms

In FY 1978 the NOAA awarded a contract to the Undersea Medical Society to develop a Glossary of Hyperbaric and Diving Terms.* Adoption of the metric system has added confusion about units of measure and terminology in diving and in other compressed-gas fields. The purpose of the Glossary is to define these terms and to promote the standard use of terms in all related fields. The Glossary was completed and published in FY 1978. It has been well received and is now serving as a standard reference for terminology and units of measure.

Underwater Fatality Statistics Study

Since 1970 the University of Rhode Island (URI) has operated a national underwater accident data center with support from the U.S. Coast Guard and NOAA. The objective of the program is to acquire and analyze reports

**Glossary of Diving and Hyperbaric Terms,* Undersea Medical Society, Bethesda, MD, 1978.

of scuba facilities in the United States. These analyses are published in an annual report. On the average, about 150 deaths occur each year in U.S. waters as a result of scuba diving (Table 21).

This report is prepared from information received by telephone (followed by verification), autopsy reports, media clipping services, and a variety of other sources. A substantial amount of information is received through unsolicited letters, which reflects the acceptance of this program throughout the diving community. It is anticipated that the program will expand to include commercial diving accidents.

Recently the data have been placed in an information retrieval system in order to speed up responses to inquiries. The information is widely used by diving training organizations, the medical profession, and the insurance industry. Even broader utilization is anticipated in the future.

Table 21—Summary of All Underwater Fatalities, Yearly, 1970-76

	1970		1971		1972		1973		1974		1975		1976	
	M	F*	M	F	M	F	M	F	M	F	M	F	M	F
Nonprofessional underwater fatality	99	11	104	8	107	12	118	7	129	15	123	8	137	10
Professional, scuba diving	3	0	2	0	2	0	0	0	6	0	4	0	6	0
Professional surface-supplied air or mixed gas	6	0	2	0	2	0	4	0	8	0	8	0	7	0†
On duty military	0	0	0	0	0	0	0	0	2	0	1	0	1	0
Skindiving	18	1	17	0	15	1	22	0	25	2	16	1	11	3
TOTAL	138		133		139		151		187		161		175	

*M = Male, F = Female
†Note: Includes one nonprofessional hose diver.

APPLIED TECHNOLOGY AND ADVANCED CONCEPTS

UNDERWATER PHYSICS RESEARCH

Project UNCLE (Undersea Cosmic Lepton* Experiments)

Cooperative diving programs related to underwater physics began in 1972 when NOAA and University of Washington/Western Washington University (U of W/WWU) scientists collaborated in a pioneering effort to determine how much filtering of stray cosmic-ray shower "particles" (protons, electrons, etc.) would accrue from selectively measuring and detecting these particles under water.

These particles, which travel constantly and randomly throughout the universe, leave a microscopic trail when they strike a photographic emulsion. The first attempts to "capture" these trails under water were conducted in 1973 in the *Hydro-Lab*, an underwater habitat, in about 15 m (50 ft) of seawater off Freeport, Grand Bahama Island.

The emulsion plates were mounted in cassettes which were in turn encased in waterproof glass spheres. The emulsions were prepared, deployed, and a few weeks later developed in the *Hydro-Lab*.

As predicted, the water acted as a homogenous and isotropic filter (in contrast to the nonuniformity of the earth surrounding mineshafts, where other cosmic-ray experiments have been performed), removing extraneous surface radiation and simplifying the interpretation of the emulsion trails. This permitted the researchers to gather important new data about cosmic-ray muons.†

NOAA/Harbor Branch Foundation Cooperative Projects‡

In early 1977 an agreement was reached between NOAA and the Harbor Branch Foundation of Ft. Pierce, Florida, allowing the use of a Harbor Branch *Johnson-Sea-Link* (JSL) submersible for Project UNCLE experiments. The JSL would be used to deploy and retrieve the photographic emulsion spheres under water. The experimenters were Jere Lord and Peter Kotzer of U of W/WWU, and Kurt Stehling of NOAA/MUS&T, who served as scientist-monitor-observer.

Harbor Branch then proposed, designed, and built a unique ocean-bottom-sitting chamber (a modified JSL aft "sphere") which would be used to deploy the emulsion spheres (see Figure 15). The chamber itself was deployed in September 1977 off West End, Grand Bahama Island.

In October 1977 two emulsion stacks in glass spheres were prepared in the JSL and deployed, one at 1000 ft (328 m) within the bottom chamber and one for reference at 400 ft (122 m). In March 1978 the 400-ft sphere was retrieved, and the emulsions were developed in the JSL. The 1000-ft emulsions were retrieved and developed in October 1978 while another sphere was deployed at 600 ft (183 m).

The following features highlight this unique experiment, which blends ocean engineering with high-energy physics using in-situ, man-in-the-sea research techniques:

- A research submersible was used as a minilab for preparing cosmic-ray detectors.
- Lockout of the cassette in the sphere into a bottom chamber was achieved at 1 atm pressure.
- The JSL crew remained, in one mission, for 12 hours at 305 m (1000 ft) with no adverse effects.
- A partnership was established between NOAA and the Harbor Branch Foundation (HBF), a not-for-profit foundation, with HBF contributing most of the technical and logistical support and equipment to the missions.
- The U of W/WWU scientists have already found evidence of new muon interactions.

The success of these experiments has attracted wide attention from cosmic-ray and other physicists. Several major neutrino/muon detection concepts have been proposed for undersea operation and are actively under study, both in the U.S. and internationally.

*Leptons are mainly neutrinos or muons (mu meson and electrons). Muons are far less elusive than neutrinos.

†See K. Stehling, *A Submersible Physics Laboratory Experiment*, NOAA Technical Report, OOE 1, Jan. 1979.

‡See "Shallow Water Research Submersible Activities, 1978."

UNCLE Workshop at University of Washington/ Western Washington University

In July 1978 NOAA, in conjunction with the U.S. Navy's Office of Naval Research (ONR) and on the advice of U of W/WWU scientists, sponsored a workshop on undersea radiation experiments. The workshop, held at U of W/WWU in Seattle, was attended by senior government and academic physicists, as well as ocean engineers and marine scientists.

About 30 contributors from a wide variety of disciplines discussed new techniques for determining the low-energy components of undersea cosmic rays. Among the viewpoints discussed were marine engineering, high-energy physics instrumentation, geophysics, advanced information acquisition and processing systems, accelerator physics, and others.

Primary topics of discussion were the engineering and physics problems related to the technique of in-situ preparation and development of nuclear emulsion chamber arrays. This technique has resulted in the only acquisition of data on the composition of undersea cosmic rays, and has led to the identification of new and important nuclear processes. These processes have been confirmed by doing "bench mark" calibration nuclear experiments at the Fermi National Accelerator Laboratory (FNAL) in Batavia, Illinois.

Also of prime interest at the workshop was the further development of undersea photoelectric light detectors. Charged particles traveling faster than light in water emit ultraviolet and visible radiation called Cerenkov radiation. Photomultiplier detector tubes can be used to detect these emissions, which are useful in studying a wide range of undersea cosmic events. The use of such detectors would also yield information for the marine biological sciences from the bioluminescence of certain species and their relation to the food chain. Problems in the deployment, alignment, operation, and reliability of Cerenkov light detectors were discussed, and it was concluded that the technological problems were solvable.

Detection of both high- and low-energy particles at the greatest depths of the ocean may be the least expensive method for studying and detecting cosmic-ray muons and supernova, atmospheric, and galactic neutrinos. The consensus of the workshop participants was that the solution of technological problems will make possible a new era of undersea cosmic-ray and radiation physics important to both astro- and high-energy physicists.

Project DUMAND (Deep Undersea Muon and Neutrino Detector)

The success of the UNCLE experiments has stimulated interest by other groups in using the oceans for neutrino detection experiments on a much larger scale. DUMAND is one of the proposed projects currently being reviewed and analyzed by such agencies as the National Science Foundation (NSF), the Department of Energy (DOE), and the Office of Naval Research (ONR). NOAA, which provided the initial impetus, stimulation, and support for

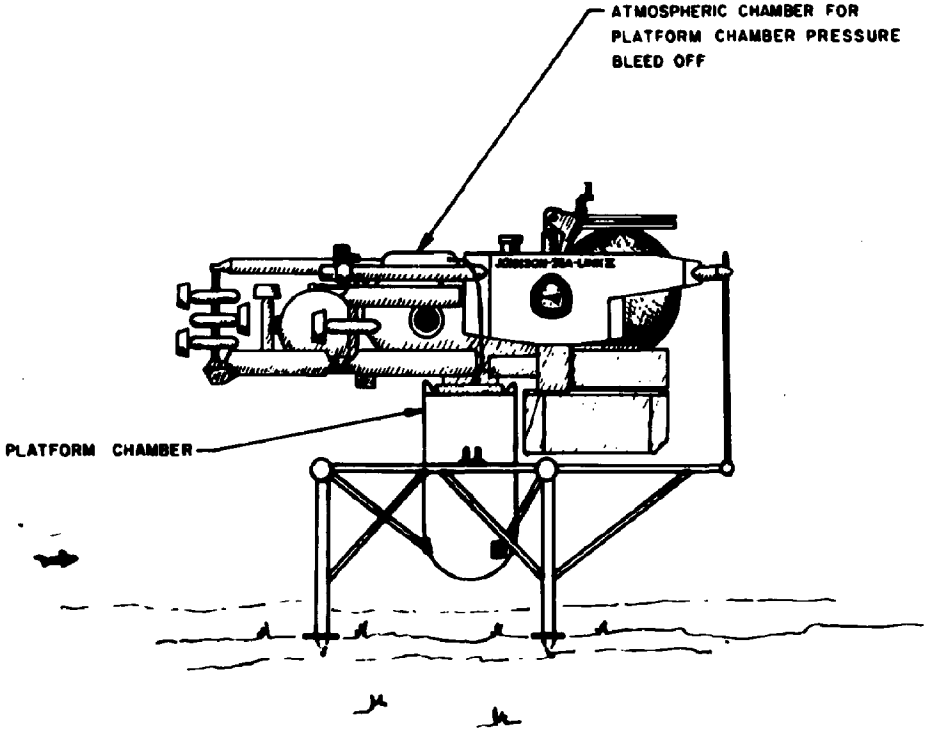


Figure 15.—Schematic of Submersible and Platform Chamber for Dry Transfer of Pellicle Plates

these projects, is presently acting as an interested observer.

The DUMAND concept has evolved from a series of seminars and meetings arranged or sponsored, in part, by NOAA and held at U of W/WWU and the University of Hawaii. A giant, solid matrix (ultimately 1 km^3) of photoelectric and/or acoustic detectors, placed at an ocean depth of 3049 m (10,000 ft), would sense the high-energy vector of extraterrestrial neutrinos. To date, neutrinos have only been observed in particle accelerator experiments. Neutrinos observed in-situ would have energies far in excess of those in the largest particle accelerators. If identified as being from a stellar source, they could yield unique historical data on stellar ages and processes (see Figure 16).

Future photoelectric missions planned for the *Johnson-Sea-Link* to depths of 610 m (2000 ft) or more may yield important preliminary data for DUMAND.

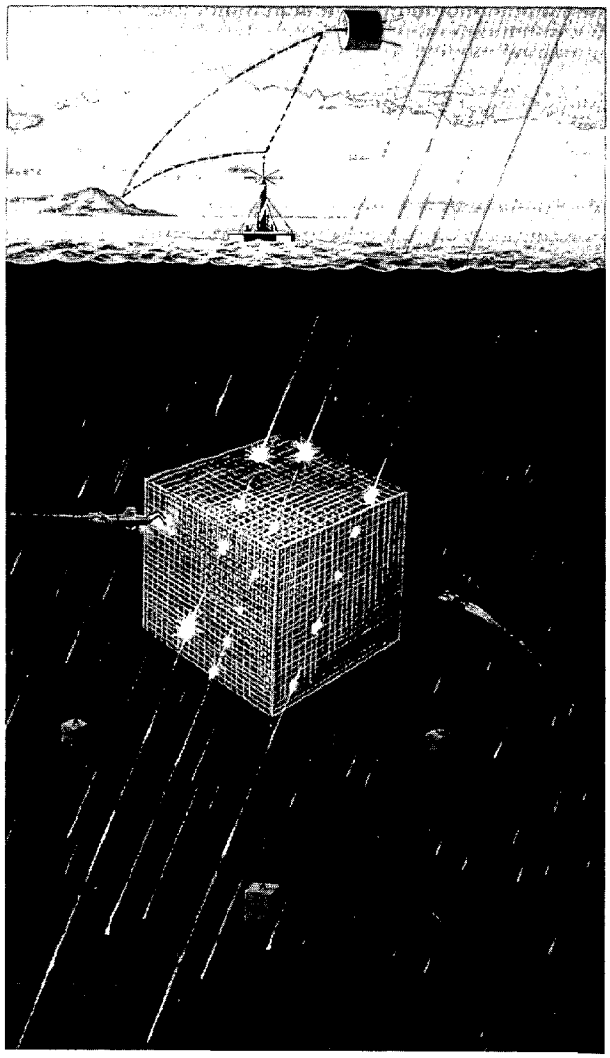


Figure 16.—Artist's Conception of 1-km^3 Cosmic Detector

NUCLEAR ACTIVATION ANALYSIS

Most elements, when irradiated with neutrons or X-rays, will emit secondary "backscatter" or fluorescent radiation with spectral characteristics unique to the nucleus or electron shell structure of the particular substance being irradiated. It is therefore possible to identify many of the elements contained in the top few centimeters of superficial ocean bottom by mounting a radiator and detector on a submersible which cruises just above the ocean floor. This method of in-situ analysis is proving to be a very valuable research technique, particularly in studies of heavy-metal pollutants.

NOAA has been sponsoring and encouraging the development of both neutron activation and X-ray fluorescence analyses since 1973. Following is a summary of recent developments in these fields.

X-Ray Fluorescence*

Standardization and evaluation tests of developmental undersea X-ray fluorescence equipment were conducted near Ft. Pierce, Florida, in June 1978. This equipment was developed by Battelle Pacific Northwest Laboratories under Department of Energy (DOE) sponsorship. The Harbor Branch Foundation provided surface support and the *Johnson-Sea-Link I* (JSL-I) submersible.

The JSL-I was launched in shallow water (9 m) off the Ft. Pierce inlet. Surface divers with scuba equipment placed standards of 12 elements on the ocean floor (arsenic, thorium, molybdenum, riobium, cadmium, nickel, manganese, copper, chromium, lead, zirconium, and iron). These standards, which varied from 1 to 1000 ppm, were used to calibrate the in-situ instruments.

Over a 2-day period, 27 sites in the West Palm Beach outfall area and sites in the Lake Worth outfall area were analyzed for their inorganic pollutant concentrations. This was the first extensive application of undersea in-situ X-ray fluorescence in the measurement of inorganic materials from specific outfall regions.

The results of these experiments indicated that in-situ X-ray analysis is, in some important ways, superior to the normal "grab" sample technique. The X-ray method measures pollutant concentrations at levels normally encountered in the environment. It also measures top-layer pollutant concentrations not provided by the "grab" sample technique (see Figure 17).

These 1978 experiments utilized a digging mechanism which scraped away successive layers of sediment prior to in-situ analysis. This mechanism worked well in areas on noncompacted sediment, but not as well in areas of hard-packed sediment. The experimenters have concluded that an X-ray analyzer should be built which can penetrate and analyze sedimentary layers without disturbing the material. Evaluations are also being conducted on the data processing and analyzing equipment.

The success of this X-ray mission has led to requests for

*See "Shallow Water Research Submersible Activities, 1978."

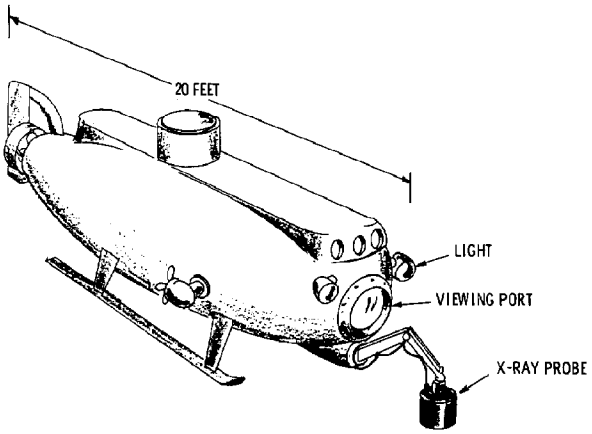


Figure 17.—X-Ray Fluorescent Probe Mounted on Submersible

further pollutant studies off the Florida coast, with the next experiment planned for FY 1980.

Neutron Activation

As with X-ray fluorescence, neutron irradiation of most heavy metals will yield a characteristic spectrum which identifies the irradiated element. The neutron technique is not quite as sensitive for detecting trace elements, but penetration into sediment is deeper than with X-ray fluorescence.

NOAA has worked with the United States Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA) since 1973 to improve analysis and provide undersea "packaging." In 1974, NOAA supported a submersible for a field test of bottom slime in New York Harbor (see FY 1974 Annual Report). An isotope neutron emission source, californium 252, and a germanium-lithium detector were used. Although useful data were obtained, there were operational problems with handling the "hot" radioactive source and with the relative insensitivity of the detector (the only one available at the time).

Scientists at NASA/Goddard Space Flight Center (GSFC), who have pioneered this field, decided with USGS in 1975 to initiate development of a pulsed neutron source. By bombarding tritium with deuterium, neutrons could be produced at will; this would eliminate the need for radioactive isotopes and their associated handling problems. GSFC also purchased an intrinsic germanium detector with higher resolution and sensitivity than other solid state devices and with fewer cooling problems. NOAA has supported studies on the marine packaging problems of the system.

The pulse source will not be available until 1980 because of power-supply and other circuit problems. When these problems are solved, field tests are planned to be conducted in Chesapeake Bay, where preliminary surveys have been initiated.

RADIOISOTOPE THERMOELECTRIC GENERATOR (RTG) POWER SUPPLY

A Sentinel 100F RTG is being transferred from the U.S. Navy to NOAA for use on the *Hydro-Lab*. The RTG is a self-contained emergency power supply, and can provide up to 150 W of continuous, uninterrupted electrical power. The system will provide *Hydro-Lab* with power for communications, atmosphere control, and lighting in the event of a life support buoy failure, thereby improving diver safety and reliability of *Hydro-Lab*.

This technical improvement to the *Hydro-Lab* system represents the first use of a large radioisotope power device by NOAA and is a significant technological exchange between the Navy and NOAA. Processing of required permits and approvals from the U.S. Nuclear Regulatory Commission is proceeding, and it is anticipated that installation of the RTG will occur during FY 1980 at the *Hydro-Lab* site in St. Croix, U.S. Virgin Islands.

This project is a part of the MUS&T program objective to use extant advanced technology where available and sufficiently developed to permit underwater use with little or no modification.

ACTIVE BIOLOGICAL SUBSTANCE STUDY

The MUS&T Office, the Office of Sea Grant (OSG), and the National Cancer Institute (NCI) decided in mid-1978 to sponsor and jointly fund a workshop on improvements in undersea diving and technology for survey, location, and recovery of biologically active substances—especially those having possible anticancer specificity.

The Undersea Medical Society (UMS) of Bethesda, Maryland, was chosen to organize the workshop. Held in the autumn of 1978, the workshop was attended by about 25 biologists, pharmacologists, and physiologists.

Mass screening of compounds for their medical value still seems to be the best way to discover useful undersea materials. The problems in screening under the sea, as compared to land-based screening, are compounded many times over. The search is difficult, harvesting requires special techniques, and re-collection and supply present formidable tasks. Despite these difficulties, the workshop participants stressed the importance of pushing ahead with the development of technologies which will solve these problems.

A final report on the findings of the workshop is in preparation.

MARINE SCIENCE APPLICATIONS

This section summarizes activities that deal with practical applications of scientific studies and missions, such as surveys of ocean dumping and dumpsites, deep-sea studies of fauna, fisheries potential, and assessments of marine geologic features and processes. The missions summarized herein are mainly U.S. coastal zone endeavors conducted with MUS&T-provided submersibles. Other scientific missions are described under the section on Interagency and International Activities.

NOAA supported four general types of manned underwater activities which were used in the marine science applications described below. These activities included surface-supported diving, a deep-water research submersible system, shallow-water research submersibles, and saturation diving from a sea-floor-based habitat.

SURFACE-SUPPORTED DIVING RESEARCH

Surf Clam—Ocean Quahog and Ocean Pulse Survey

Date: July 25-August 4, 1978

Facilities and Operations: Surface-supported diving from R/V *Kyma*

Location: Off Rockaway Beach, Long Island, NY

Comment: This cruise was an extension of the MUS&T-sponsored program conducted August 17-26, 1977.

Purpose: (1) Replant marked ocean quahogs and surf clams; (2) investigate various clam-related parameters (density, depth, predators, and others); (3) investigate the practicality of studying the metabolism of surf clams and ocean quahog communities in-situ; and (4) reevaluate the efficiency of an airlift clam sampler versus diver sampling.

Participants: NMFS—Thomas Meyer, Principal Investigator (NEFC, Woods Hole), and William Phoel (NEFC, Sandy Hook); U. of Rhode Island—Eric Anderson (Kingston, RI); Manned Undersea Research and Technology (MURT) team of NEFC.

Accomplishments: (1) The surf clam and ocean quahog marking and planting experiment showed that 80 percent of the surf clams and 20 percent of the ocean quahogs were able to reburrow. The smaller ones were better able to reburrow than the larger ones. (2) The 11 ocean pulse stations established during the 1977 cruise were reoccupied. Variations in clam size and population were noted. (3) The in-situ metabolic experiments conducted on surf clams were successful; the results are still being analyzed. (4) The air-lift clam sampler did not function as well as expected; redesign of the dredge head is being considered. (5) The quantitative photographic quadrate system was not evaluated because of underwater strobe light problems.

Ocean Pulse and Herring Spawning Survey

Date: September 24-November 5, 1978

Facilities and Operations: Surface-supported diving from M/V *Barbara L.*, M/V *Miss Paula,* R/V *Tioga*; 202 dives, depth to 39.6 m (130 ft)

Location: Jeffreys Ledge and Cashes Ledge, Gulf of Maine

Purpose: Technical—Evaluate NOAA Nitrox I gas mixture and Doppler bubble detector.* *Scientific*—Herring Spawning Survey: (1) Define the distribution of herring spawning grounds, substrate and thickness of egg cover, and predation on adult herring and spawned eggs; (2) measure success of hatch as a function of substrate type, egg layering, temperature, and other factors; and (3) study the general ecology of spawning grounds and newly hatched larvae. Ocean Pulse Survey: (1) Assess proposed stations; (2) study "key indicator species" ecology; (3) photograph and collect species; and (4) train scientists in deep diving techniques.

Participants: NMFS—Dr. Richard Cooper, Principal Investigator (NEFC, Woods Hole), MURT team, Dr. Harold Pratt (NEFC, Naragansett), William Phoel (NEFC, Sandy Hook), and Robert Ford (SEFC, Pasagoula); ERL—Richard Rutkowski (AOML, Miami); OOE (MUS&T)—Dr. J. Morgan Wells; UNH—Dr. Alan Waterfield (Durham, NH); URI—Eric Anderson (Kingston, RI); SMU—Dr. James Sears (N. Dartmouth, MA.); Virginia-Mason Med. Ctr.—Richard Dunford (Seattle); Chris Davis (Osterville, MA).

Accomplishments: Technical—Nitrox I gas mixture was used on 66 of the 202 dives to depths of 130 feet. The Doppler bubble detector was evaluated on the basis of approximately 200 readings taken of divers using both air and Nitrox I. Test dives to a variety of depths will have to be conducted before a complete profile can be drawn of the advantages of Nitrox I. *Scientific*—(1) A herring egg

*See full descriptions of Nitrox I and Doppler bubble detector in section on Operational Effectiveness and Safety.

bed was located off Jeffreys Ledge at a depth of 25 fathoms. (2) A permanent Ocean Pulse station, at two depths, was established at Pigeon Hill on Jeffreys Ledge, with the following accomplishments: (a) studied in-situ the respiration of two starfish species; (b) permanent study transects established; (c) collected algae and sea stars; (d) placed two multisurface racks at both study depths for study of algae establishment; (e) documented species composition by random photography at both study depths; and (f) collected all material within a randomly located ¼-m² area at 100-ft station.

DEEPWATER RESEARCH SUBMERSIBLE ACTIVITIES, 1977

NMFS/Systematics Laboratory—Tongue of the Ocean

Date: January 4-12, 1977

Facilities and Operations: DSRV *Alvin*; 8 dives, depth 1337 to 3663 m

Location: Tongue of the Ocean and Northeast Providence Channel, Bahamas (Figure 18)

Purpose: Make firsthand observations on the biology of deepwater benthic fishes and larger invertebrates, and take qualitative and quantitative data by visual and photographic methods.

Participants: NMFS/Systematics Lab—Dr. Daniel Cohen, Principal Investigator; Smithsonian—Dr. D. L. Pawson; U. of Miami—Dr. J. Staiger

Accomplishments: Approximately 35 species of benthic and benthopelagic fishes were observed. Among the larger invertebrates observed, holothurians were the most abundant. Echinoids were relatively common. Plant debris was common in many areas. Sediment appeared to be extremely cohesive and very light colored. Much particulate matter was present in midwater; luminescence was relatively common. Results indicate that fish population density is lower and diversity higher than the similar depths near Hudson Canyon.

More than 96,000 m² were surveyed in the depth range (1337 to 3663 m). A deep, uncharted hole was discovered and photographed.

Great Abaco Canyon Study

Date: May 17-24, 1977

Facilities and Operations: DSRV *Alvin*, R/V *Lulu*, R/V *Virginia Key*; 2 dives, depth 100 m

Location: Great Abaco Canyon, Bahamas

Purpose: This mission completed a series of cruises begun in 1969 in support of the AOML/MG&GL project COMSED (Continental Margin Sedimentary Processes). These studies were done to obtain information on the morphology, structure, stratigraphy, and sedimentary transporting mechanisms of Great Abaco Canyon. This final cruise was undertaken to sample areas of the canyon head.

Participants: ERL—J. Kofoed, Principal Investigator (AOML), D. Lambert (AOML/MG&GL); Rice U.—J. Warme; U. of Delaware—H. Mullins

Accomplishments: Each dive obtained extensive color and black and white photographs. Scoop samples were collected of pteropods and surficial sediments of rocks showing active bioerosion. Two cores were obtained of the carbonate mud in the canyon axis. Sediment samples collected are expected to verify that Little Bahama Bank is the source of the material.

Baltimore Canyon Slump—Mission I

Date: June 10-14, 1977

Facilities and Operations: DSRV *Alvin*, R/V *Lulu*, R/V *Pierce*; 3 dives, depth 900 to 2000 m

Location: Vicinity of Baltimore Canyon on the continental slope

Purpose: Observe and photograph the physiography of the continental shelf edge slump; determine the nature of geomorphic change from layered to slumped sediments.

Comment: Baltimore Canyon Slump—Mission II is described under "Deepwater Research Submersible Activities, 1978."

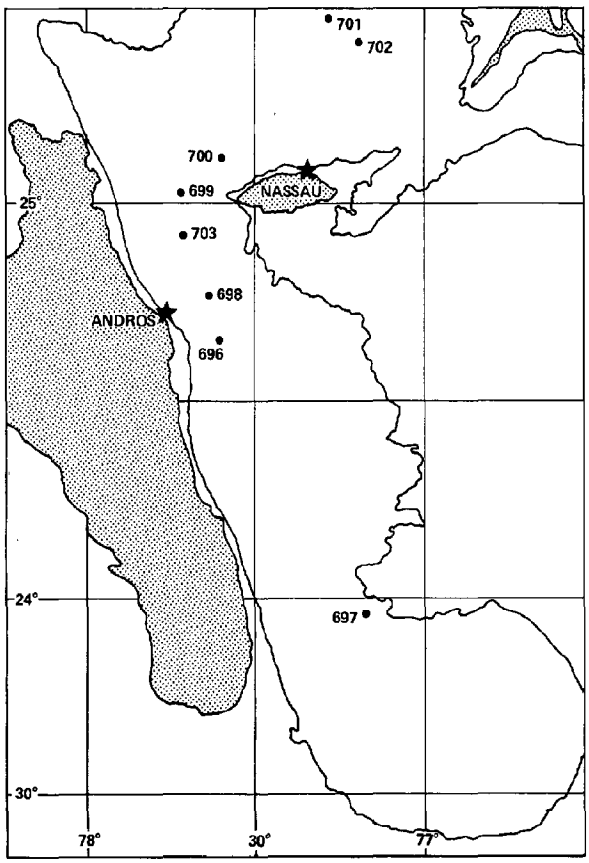


Figure 18.—*Alvin* Dive Locations for Tongue of the Ocean Project

Participants: NOS—Dr. Alexander Malahoff, Dr. Richard Perry; Lamont-Doherty Geol. Observ.—Dr. Robert Embley, Daniel Fornari

Accomplishments: Observations showed no evidence of recent sea floor movements. The entire area is blanketed by a layer of fine-grained sediment about 40 cm thick. This blanket covers probable evidence of faulting and sliding. Studies on a box core at 2800 m depth near Baltimore Canyon showed a radiocarbon date of 5265 ± 210 years BP (before present) for a major debris flow.

Atlantis Canyon Mission

Date: September 6-15, 1977

Facilities and Operations: DSRV *Alvin*, R/V *Lulu*; 4 dives, 220 to 1886 m; observations recorded on videotape, voice tape, and 35-mm photos; rock and sediment samples collected by externally mounted mechanical manipulator.

Location: Atlantis Canyon, southern New England continental shelf

Purpose: Conduct biological and geological surveys of the Atlantis Canyon axis and slope over the depth range of 200 to 1900 m.

Participants: NMFS—Dr. Richard Cooper, Principal Investigator (NEFC, Woods Hole); USGS—Dr. David Folger (Woods Hole)

Accomplishments: Preliminary impressions from the diver series indicate: (1) Atlantis Canyon is geologically similar to Veatch Canyon in depth range studied; (2) the faunal distributions are similar, but notably less abundant, species by species; and (3) the axis of the canyon, where occupied, was typically of low relief and poorly defined. Geological observations included a silt overlay over the canyon surface with some boulders. Species noted included lobsters, flounders, squid, red and cancer crabs, tilefish, galatheid crabs, and one swordfish. Ghost lobster pots were noted and included one ghost fishing string of pots.

DEEPWATER RESEARCH SUBMERSIBLE ACTIVITIES, 1978

Hatteras Transect Submersible Studies

Date: May 23-June 5, 1978

Facilities and Operations: DSRV *Alvin*, R/V *Lulu*; 5 dives, depth 315 to 3575 m

Location: Continental margin off Cape Hatteras

Purpose: Observe the coupling mechanism of the Middle Atlantic continental shelf sediment transport system—including entrained waste materials—to the sediment transport system of the continental slope and upper continental rise.

Participants: AOML—Dr. Peter Rona, Principal Investigator; Smithsonian—Dr. Daniel Stanley; Texas A&M—Dr. David McGrail

Accomplishments: An integrated data set was obtained using 6 current measurements by dye injection, numerous bottom inclination measurements, 30 cores, 4 rock samples, and photographs.

- Dive 1—The presence of slump blocks was confirmed, and integrated observations were made at three sites of massive slumping.
- Dive 2—Integrated observations were made across the boundary between the upper continental rise and lower continental slope.
- Dive 3—Integrated observations revealed a zone slumping between 1000 and 1150 m below sea level and homogeneous bottom above 1000 m.
- Dive 4—Integrated observations made in Pamlico Canyon revealed abundant fresh garbage (food wrappers, metal and glass containers) along the canyon axis and termination of the canyon between 400 and 500 m below sea level below the Outer Continental Shelf, confirming prior seismic reflection evidence that the canyon head is buried where the Gulf Stream impinges against the continental slope.
- Dive 5—Integrated measurements made along a transect from the northeast to the southwest wall of Pamlico Canyon documented the interaction between axial canyon processes and the Western Boundary Undercurrent flowing south transverse to the canyon axis.

Baltimore Canyon Slump—Mission II

Date: June 6-16, 1978

Facilities and Operations: DSRV *Alvin*, R/V *Lulu*; 8 dives, depth 170 to 1950 m

Location: Baltimore Canyon area

Comment: Mission II was a sequel to Mission I (described under "Deepwater Research Submersible Activities, 1977").

Purpose: Examine the continental shelf-slope break to the upper rise to determine slump morphology, triggering mechanisms, age of occurrence, and extent of encroachment upon the continental shelf to evaluate the impact of continental shelf oil lease areas.

Participants: NOS—Dr. A. Malahoff, Dr. R. Perry; Lamont-Doherty Geol. Observ.—Dr. R. Embley, D. Fornari

Accomplishments: The Mission II dives were further south than the Mission I dives. One dive was in an area of zigzag relief to the north of Norfolk Canyon, three were in different parts of Norfolk Canyon, and one was in Washington Canyon. As in Mission I, there was no evidence of biological activity contributing to erosion in the canyons. An outcrop in Washington Canyon was dated as Miocene based on the diatoms found there. The continental slope and upper rise in this area apparently have been subject to major slumping in the past, but there was no evidence of recent movements. The uppermost sediments appeared undisturbed; however, they could move if triggered by a major earthquake.

Oceanographer Canyon Survey

Date: September 9-October 1, 1978

Facilities and Operations: DSRV *Alvin*, R/V *Lulu*; 6 dives, depth 300 to 2000 m. Three of the six dives were made with a biologist-geologist observer pair; the other three were made by a pair of biologists.

Location: Oceanographer Canyon, southern New England continental shelf (see Figure 19)

Purpose: Conduct biological and geological surveys of the Oceanographer Canyon axis and slopes over the depth range of 300 to 2000 m.

Participants: NMFS—Dr. Richard Cooper, Principal Investigator (NEFC, Woods Hole); Joseph Uzmann (Woods Hole); URI—Page Valentine (Kingston, RI)

Accomplishments: The canyon axis was well defined at all six points of entry and was generally overlain with a mantle of Pleistocene clay sediments with occasional glacial boulders and patches of glacial till. Bioturbation was widely evident in burrows and excavations of red crabs, pandalid shrimps, jonah crabs, and hakes. Some 35 species of invertebrates and fishes were encountered. The faunal list developing from this survey is qualitatively similar to that of other southern New England canyons with the exception of first sightings of several species of octocorals and an unidentified sponge species.

SHALLOW WATER RESEARCH SUBMERSIBLE ACTIVITIES, 1977

Reconnaissance of Proposed OTEC Pipeline Route

Date: October 21-22, 1977

Facilities and Operations: Submersible *Star II*; 1 dive, 600 m

Location: Off Keahole Point, Hawaii

Comment: The NOAA Office of Sea Grant contributed a portion of the financial support for this mission.

Participants: U. of Hawaii—Edward Noda, Principal Investigator

Accomplishments: The survey indicated that no severe bottom conditions existed that would preclude the design and ultimate construction of a cold-water intake pipeline. Bottom conditions were ideal along most of the surveyed route. In only one section was there any formidable problem: a gently sloping shelf, 548.5 m (1800 ft) wide, joins the main ocean bottom slope (30°) at a depth of 137.2 m (450 ft). At this juncture rocky outcroppings were observed, with vertical drops of about 3 to 6 m and a rocky surface texture. Interspersed among the rocky outcrops, however, are 3- to 6-m-wide sand channels which form a smooth transition from the gently sloping shelf to the main ocean bottom slope.

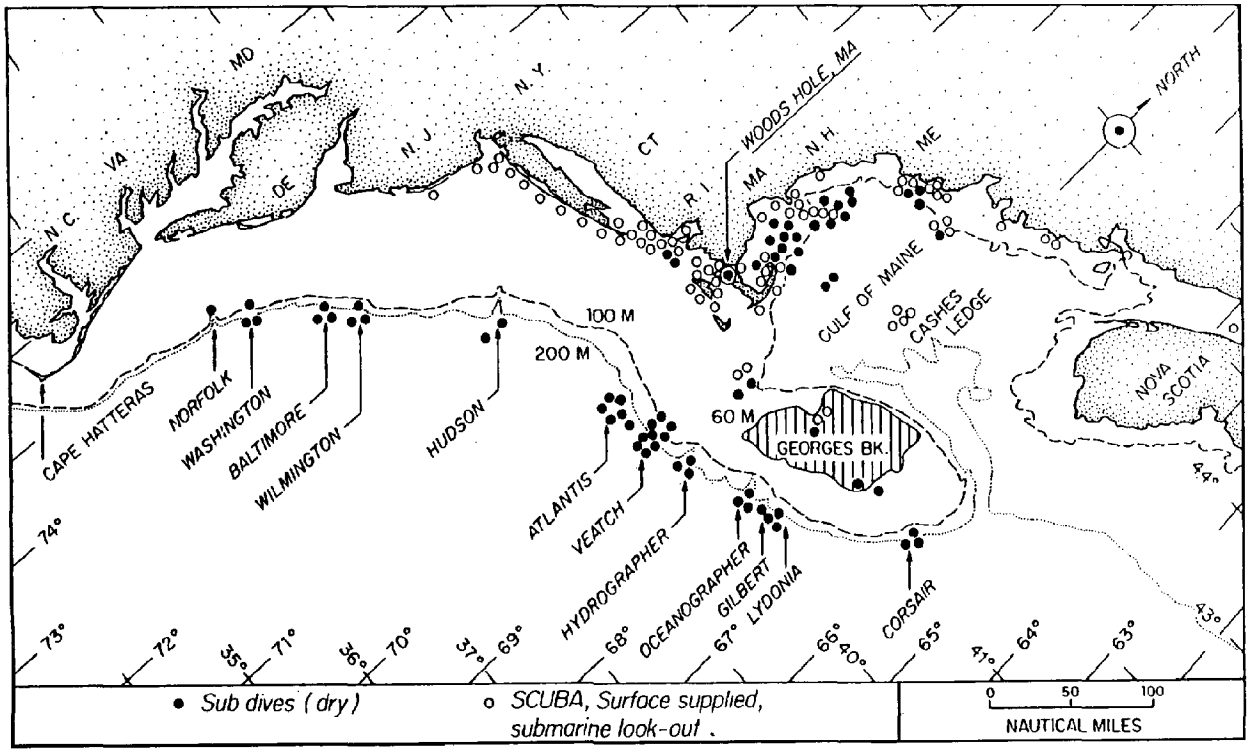


Figure 19.—Dive Sites on Mid-Atlantic Continental Shelf Missions

SHALLOW WATER RESEARCH SUBMERSIBLE ACTIVITIES, 1978

Slipper Lobster Investigation

Date: June 19-30, 1978

Facilities and Operations: Submersible *Diaphus*, M/V *State Arrow*, R/V *Rounsefell*; 27 dives, depth 61 m (200 ft)

Location: Northeast Gulf of Mexico

Purpose: Determine the fishery potential in the Gulf of Mexico shelf area of the slipper lobster, *Scyllarides nodifer*.

Participants: U. of South Alabama—Dr. Robert Shipp, Principal Investigator, and Dr. James Langdon; Dauphin Island Sea Lab, Alabama Sea Grant Consortium—Dr. Thomas Hopkins

Accomplishments: This research effort provided information regarding the species' value as a fishery resource, including geographic, temporal, and spatial distribution of lobsters, population life history characteristics, and epifaunal associations and habitats.

Mid-Atlantic Megabenthic Crustacean Survey

Date: July 9-18, 1978

Facilities and Operations: R/V *State Arrow*, Submersible *Diaphus*; 15 dives, depth 150 to 400 m.

Location: Wilmington, Baltimore, and Washington Canyons

Purpose: (1) Define and photographically document the surface geology of the submarine canyon over a depth range of 150 to 400 m; (2) define the bottom-oriented fauna range and relate to the geologic features; (3) define the relative abundance of major fauna (lobsters, crabs, flounders, hakes, sharks, etc.); and (4) train NMFS and academic scientists in submersible operations and scientific applications.

Participants: NMFS—Dr. Richard Cooper, Principal Investigator, and Joseph Uzmann (NEFC, Woods Hole), and Peter Parker (SEFC, Beaufort, NC); National Shellfish Institute of North America—Edward Tolley; Marine Biological Laboratory—Jelle Atima (Woods Hole)

Accomplishments: The scientific, technical, and training goals of the survey were accomplished. Surface geology was similar for the three canyons studied; bottom topography was relatively featureless. Few "Pueblo Village" type communities with sheltered fauna (lobsters, crabs, fish) were observed. The bottom-oriented fauna were primarily galatheid and jonah crabs, conger eels, squirrel hake, and black-bellied rosefish. Boulder "fields" and mud anemone "forests" with their usual associated fauna were scarce.

Mid-Atlantic Continental Shelf Study

Date: July 20-28, 1978

Facilities and Operations: M/V *State Arrow*, Submersible *Diaphus*; 13 dives

Location: Continental shelf edge from Block Canyon to Baltimore Canyon

Purpose: Gather geological information regarding the depth, nature, and rate of change with depth of bottom sediment at both sharp and gradual shelf break slopes.

Participants: AOML/MG&GL—Dr. George Freeland, Principal Investigator; Universidad du Sol, Brazil, and Columbia U.—Alberto Figueiredo; students from Brooklyn College, NY.

Accomplishments: Above the shelf break, sediments were very fine grained sand with some silt and varying amounts of shell debris. The bottom was relatively hard, with traces of small ripples, giving the impression of being swept clean frequently. Silt content and bioturbation increased with depth.

Atlantic Continental Slope Geological Investigation

Date: July 30-August 19, 1978

Facilities and Operations: M/V *State Arrow*, Submersible *Diaphus*; 46 dives, depth 16.8 to 57.9 m (55 to 190 ft)

Location: Mid- and North Atlantic upper continental slope and Georgia Bight

Purpose: Make observations of geologic hazards, especially slumping, off the Georgia Bight and Baltimore Canyon areas, and investigate the geology of the Georgia Bight.

Comment: In light of recent discoveries of natural gas on the mid-Atlantic continental shelf, these studies were undertaken to determine potential geologic hazards to the siting of exploration wells, platforms, and pipelines. Submersible study permits correlation of seismic and side-ocean sonar profiles to in-situ observation and the resolution of small-scale features.

Sponsor: USGS

Participants: USGS—Dr. David Folger, Principal Investigator for northern cruise (Woods Hole); U. of Sydney, Australia—Charles Phipps; USGS—Mahlon Ball, Principal Investigator for southern cruise (Woods Hole); Bureau of Land Management—Jesse Hunt (New Orleans); Skidway Institute of Oceanography—V. Henry.

Accomplishments: A total of 24 dives were made in slump and interslump areas along the uppermost continental slope in Lease Area #49 in the Baltimore Canyon trough area and south of the Georgia Bight. These dives revealed slump scars characterized by slopes of 20 to 45°, clay outcrops, and borings and depressions inhabited by a diversity of megabenthic crustaceans and fish. Below the scars, step topography, reverse slopes, and hummocky sea floor were observed. Small slumps were observed at shallower depth (170 to 366 m) than previously had been by resolved by seismic profiles. In contrast, areas with no slumps were characterized by smooth, gently dipping sea floor and sparse fauna.

A total of 22 dives at depths ranging from 16.8 to 57.9 m (55 to 190 ft) were made in the Georgia Bight area. Bottom observations correlated bottom features with fathometer records.

Southeast Coast of Alaska Fisheries Investigation

Date: July 15-August 6, 1978

Facilities and Operations: Submersible *Nekton Gamma*, M/V *Antares*, R/V *John Cobb*; 61 dives, depth 18.3 to 304.9 m (60 to 1000 ft)

Location: Southeast coast of Alaska from Lisianski Inlet to Boca de Quadra Inlet

Purpose: (1) Survey the distribution, abundance, habitat character, and depth zonation of precious corals and epibenthic fish, crab, and shrimp populations, and behavioral responses to traps; (2) assess the nature of the deep, rocky substrate as it applies to the design and use of fishing gear; and (3) study the effects of logging debris on marine habitats.

Participants: NMFS, NWAFC—William High, Principal Investigator, Dr. Richard Straty, Louis Barr; NMFS, NEFC—Joseph Uzmann; U. of Alaska—Dr. Howard Feder; Alaska Department of Fish and Game—Timothy Koeneman; Hawaii Institute of Marine Biology—Dr. Richard Grigg

Accomplishments: The investigation confirmed the hypothesis that the coastal rocky areas of southeastern Alaska are important as nursery areas for juvenile rockfish. Schools of literally thousands of juvenile rockfish identified as Pacific Ocean perch were observed. These fish were estimated to be young of the year and averaged about an inch in length. Information was obtained on the habitat occupied by both juvenile and adult rockfish. A small, unidentified gorgonian was observed in small numbers on the Cross Sound reef and on the Goff Rock dives.

Visibility was generally poor (3 to 15 ft). The bottom was heavily covered with silt, indicating a generally poor or marginal habitat for the precious coral, although occasional specimens have been collected by fishermen in the area. Vertical stratification of invertebrates such as shrimp, brittle stars, and juvenile halibut were documented (see Figure 20).

It was found that the submersible was an appropriate vehicle for observing both habitats, but not for "blind" searches for gorgonians and similar organisms that may have restricted habitats.

Cosmic Ray Photo Emulsion Detector Deployment Missions

Date: October 4-7, 1977; March 16-19, 1978; October 2-7, 1978

Facilities and Operations: R/V *Sea Diver*, R/V *Johnson*, Submersible *Johnson-Sea-Link I*; bottom-sitting cosmic chamber

Location: Off Grand Bahama Island, lat. 26°41'4" N, long. 70°00'8" W

Purpose: The purposes of the missions were to deploy, via lockout from the *Johnson-Sea-Link*, photographic emulsion detectors on the ocean floor in order to "capture" cosmic ray particles such as mu mesons (muons). These particles reveal their energies and origins in their microscopic trails in the emulsions.

Sponsors: NOAA and Harbor Branch Foundation, Ft. Pierce, Florida

Participants: OOE/MUS&T—Dr. Kurt Stehling; U. of Washington—Dr. Jere Lord; WWU—Dr. Peter Kotzer

Comments: The science and technology of these missions are described in "Applied Technology and Advanced Concepts." See also K. Stehling, "A Submersible Physics Laboratory Experiment," NOAA Technical Report OOE 1, Jan. 1979.

X-Ray Fluorescence Probe Evaluation

Date: June 26-30, 1978

Facilities: R/V *Johnson, Johnson-Sea-Link I*

Location: Southeast Florida outfalls

Purpose: Assess X-ray fluorescence technology for pollutant trace metals on the sea floor.

Sponsors: NOAA and Harbor Branch Foundation

Participants: Battelle-Northwest Laboratories—Ned Wogman, Principal Investigator; Harbor Branch Foundation—Dr. R. Jones; MUS&T—William Muellenhoff.

Comments: This mission is described under "Applied Technology and Advanced Concepts."

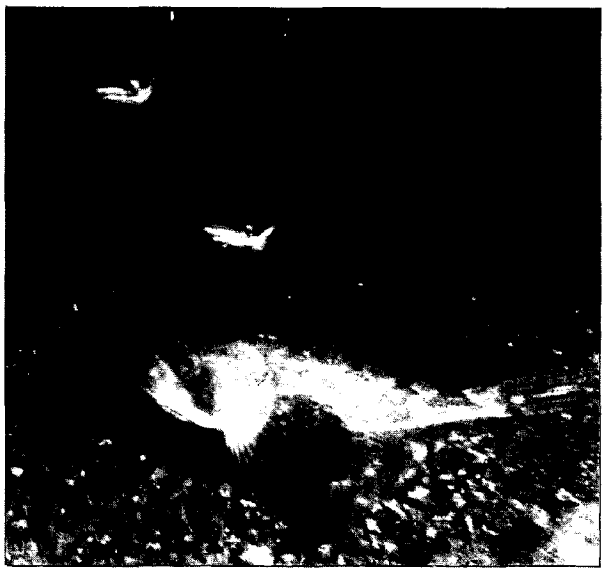


Figure 20.—Sculpins (*Cottidae*) on the Bottom of Frederick Sound, Alaska

HYDRO-LAB REGIONAL PROGRAM SCIENCE MISSIONS

Extensive research, sponsored by NOAA and other agencies, is being conducted in U.S. coastal waters on a wide range of environmental problems of national significance. As a part of this ongoing research effort, NOAA initiated a cooperative national manned underwater laboratory regional program designed to provide facilities (underwater laboratories) and technical support to these scientific missions, with the *Hydro-Lab* at St. Croix as the first step*.

The first announcement of opportunity for science missions using saturation diving was sent to the U.S. science community in November 1977. Thirty-one indications of interest were received prior to the first peer review meeting in February 1978. Fourteen proposals were reviewed at this meeting and nine proposals accepted.

The second peer review meeting was held in August 1978. Eleven proposals were reviewed at this meeting and eight proposals accepted. Eight missions were completed in 1978 during which twelve science projects were conducted. These missions are summarized in Table 22. Those science projects completed in FY 1978 (through September 30, 1978) are discussed in the following paragraphs. At the end of 1978 the *Hydro-Lab* habitat was removed from the sea floor for refurbishment and American Bureau of Shipping classification.

Following are concise descriptions of the scientific missions undertaken in the *Hydro-Lab* habitat during FY 1978. The reports are presented chronologically. The specific location for all missions is Salt River Canyon, St. Croix, U.S. Virgin Islands (see Figure 21).

*A grant was awarded by NOAA to Fairleigh Dickinson University's West Indies Laboratory at St. Croix, U.S. Virgin Islands, to provide the support to operate the *Hydro-Lab*.

Comparative Study of Chaetodontid Foraging Patterns

Date: May 25-June 2, 1978

Purpose: Obtain quantitative behavioral, distribution, and feeding data for some chaetodontid and pomacanthid fishes as part of a larger comparative study of the niche dimensions and overlap among species in these families between relatively comparable reef communities in the Caribbean and Indo-West Pacific.

Participants: U. of Guam—Charles Birkeland, Principal Investigator, and Steve Neudecker

Accomplishments: A microscopic examination of the stomach contents of fishes was done to provide verification of the field observations on foraging behavior. Individual fish were observed for 5-minute intervals to obtain samples of feeding habits. Several individuals, each of *Chaetodon capistratus* and *Prognathodes aculeatus,* were observed near the transects at 15.2- and 30.5 m (50- and 100-ft) depths along the east and west canyon walls during both morning and late afternoon. It was found that, despite traditional conceptions of fish feeding patterns in the Caribbean, one of the species studied fed predominantly on scleractinian corals.

The Role of Light in Nocturnal/Diurnal Changeover Patterns of Certain Coral Reef Fishes

Date: June 10-17, 1978

Purpose: Test the hypothesis that fish respond directly to light intensity each time they enter or leave their shelters.

Participants: Sarah Lawrence College—Raymond D. Clarke; Fordham U.—George Dale

Accomplishments: Technical—Two recording hydrophotometers were designed and constructed specifically for this project. These instruments were capable of

Table 22—Cooperative National Regional Underwater Laboratory Program *Hydro-Lab* FY 1978 Science Projects (through Sept. 30, 1978)

Investigating Institution	Dates (1978)	Project
University of Guam	May 25-June 2	Tropical Fish Feeding Patterns
Sarah Lawrence College Fordham University	June 10-17	Coral Reef Fish Reactions to Light
American Museum of Natural History	June 10-17	Colonization Behavior of Coral Reef Fishes
University of Puerto Rico	July 24-31	Diurnal Changes in Distribution and Abundance of Herbivorous Fishes
Department of Agriculture, Puerto Rico	July 24-31	Diurnal Changes in Distribution and Abundance of Carnivorous Fishes
University of Texas	September 1-7	Reaction of Squid and Octopus to Variations in Light Levels
University of Puerto Rico	September 18-25	Spawning of Western Atlantic Reef Fishes and Coral Distribution in the Salt River Canyon

recording light levels three orders of magnitude lower than the minimum level observable by the unaided human eye. *Scientific*—The experimenters used artificial lighting to illuminate the study reef just prior to the normal evening changeover in fish assemblage from diurnal to nocturnal. The lighting seemed to delay the changeover but not prevent it. When the reef was darkened prematurely by the experimenters, many of the changes associated with evening changeover were initiated.

One of the striking features observed was the rapidity with which the diurnal assemblage of fish was replaced by the nocturnal assemblage (18 minutes) and vice versa (15 minutes). This replacement did not include a quiescent period, as some experimenters have reported; on the contrary, there was a period when the nocturnal and diurnal fishes were intermixed over the reef. For the first time, light intensity measurements showed a correlation between light intensity and a predictable sequence of changeover events, supporting the theory that nocturnal fishes use light intensity as a cue for the onset of changeover behavior. The diurnal fish seem to be less dependent on light intensity, though it may still be important in controlling activity patterns.

Regulatory Mechanisms in Coral Reef Fish Communities

Date: June 10-17, 1978

Purpose: Determine whether habitat selection is a function primarily of size or of species-specific advantages.

Participants: American Museum of Natural History—C. Lavett Smith, James C. Tyler

Accomplishments: After preliminary censusing of five separate reef patches, selected individuals representing six species of fish (four gobies, two blennies) were removed from their habitats. Subsequent observations revealed that none of the spinyhead blennies—which have a very specialized habitat in abandoned worm tubes—were replaced. Areas from which less specialized fishes were removed, however, were filled within 3 days. The rate of recolonization is apparently influenced by the availability of recruits that have recently transformed from the pelagic larval stage. Therefore, there should be a strong seasonal effect on recolonization patterns.

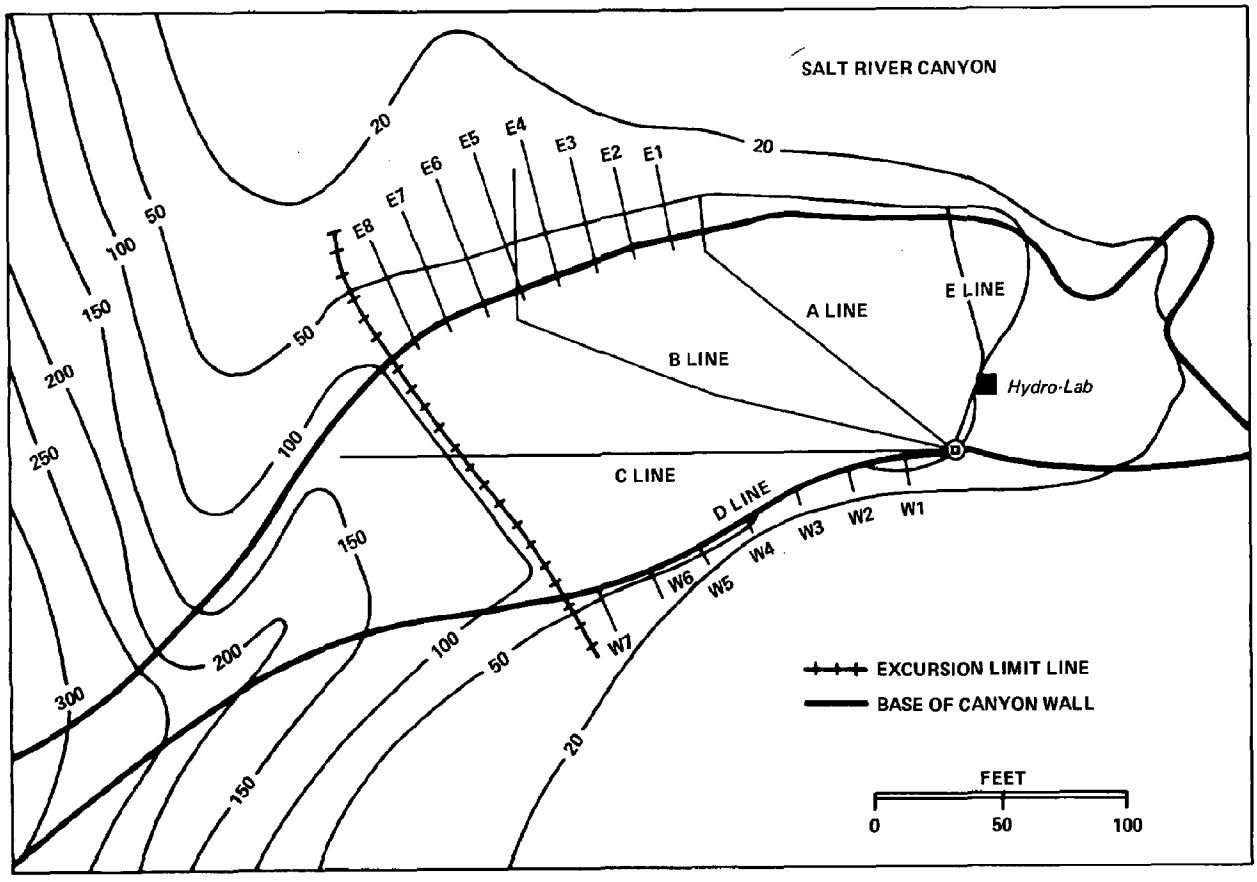


Figure 21.—Transect Location Map for *Hydro-Lab* Scientific Missions

Diel and Depth Variation in the Population Densities of Herbivorous Fishes

Date: July 24-31, 1978

Purpose: Determine the variation in the population densities of herbivorous fishes in relation to food resources and depth along the east and west walls of the Salt River Canyon.

Participants: U. of Puerto Rico—Ileana E. Clavijo, Principal Investigator

Accomplishments: The results of the study show that species diversity and abundance of herbivorous fishes decreases with increasing depth. Three families of herbivorous fishes were represented in the canyon: damselfishes, surgeonfishes, and parrotfishes. The parrotfish, *Sparisoma aurofrenatum*, was most abundant on the east wall at depths of 15 m. The surgeonfish, *Acanthurus bahanius*, was more abundant on the east wall than the west wall; the opposite was true of the closely related doctorfish, *A. chirurgus*. These two species have nearly identical diets; the differences may be due to competitive exclusion or habitat preference. The parrotfishes observed appeared not to utilize the food resources on the canyon walls.

Herbivorous fishes, especially species in the family *Scaridae*, are not limited to shallow depths in their distribution. The abundance of scarids decreases with increasing depth due mainly to the decrease in the quantity rather than the quality of plant foods. Certain migratory species utilize deeper areas for shelter rather than for feeding.

Diel and Depth Variation in Population Densities of Commercially Important Carnivorous Fishes

Date: July 24-31, 1978

Purpose: Investigate population densities of commercially important carnivorous fishes along the walls of the Salt River Canyon. Examine variations in densities over depth and time of day.

Participants: Commercial Fisheries Laboratory, Dept. of Agriculture of Puerto Rico—Deborah Arneson, Principal Investigator, and University of Puerto Rico—Linda Meiklejohn

Accomplishments: Thirty-seven species of fishes were recorded from eleven families. Each of the following families contributed more than 10 percent of the total number of fishes recorded for each wall (east = 275, west = 540): *Lutjanidae* (snappers), *Serranidae* (groupers), *Pomadasyidae* (grunts), *Mullidae* (goat fishes), and *Carangidae* (jacks).

For total number of fishes, there appeared to be no statistically significant differences over time or depth or between most of the transect areas. Bottom type seemed to be the most important factor influencing numbers of fishes.

Response of Squids to Night Lights and Reef Behavior of Octopuses

Date: September 1-7, 1978

Purpose: Study the behavior and ecology of cephalopods: determine the behavioral responses of squids to various night lighting schemes, and evaluate the role of the octopus as a prominent night predator.

Participants: U. of Texas—Roger Hanlon and Raymond Hixon

Accomplishments: Four squid species were attracted to night lights set up by the experimenters. Observations of their behavior near the underwater lamp indicated that all species were attracted individually and not as a school, and that they did not subsequently group together. They seemed to be in a dazed or mesmerized state (see Figure 22).

The Salt River Canyon does not support as large an octopus population as other reef areas observed in the Caribbean. Three species of benthic octopuses were present in the area; all three are nocturnal. Two of the species were found only in the restricted habitat characterized by cobble-filled tributaries with slope angles of approximately 15 to 20 degrees. Various aspects of their hunting and movement patterns were observed. During the dive, several octopuses were collected for laboratory observation. One larval species was collected and taken to the U. of Texas for rearing. If successful, it will be a first, and the experimenters will be able to determine what this animal looks like as an adult, something unknown throughout 40 years of investigation of that species.

Spawning of Western Atlantic Reef Fishes

Date: September 18-25, 1978

Purpose: (1) Investigate the occurrence and duration of spawning by western Atlantic marine shore fishes. (2) Determine behavior and movement of various species before, during, and after spawning. (3) Collect eggs of selected species for larval rearing.

Participants: U. of Puerto Rico—Patrick Colin, Principal Investigator, A. Charles Arneson, and Ralf Boulon, Jr.

Accomplishments: Definite spawning was observed for seven species of fishes, all in a limited area within 100 m of the east wall "tank drop" area. Potential courtship was observed in several other species, but no definite spawning was observed.

Observations were made at various locations and times of day, with emphasis on the late afternoon period. With dawn representing 0% day and sunset representing 100% day, the most intensive observations were made during the period from 80-100% day, and then extending to 2.5% night (using the same system). This relative day length (RDL) measurement system is useful for comparison with similar observations at different locations and different times of year.

During the dive, 52 definite spawning events were observed. Results correlated well with those gathered by

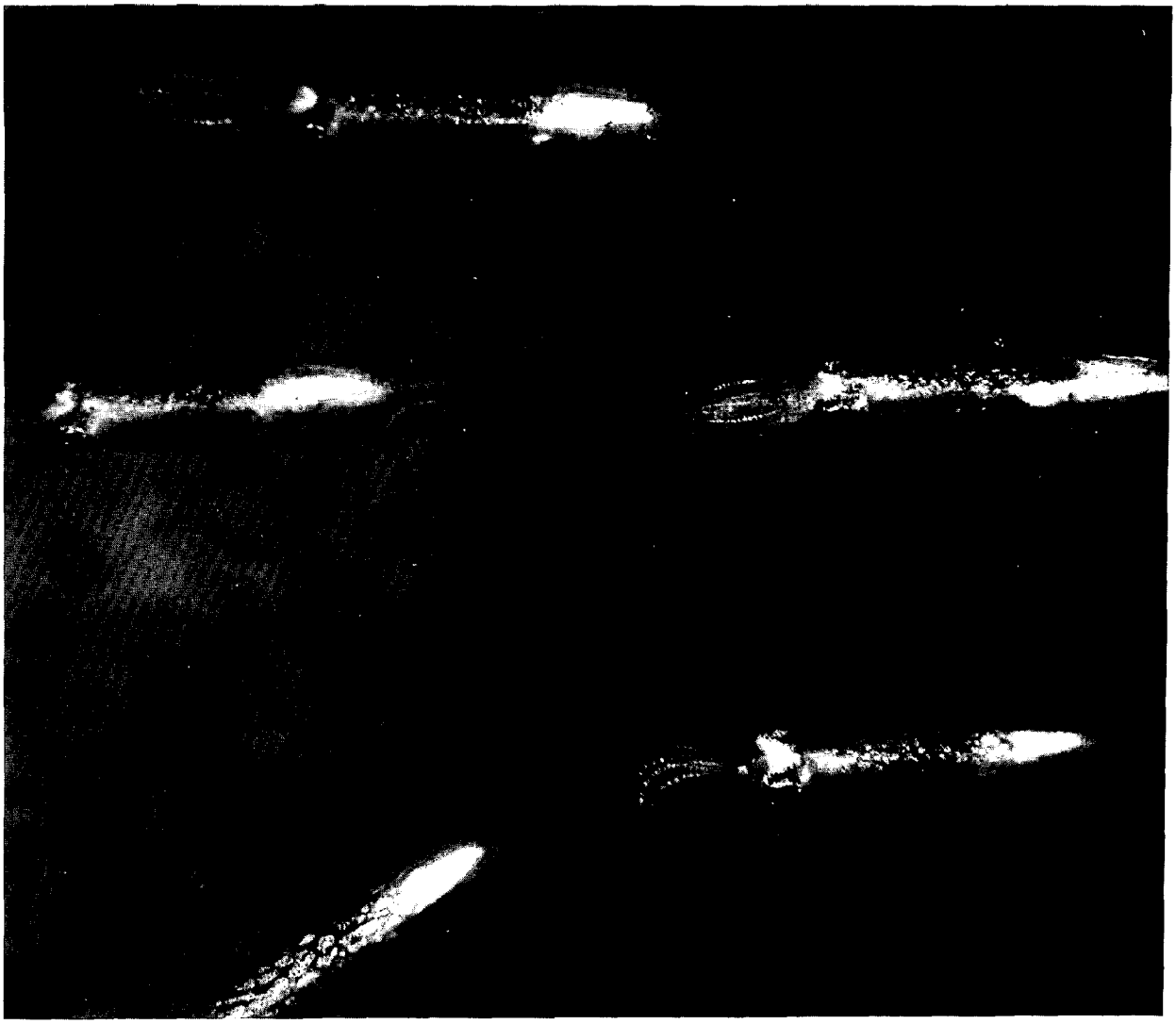


Figure 22.—School of Squid (*Loligo plei*) under a night-light station

Principal Investigator Colin in Puerto Rico. In addition, the ability to observe complete courtship and spawning cycles confirmed many of the preliminary but untested hypotheses based on segmented observations of each cycle on a number of different dives.

Several relatively uncommon marine invertebrates were found in the west wall area. These included the small lobster *Palinurellus gundlachi* and various slipper lobsters. The lobster *Justitia* was particularly common in reef caves outside the excursion limit line on the east wall.

Coral Distribution in the Salt River Canyon

Date: September 18-25, 1978

Purpose: Determine the gross distribution of scleractinian corals on the walls of the Salt River Canyon, and compare the coral distributions of the east and west walls.

Participants: U. of Puerto Rico—Patrick Colin, Principal Investigator, A. Charles Arneson, and Ralf Boulon, Jr.

Accomplishments: Percentage of coral cover was tabulated for the most abundant species along with total distance photographed. A list of coral species was compiled from observations made during excursions. The east and west walls of the canyon differ markedly in percentage of coral cover; this may be due to the differences in substrate and vertical profile. The east wall exhibited a change in coral distributions which appears to be related to the change in vertical profile and substrate characteristics. The west wall was fairly uniform in coral coverage, with an increase in its outer portions due to the increased abundance of large, platelike *Agaricia* species on the deeper portions of the wall. A relatively high number of Western Atlantic hermatypic corals (at least 26) and some of the more common shallow water ahermatypic corals were found in the canyon.

Comparison of Mediterranean and Caribbean Benthionic Biological Systems

Date: October 9-16, 1978

Purpose: (1) Study the ocean-floor behavior of two current-oriented plankton nets; compare samples every 6 hours. (2) Study growth of different species of *Caulerpale* (algae) and the increase of thalles by first making 12 plantings in 1-m^2 areas and then harvesting one planting per month. (3) Measure the oxygen consumption and production on a selected area to study the metabolism rate of certain species and subsystems.

Participants: U. of Nice (France)—Prof. Raymond Vaissiere, Principal Investigator, Dr. Alexandre Meinesy, and Dr. Claude Falconetti; U. of Liege (Belgium)—Dr. Daniel Bay

Accomplishments: The investigators are still analyzing their results, which are expected to be published in mid-1979.

INTERAGENCY AND INTERNATIONAL ACTIVITIES

NOAA has continued to cooperate with other federal agencies with interests in underwater activities and has participated in the manned underwater activities of international oceanographic cooperative programs.

As noted in the Fiscal Year 1976 Report, NOAA has served as a coordinating mechanism for civil federal agency program activities involving the use of manned underwater platforms. The results of a continuing assessment of these program activities are presented in the Requirements and Systems Analyses section of this report, as are the utilization and status of undersea platforms through FY 1978. NOAA's use of manned underwater platforms for underwater physics research has been a multi-agency effort, including cooperation with the Department of Energy (DOE) and the Office of Naval Research (ONR) of the U.S. Navy, as cited in the Applied Technology and Advanced Concepts section of this report. Of particular importance has been NOAA's continuing cooperative efforts with the U.S. Navy diving program, as noted in the Operational Effectiveness and Safety section of this report—particularly in physiology, medicine, and diving technology.

This section presents additional major programs involving interagency and international activities.

RESEARCH SUBMERSIBLE *ALVIN/LULU* SYSTEM SUPPORT

The U.S. Navy-owned *Alvin/Lulu* deep research submersible/support ship system is operated by the Woods Hole Oceanographic Institution under a grant from the National Science Foundation (NSF) with support from NOAA and the U.S. Navy's Office of Naval Research (ONR). The initial three year agreement for calendar years 1975-1977 operation of the *Alvin/Lulu* system as a national oceanographic facility under the aegis of the University National Oceanographic Laboratory System (UNOLS) was renewed for another three years (1978-1980) by NSF, NOAA, and ONR. In the new agreement, the three agencies guarantee utilization of the system for not less than 150 use days per calendar year, with NSF responsible for 90 use days and NOAA and ONR 30 use days each. The NOAA projects in calendar 1976, described in the MUS&T Fiscal Year 1976 report were funded from FY 1977 appropriations. The calendar year 1977 *Alvin* missions studying benthic fishes in the Tongue of the Ocean, the sedimentary processes and stratigraphy of the Great Abaco Canyon, continental shelf slump physiography in Baltimore Canyon, and biological processes in Atlantis Canyon, were funded from FY 1978 appropriations (see "Marine Science Applications"). The calendar year 1978 *Alvin* missions, studying sediment transport coupling near Cape Hatteras, further continental slump physiography in Baltimore Canyon, and biological processes in Oceanographer Canyon were funded from FY 1979 appropriations (see "Marine Science Applications").

Science proposals for *Alvin* missions are solicited from NOAA major program elements such as the Atlantic Oceanographic and Meteorological Laboratories and the Pacific Marine Environmental Laboratory of the Environmental Research Laboratories, components of the Office of Research and Development, the National Ocean Survey, and the research centers of the National Marine Fisheries Service. These science proposals are evaluated by a Scientific Program Review Committee of NOAA scientists with expertise in the major oceanographic disciplines. The proposals are evaluated against the unique capabilities of the *Alvin* system [e.g., depths to 3660 m (12,000 ft)] and agency goals and objectives. The results of the NOAA evaluation are forwarded to the UNOLS DRV Review Committee which meets each spring for scientific evaluation of all proposals for *Alvin* use to determine the calendar year program formulation and scheduling for the subsequent operating year. Supporting agency recommendations (based on in-house reviews) play a key role in formulating the annual schedule.

SUBMERSIBLE SAFETY

NOAA, together with the U.S. Navy, supported the U.S. Coast Guard's Underwater Safety Project in the Office of Merchant Marine Safety in its contract with the Marine Technology Society (MTS) to prepare a handbook of guidelines for the operational safety of submersibles. The results of this three-agency-supported contract will include inputs from leading experts in the

submersible industry from the United States, Canada, and Europe and will be published as the third volume in the MTS series, "Safety and Operating Guidelines for Undersea Vehicles." Included will be the results of an international symposium to improve the operating safety of undersea vehicles and rescue response activity. The symposium was preceded by meetings in which groups (composed of experts in the undersea vehicle field) drafted standards for the safe operation of undersea vehicles. The symposium will produce (on the basis of the draft standards) international consensus safety standards for undersea vehicles. The major categories in which guidelines are to be established are Personnel, Plans and Procedures, and Equipment.

NOAA requires that all the U.S. submersibles it leases must have ABS classification or U.S. Navy certification. This establishes an acceptance level of submersible characteristics and capabilities, including design and construction integrity, safety and emergency capabilities, and proof of hydrostatic testing. Depending on the NOAA mission, various other requirements such as the extent of life support, endurance, and type of communications are often stipulated beyond ABS minimums. In addition, all diving operations are reviewed by the NOAA Diving Safety Board to assure conformance with NOAA safety diving systems. The activity in the undersea vehicle field now centered in the North Sea area is expected to shift as exploration of U.S. domestic sources of subsea energy expands. Development of safety standards for construction, equipping, and operation of undersea vehicles, as well as coordination of rescue efforts in the case of distressed submersibles, is the responsibility of the Coast Guard.

NOAA also joined the U.S. Navy and the U.S. Coast Guard in supporting a study by R. Frank Busby Associates, under Navy Contract N 68463-77-C-0085, which resulted in a July 1978 report, "Review of Manned Submersibles—Design, Operations, Safety and Instruments."

UNOLS RESEARCH SUBMERSIBLE FACILITY REQUIREMENTS STUDY

NOAA has joined with the National Science Foundation (NSF) and the Navy's Office of Naval Research (ONR) to fund a UNOLS-sponsored study entitled "Research Submersible Facility Requirements for Short- and Long-Term Needs within the U.S. Scientific and Technical Community."* Beginning in 1977, the UNOLS *Alvin* Review Committee worked with representatives from ONR, the Office of Oceanographic Facilities and Support in NSF, and the MUS&T Office to establish the requirements for this independent study. As stated in the work statement approved by the UNOLS Advisory Council:

> The purpose in undertaking this study is to assess the current and projected requirements for UNOLS submersible science facilities; to review the alternatives to meet these needs; and to recommend specific systems both in the short and long term, along with priorities and associated costs. Specifically, to establish priorities and costs with regard to:
>
> 1. Identification of short-term needs and directions for UNOLS submersible science and engineering:
>   a. What is the useful expectancy of the present facilities meeting UNOLS' needs (*Alvin* and present *Lulu*).
>   b. What options exist for improvement within the short term.
> 2. Identification of long-term needs and directions:
>   a. What are the specific capabilities the scientific community will be looking for.
>   b. What options exist for meeting these needs.

The objective of this study is to develop a comprehensive facilities plan which identifies and satisfies UNOLS submersible science requirements from the present through the year 1980. The plan will consider *Alvin/Lulu* modifications, leasing of submersible systems, or capital expenditures for reactivation of existing facilities and/or construction of new or additional systems, as well as plans for maintenance and operations.

The plan will involve (1) assessing the needs for and a review and analysis of projected ocean science and technology research programs, and hence to define current and future UNOLS submersible facility requirements, (2) the definition of alternative operational systems (submersible, support ship, and handling equipment) capable of satisfying the requirements identified in (1), and (3) completion of detailed cost-effectiveness analyses resulting in recommended operation systems, including a discussion of arrangements for operational and scientific program management.

It is assumed that the facilities for which a need is defined will be National Oceanographic Facilities available for use by qualified scientists from any institution (academic, government, and other appropriate institutions) through an allocation procedure of a UNOLS Review Committee. In addition to determining the needs of the academic ocean science and technical community for research facilities (such as those within NSF), the survey effort will include civilian government agencies (e.g., NOAA, DOE, EPA, USGS, DOT, BLM) and the U.S. Navy through the Office of Naval Research.

The assessment of existing operational systems and their components will include a determination of the general specifications and status of current and recently active U.S. submersibles and foreign civilian submersible systems which represent advanced developments in the design of submersibles, support vessels, and handling equipment. The study emphasis shall be on conventional manned submersibles.

The study is to be conducted as a UNOLS-sponsored effort, organized by the UNOLS Advisory Council and the *Alvin* Review Committee in behalf of UNOLS, the three federal agencies, and the U.S. scientific and

*Short-term refers to utilization (or updating) of existing facilities. Long-term refers to replacement and/or procurement of new facilities. This study should identify the associated time-frames.

technical research community. Three components are to be established for the effort:

1. A Submersible Science Assessment Panel (Science Panel)
2. A Submersible Science Facilities Planning Task Force (Task Force)
3. A UNOLS Submersible Study Project Office (Project Office)

The Science Panel's major responsibility will be to assess the role submersible science plays in the larger context of ocean science and technology research and to define the scientific requirements, if any, for UNOLS Submersible Facilities in the short and long term. The Task Force's major responsibility will be to use the assessments of the Science Panel to develop the mission requirements (if any) for science submersible(s) and develop specific recommendations, if warranted, for UNOLS Submersible Facilities in the short and long term. The Project Office, funded by an NSF grant supported by NOAA and ONR, will provide staff and technical support to the Science Panel and the Task Force, and shall coordinate the study and produce the final report.

NATIONAL DIVING SAFETY RESEARCH

As noted in a recent National Research Council Assembly of Engineering Marine Board Report, diving safety is the area where national and NOAA needs most nearly coincide.* As discussed in this and previous MUS&T fiscal year reports, NOAA's funding for research on shallow saturation decompression tables and for development of tables for excursion dives from a saturation base has produced useful decompression protocols for this type of diving. This could only have been done with the cooperation of the U.S. Navy. NOAA's role in advancing the safety of diving for civilian scientific purposes is further evidenced by the standards and operating criteria for the safety of NOAA divers published in the NOAA Diving Manual and its first complete revision to be published in late 1979. As noted in the MUS&T Fiscal Year 1976 Report, NOAA has been working closely with the Department of Health, Education and Welfare's National Institute for Occupational Safety and Health (NIOSH) concerning safety standards for commercial divers. The publication of the "National Plan for the Safety and Health of Divers in their Quest for Subsea Energy" by the Undersea Medical Society (UMS) in January 1976 was supported by NIOSH, the National Heart and Lung Institute, the Environmental Protection Agency (EPA), NOAA, and ERDA, now the Department of Energy (DOE).

*"The Manned Undersea Science and Technology Program—An Approach," A Marine Board NRC report dated October 1976 supported by Department of Commerce Contract No. 5-35219 to the National Academy of Sciences.

Beginning in FY 1976, funding has been provided by ERDA, and now DOE, for national diving safety research projects which were cited in the UMS National Plan as priority items. NOAA has supported the following projects through Department of Commerce contracts and grants using DOE funding, most of which are described in the Operational Effectiveness and Safety section of this report: Hyperbaric Training for Physicians—through 1978, five courses will have been given through the UMS; Emergency Medical Technician/ Diving Training Evaluation; Diver Technican Training at the Florida Institute of Technology; coordination of a Nationwide Diving Accident Network; and continuation of the UMS Biomedical Advisory Services.

NOAA has continued to work with the U.S. Coast Guard and NIOSH in their efforts to develop diving safety standards for commercial divers responsive to their legislatively mandated roles and jurisdictions. At the end of FY 1978 (September 18, 1978), the Outer Continental Shelf Lands Act Amendment of 1978 was signed into law as Public Law 95-372. Section 21(e) of Section 208 of Title II of this Act tasks the Secretary of Commerce with the responsibility to "conduct studies of underwater diving techniques and equipment suitable for protection of human safety and improvement of diver performance." This responsibility was assigned to NOAA by the Secretary of Commerce on February 13, 1979. In order to fulfill this responsibility, NOAA, with the assistance of representatives of seven other federal agencies, is preparing a plan which identifies suggested areas of study.

In the development of this plan, comments and advice will be actively solicited not only from the academic community and private industry, but from all concerned entities, to ensure that studies undertaken will contribute to improvements in human safety and the performance of divers involved in offshore diving in the Outer Continental Shelf regions. Accordingly, comments on the plan will be sought with respect to the general objectives and research and development programs cited as well as suggestions pertaining to the relative priority of programs.

To facilitate communication between the federal government and the private sector, public forums and workshops are planned, at which time interested persons may attend for the purpose of submitting written and/or oral comments on drafts of the plan.

The Outer Continental Shelf Lands Act Amendments of 1978 were signed into law "to establish a policy for the management of oil and natural gas in the Outer Continental Shelf; to protect the marine and coastal environment; to amend the Outer Continental Shelf Lands Act; and for other purposes."

The "Outer Continental Shelf" as used in this Act means that portion of the continental margin lying beyond state boundaries but within U.S. federal jurisdiction. The continental margin consists of the continental shelf, the continental slope, and the continental rise. Bounding the continental margin is the land (continent) on one side and the deep seabed on the other (see Figure 23). A more specific definition of the

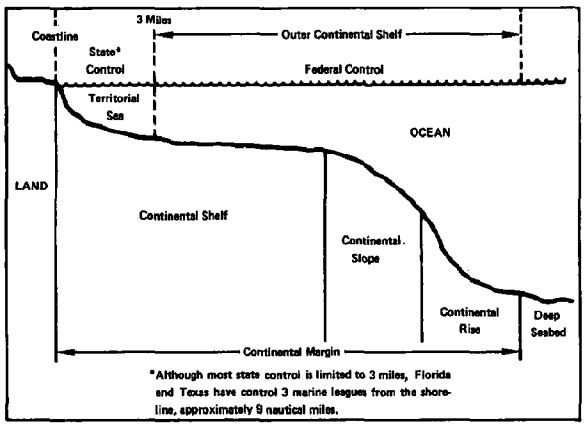


Figure 23.—Profile of Continental Margin

Outer Continental Shelf (OCS) is difficult because the legal meaning of the term "continental shelf" is inconsistent with the general scientific meaning, i.e., variations in the state jurisdiction (some states have 3-mile limits while others have 3 marine league limits), depth of water, and location and classification of shelf resources.

Section 21 of the Act establishes procedures for study, review, coordination, and, if necessary, revision of safety regulations to promote safety and health in the exploration, development, and production of the minerals of the Outer Continental Shelf. Section 21(e) states:

> The Secretary of Commerce, in cooperation with the Secretary of the Department in which the Coast Guard is operating, and the Director of the National Institute for Occupational Safety and Health, shall conduct studies of underwater diving techniques and equipment suitable for protection of human safety and improvement of diver performance. Such studies shall include, but not be limited to, decompression and excursion table development and improvement and all aspects of diver physiological restraints and protective gear for exposure to hostile environments.

In accordance with Section 21 of Section 208, of Title II, paragraph (e) of the Act, the draft plan for this program was developed by the three lead agencies, National Oceanic and Atmospheric Administration (NOAA), the Coast Guard, and the National Institute for Occupational Safety (NIOSH), with the assistance of the Navy; the Occupational Safety and Health Administration (OSHA); National Heart, Lung and Blood Institute; the Department of the Interior (DOI), and the Department of Energy (DOE).

UNITED STATES-JAPAN PROGRAM

NOAA has continued its United States-Japan Cooperative Program in Natural Resources (UJNR), and OOE/MUS&T participates in the Panel on Diving Physiology and Technology, with Dr. James W. Miller as U.S. Co-Chairman. A fourth joint meeting of the Panel was held in Buffalo, New York, in May 1977. A report on the proceedings of that meeting has been published with papers presented as follows:

1. Review of Hyperbaric Physiology at the State University of New York and Buffalo, by Hermann Rahn, M.D.
2. Review of the Diving Physiology and Technology Program of JAMSTEC, by Motohiko Matsuda, M.D.
3. The Present State of Diving Fisheries in Ariake Bay, by Ichiro Nashimoto, M.D., Yoskiyuki Gotoh, M.D., and Akinori Morita, M.D.
4. Diving Activities in Support of Coastal Research, Pacific-Arctic Branch of Marine Geology, U.S. Geological Survey, by H. Edward Clifton, Ph.D.
5. Work Systems for Submersible, by David E. Adkins
6. The Challenge of Writing a Standard for Decompression, by R. W. Hamilton, Jr., R. E. Peterson, K. H. Smith, and M. Beckett Kent
7. Pathological Review of Osteonecrosis in Divers, by Mahito Kawashima, M.D., Takehika Torisu, M.D., Ko Hyashi, M.D., and Motoo Kitano, Ph.D.
8. The Osteonecrosis Problem, by J. Leon Sealey, M.D.
9. Technology Applications in Diving Support of Offshore Operations, by C. J. Lambertsen, M.D.
10. JIM—An Armored Diving Suit, by Arthur J. Bachrach, Ph.D.
11. Physiological Responses to Head-Out Immersion in Water at 11 ATA (A Report on the Third UH-JAMSTEC Cooperative Dive), by Suk Ki Hong, Ph.D., and M. Matsuda, M.D.
12. Ultrasonic Doppler Detection of Blood Bubbles in Caisson Workers, by Ichiro Nashimoto, M.D., Yoshiyuki Gotoh, M.D., and Akinori Morita, M.D.
13. Survey of Decompression Sickness in Compressed Air Workers, by Akinori Morita, M.D., Yoshiyuki Gotoh, M.D., and Ichiro Nashimoto, M.D.
14. Dissolved Carbon Dioxide: Evidence for a Significant Role in the Etiology of Decompression Sickness, by Joseph S. D'Arrigo, M.D.
15. Problems Around the Job Site: Treatment of Decompression Sickness in Compressed Air and Diving Working, by Ichiro Nashimoto, M.D., and Yoshiyuki Gotoh, M.D.
16. Revised Ordinance on Prevention of Compressed Air Hazards, by Yoshihiro Miyano, M.D.

At the first meeting of the UJNR (the United States-Japan Cooperative Program in Natural Resources) Panel on Diving Physiology and Technology held in Tokyo in September 1972, a need for developing a U.S.-Japan cooperative research program in the field of diving and hyperbaric physiology and technology was

recognized. Subsequently, such a cooperative program was developed between the University of Hawaii (UH) and the Japan Marine Science and Technology Center (JAMSTEC) in 1973, and three cooperative saturation dives were carried out as follows:

1. Saturation dive at 7 ATA (Seatopia) in 1973: JAMSTEC sponsored this dive and 4 UH scientists participated.
2. Saturation dive at 18.6 ATA (Hana Kai II) in 1975: UH sponsored this dive and 4 JAMSTEC scientists participated.
3. Saturation dive at 11 ATA (Seatopia) in 1975: JAMSTEC sponsored this dive and 6 UH scientists participated.

These dives were designed to study primarily the effects of a prolonged stay in the hyperbaric helium-oxygen environment on certain physiological functions (e.g., energy exchange, body fluid exchange, and cardiorespiratory function) and resulted in the publication of the following scientific articles:

1. Matsuda, M., et al. 1975, Physiology of man during a 10-day dry heliox saturation dive (SEATOPIA) to 7 ATA. I. Cardiovascular and thermoregulatory functions, *Undersea Biomed. Res.* 2: 101-118.
2. Matsuda, M., et al. 1975, Physiology of man during a 10-day dry heliox saturation dive (SEATOPIA) to 7 ATA. II. Urinary water, electrolytes, ADH, and aldosterone, *Undersea Biomed. Res.* 2: 119-131.
3. Hong, S. K., et al. 1977, Hana Kai II: a 17-day dry saturation dive at 18.6 ATA. I. Objectives, design, and scope, *Undersea Biomed. Res.* 4: 211-220.
4. Webb, P., et al. 1977, Hana Kai II: a 17-day dry saturation dive at 18.6 ATA. II. Energy balance. *Undersea Biomed. Res.* 4: 221-246.
5. Hong, S. K., et al. 1977, Hana Kai II: a 17-day dry saturation dive at 18.6 ATA. III. Body fluid balance, *Undersea Biomed. Res.* 4: 247-265.
6. Matsuda, M., et al. 1978, Physiological responses to head-out immersion in water at 11 ATA. *Undersea Biomed. Res.*, March.

Based on the success of the above cooperative program, it was decided at the third meeting of the UJNR Panel on Diving Physiology and Technology (held in Tokyo in 1975) to expand the scope of cooperation between the two countries. At the same meeting, Drs. Matsuda and Hong were designated as coordinators for Japan and the U.S., respectively, and were charged with the responsibility for developing the next phase of a joint research program. At the fourth meeting of the UJNR Panel on Diving Physiology and Technology (held in Buffalo in 1977), the two coordinators agreed to conduct the next cooperative dive experiment at JAMSTEC in 1979. An initial grant has been issued to the Research Foundation of the State University of New York at Buffalo under the direction of Dr. Suk Ki Hong to develop the plan for a group of U.S. (mostly Buffalo and Hawaii) and Japanese scientists to conduct a simulated saturation diving experiment to be carried out at JAMSTEC in 1979. This will include study of:

1. Effects of a 14-day saturation dive at 31 ATA on:
   a. Energy balance
   b. Body fluid balance
   c. Cardiopulmonary functions
   d. Psychomotor functions
2. Effects of head-out immersion at 31 ATA on:
   a. Thermal balance
   b. Cardiovascular functions
   c. Renal functions

The proposed research will consist of two phases. Phase I will develop the final research plan and will include the results of a survey of the research facilities available in Buffalo, New York, Hawaii, and JAMSTEC, Japan. Phase II will consist of the actual research during the summer of 1979, and it is planned that U.S. diving scientists from the State University of New York at Buffalo and the University of Hawaii will be at JAMSTEC for about a month.

UNITED STATES-FRANCE PROGRAM

Cooperative efforts on man-in-the-sea have been an integral part of the United States–France Cooperative Program of Oceanography, led by NOAA in cooperation with the French Centre National pour l'Exploration des Oceans (CNEXO). The scientific leaders for the man-in-the-sea cooperative effort are M.D. Girard for France (CNEXO), Dr. D.C. Beaumariage for NOAA, and Dr. R.C. Bornman for the U.S. Navy. At the September 1977 meeting in Bandol, France, a report was issued which included the following topics in the man-in-the-sea portion of the overall program.

Man in the Sea

I. *Research in Diving Medicine*

1.1 *Intravascular Bubble Detection*

Objective: To determine ways in which intravascular bubble detectors can be used to help understand decompression, inert gas exchange, bubble formation, and decompression sickness. Both moving and static bubble detectors are under study.

Progress: In July 1977, Capt. Bornmann met with Dr. Guillerm at Centre d'Etudes et de Recherches Technique Sous-Marine (CERTSM) in Toulon. A transcutaneous bubble detector has been developed in France, and its characteristics have been sent to the U.S. A comparison of the U.S. and French decompression tables is planned using this instrument.

Plans: The U.S. Navy is investigating the development of a bubble detector using an alternate physical principle which will permit the detection of nonmoving bubbles within the body by means of an external instrument, for which studies have been encouraging. Reports on the results of new instruments and experiments are planned. France will extend an invitation to the appropriate American scientists to visit CERTSM to discuss instrumentation.

1.2 *High-Pressure Neurological Syndrome*
Objective: To understand the neurophysiological changes which accompany compression to deep depths.

Progress: In September 1976, the U.S. Navy completed a 427-m (1400-ft) chamber dive at the Ocean Simulation Facility in Panama City. Dr. Lambertson in July 1977 visited Toulon. A representative of the U.S. Navy participated as an observer for the October 1977 *Janus IV* deep dive off Toulon.

1.3 *Respiratory Functions*
Objective: To achieve a better understanding of respiratory physiology at great depths.

Progress: Captain Broussolle and Cdr. Le Chuitton visited Bethesda and Panama City in October 1976. Plans for the 1037-m (3400-ft) chamber now being installed at the Naval Medical Research Institute in Bethesda and the planned research program were reviewed.

Plans for a 1000-m research chamber in Toulon were also discussed. In May 1977, Mr. Girard also visited the Bethesda facilities. Captain Bornmann visited Captain Broussolle at CERB in Toulon in July 1977.

Plans: A U.S. and French proposal to exchange scientists for a 12-month period in 1978 or 1979 is under consideration. The U.S. invited a team of French scientists for an experiment using Bethesda's hyperbaric chamber when it is completed. Areas of cooperation could include the measurement of blood and tissue gases by means of hyperbaric mass spectrometry and respiratory problems of diving.

1.4 *Aseptic Bone Necrosis*
Purpose: To understand the cause of aseptic bone necrosis in diving and how it is produced by conditions of diving exposure, and to determine early indications of bone necrosis in divers.

Progress: The initial review by the U.S. Navy of its divers for X-ray changes of aseptic bone necrosis was completed in 1976 with a final report sent to Dr. Merer. Dr. Merer is organizing a similar study of such data in France, which in computerized form will be available in 1979. NOAA is also completing a cooperative study of NOAA divers who have had long-bone X-rays to note the possible presence of bone necrosis. Dr. Spahr and Dr. Merer met in Toulon in July 1977. A representative of the U.S. Navy was to attend the European Underwater Biomedical Society (EUBS) workshop in Paris, in October 1977 and be a member of the dysbaric osteonecrosis committee.

Plans: Compare results from the above studies when available. To extend cooperation, a French radiologist, familiar with X-ray manifestations of aseptic bone necrosis, was added to the Consultant Panel at Groton, Connecticut, for the Fall 1978 meeting. The standardization of data collection and recording procedures was also a subject of discussion.

1.5 *Decompression Sickness*
Plans: Since no exchange of information has occurred, the subject has been abandoned.

1.6 *Tolerance for cold*
Plans: Since no exchange of information has occurred, the subject has been abandoned.

II. Joint Man-in-the-Sea Projects

a) Saturation Diving
1. *Objective:* To utilize the technique of saturation diving for scientific and technological investigations, for example, in deriving necessary ecological and other biological information for fisheries resources management.
2. *Progress:* French diving scientists have participated in saturation diving missions using *Hydro-Lab* in 1974 and 1975 and also the *Helgoland* laboratory near Lubeck in 1974. With the purchase of the *Hydro-Lab* by NOAA and its use for cooperative research and training programs, further opportunities for joint French-U.S. saturation science missions will occur.
3. *Plans:* A possible combined program to evaluate instruments used for benthic metabolic processes connected to man-induced pollution was also examined.

b) Submersible Diving
1. *Objective:* To conduct mutually attractive scientific or technological investigations that depend upon manned submersibles.
2. *Programs:* French scientists have been working independently with scientists from the U.S. including Scripps Institution in preparation for the East Pacific Rise program. The *Alvin,* jointly funded by NSF, U.S. Navy, and NOAA, will be used in 1979 on the above program, as well as French submersible *Cyana* in 1978.
3. *Plans:* Schedules of the planned *Alvin* use in future years and NOAA's use of shallow water submersibles will be made available to CNEXO, and invitations are possible for French scientists and technologists to participate as observers. A planned UNOLS study of future submersible science requirements to be made by NOAA in cooperation with NSF and the U.S. Navy ONR was to be reviewed with CNEXO.

III. *International Safety and Operating Standards for Research Submersibles and Diving*

1. *Objective:* To formulate and establish international safety and operational standards for use of submersible and related undersea platforms and for diving.

2. *Progress:* The U.S. Marine Technology Society (MTS) contract to develop international plans and procedures for standards of submersible operations is well underway. Sponsored by the U.S. Coast Guard, U.S. Navy, and NOAA, meetings were held in May 1977 and May 1978 with three groups, as follows:

   "Personnel Group"—Woods Hole Oceanographic Institution, COMEX, Subseaoil, IUC, Canadian Navy.

   "Operational methods and procedure group"—Vickers, Hyco, Harbor Branch Foundation, CNEXO, NOAA.

   "Equipment Group"—Perry, USN Sub Dev Group One, Intersub, P&O, Horton Maritime.

3. *Plans:* As NOAA's plans for an expanded safety and diving program, which will also be responsive to U.S. diving regulations, develop, they will be made available to CNEXO.

APPENDIX: SURVEY OF FEDERAL-AGENCY CIVILIAN MANNED UNDERSEA ACTIVITIES

This appendix presents the results of a fourth review of the civilian manned undersea activities of the federal agencies. This review summarizes reported programs that have used or definitely plan to use manned underwater facilities as well as those programs that are potential users of such facilities.

REPORTED PROGRAMS

National Oceanic and Atmospheric Administration (Department of Commerce)

Fisheries: Ocean Pulse

Monitor and compare the relative health of waste dumpsites and control sites on the northeast coast. Standardized observation and sampling several times per year will allow assessment of dumping activities related to coastal fishery populations.

Point-of-Contact: NMFS, Northeast Fisheries Center

Remarks: Use existing research submersibles from 46 to 305 m (150 to 1000 ft).

Fisheries: Herring Spawning, Eggbed Dynamics

Investigations to define the timing and location of herring spawning and the dynamics of the eggbeds and ecological factors determining survival.

Point-of-Contact: NMFS, Northeast Fisheries Center

Remarks: Submersible operations will be conducted in water depths from 30.5 to 91.5 m (100 to 300 ft). Diver lockout capability is highly desirable.

Fisheries: Megabenthic Crustacean Biology and Assessment

Assess the abundance and ecology of lobsters, crabs and shrimp; the effects of "ghost pots" and the magnitude of this problem; and calibrate certain types of sampling gear such as otter trawls.

Point-of-Contact: NMFS, Northeast Fisheries Center

Remarks: Submersible operations from 30.5 to 305 m (100 to 1000 ft) and also using deep water research submersible *Alvin*.

Fisheries: Mollusk Assessments

Assess the abundance and ecology of clams, quahogs, and scallops and calibrate such sampling gear as dredges and air lifts.

Point-of-Contact: NMFS, Northeast Fisheries Center

Remarks: Submersible operations from 30.5 to 91.5 m (100 to 300 ft). Diver lockout is desirable.

Fisheries: Offshore Reef Fish Assessment

Define the distribution of coral/rock reefs off Cape Hatteras and qualitatively and quantitatively describe the fish fauna supporting commercial and sport fisheries.

Point-of-Contact: NMFS, Atlantic Estuarine Fisheries Center

Remarks: Use existing research submersible operations in waters 30.5 to 244 m (100 to 800 ft) deep.

Geology: Investigations of Seafloor Physical Properties

Program to obtain in-situ measurements of shear strength, bulk density, pore water pressure, and other mass physical properties of the bottom at ambient pressures. Bottom sampling will include 12.2 m (40-ft) cores that will also be analyzed at ambient pressure to prevent changes resulting from decompression.

Point-of-Contact: Atlantic Oceanographic and Meteorological Laboratory, Miami

Remarks: Initially, investigations are to be carried out in water depths to 91.5 m (300 ft) and then to 305 m (1000 ft). Diver lockout capability is desired.

Biology: Submarine Canyon Ecology and Geology

Assess the abundance and distribution of bottom fauna in submarine canyons; relate faunal distributions to canyon geology and investigate the existence, composition, and interaction of communities maintaining a high concentration of animals (Pueblo Village study).

Point-of-Contact: NMFS, Northeast Fisheries Center

Remarks: Program requires utilization of both a "shallow water" submersible for dives to 305 m (1000 ft) and a submersible with diving capability to 3050 m (10,000 ft). Diver lockout capability is desired.

Department of Energy

RDT&E: X-Ray Fluorescence Pollution Analysis

Program for test and evaluation of an X-ray fluorescent sub-bottom sediment/pollution analyzer. The new instruments look at sub-bottom pollutants and sediment characterization instead of only at the water-sediment interface. Use of a submersible is considered the best way to carry equipment to the seafloor and over given navigational tracks.

Point-of-Contact: Battelle-Northwest, Richland, WA

Remarks: These study programs could utilize submersibles for several weeks per year for over 5 years or more. Submersibles are presently being used for evaluation of the surface sediment analyzer instrument.

Department of the Interior

Geology: Geologic Structure Investigation

Investigation of ocean bottom geologic structures and processes as they may relate to or impact the management decisions of OCS (outer continental shelf) lease blocks for oil exploration and development. Efforts on the Atlantic Outer Continental Shelf have been made to assess geologic hazards as related to production platforms, pipelines, etc., and will continue.

Point-of-Contact: Bureau of Land Management, Division of Marine Assessments, New York

Remarks: Submersibles have been used in previous investigations and will continue to be used if there are no drastic changes in the ongoing program. These efforts have been carried out in conjunction with USGS, Woods Hole, MA.

Geology: Rock Drilling in Deep Reefs

Testing and use of hydraulic rock drill to obtain cores from deep reefs, particularly in the Florida Gulf of Mexico region. Drill has been used by divers but could be modified for submersible work in deeper reef areas.

Point-of-Contact: USGS Oil & Gas Branch, Fishers Island Station, Miami Beach

Remarks: Have used submersible in past operations and would like to continue the work in depths to 610 m (2000 ft).

Geology: Geologic Research

General geologic research on sediments, sedimentation rates, and transport, and related to investigations of geologic hazards such as slumps and slope stability or other critical geologic structures.

Point-of-Contact: USGS Atlantic and Gulf of Mexico Laboratory, Woods Hole, MA

Remarks: Have used submersibles in the past and desire to continue these investigations in Caribbean and Gulf of Mexico areas in depths to 91.5 m (300 ft). BLM funding.

Oil Activity Research: Delineation of Unique Features

This is a study program designed for delineation and surveying of unique biologic and geologic features which should be protected from destruction by oil exploration or production activities. This work is being conducted in the Gulf of Mexico, but will continue into the South Atlantic Region in the near future.

Point-of-Contact: Bureau of Land Management, New Orleans OCS Office

Remarks: This program is funded, has utilized submersibles in the past, and will continue to do so in areas where submersibles are required.

Environmental Protection Agency

Pollution: Ocean Dumping Research

This is an ongoing program related to R&D and regulatory efforts associated with dumping of low-level radioactive wastes, toxic materials, and munitions in the ocean. Have used submersibles in the past and feel that continued use is required.

Point-of-Contact: Office of Radiation Programs

Remarks: Operated to 915 m (3000 ft) off California in late 1977; has used *Alvin* for R&D work in Atlantic. Would like to engage in cooperative efforts with other agencies using manned facilities. Also plan to use remotely manned/operated vehicles.

Pollution: Ocean Dumping

Assessment of the effects and impact of ocean dumping in the Philadelphia and du Pont dump sites off Delaware Bay via observation and sampling. One interest is in solution of sample replicate differences that were obtained via surface techniques. This would entail sampling sand wave ridge and trough sediments and other bottom sampling and monitoring.

Point-of-Contact: EPA Marine Protection Program, Philadelphia

Remarks: Submersibles have been used but sampling has been done primarily from surface ships. It is believed that submersible work is required to complete this project.

Oil Activity Research: Biological Research

Study of the effects of ongoing oil drilling operations and materials on corals, fish, and benthic organisms. The work would be conducted in the Gulf of Mexico and St. Croix, and would entail emplacement and observation of contained organisms near a working well and sampling and collection or organisms and sediments in the same area. Would also expose coral reef community to drilling materials and would monitor effects.

Point-of-Contact: ERL, Sabine Island, Florida

Remarks: Initial studies have been made in the laboratory. On-site research is needed to continue and complete project. These efforts could utilize submersibles and a habitat, depending on the project focus.

National Atmospheric and Space Administration

RDT&E: Neutron Gamma Research

This project requires studies to verify a new "prompt effect" neutron gamma measurement technique which could be used to measure metals in ocean dump sites and to determine mineral concentrations.

Point-of-Contact: NASA/Goddard Space Flight Center, Solar Activity Branch

Remarks: The equipment is ready and could be used on a "ship of opportunity" or with other ongoing bottom pollution or mineral assessment studies using submersibles.

POTENTIAL PROGRAMS

National Oceanic and Atmospheric Administration (Department of Commerce)

Fisheries: Standing Stock Survey; Reefs

Observation and survey of standing stock in reef and benthic communities in the North and Northwest Gulf of Mexico at depths of 200 m.

Point-of-Contact: NMFS, Southeast Fisheries Center

Remarks: Would use existing submersibles.

Fisheries: Harvesting Equipment Evaluation

Bottom studies are needed to evaluate existing tile fish harvesting gear in terms of bottom substrate and catch rate. These surveys would be made in the Gulf of Mexico and South Atlantic.

Point-of-Contact: NMFS, Southeast Fisheries Center

Remarks: These studies could utilize existing submersibles with standard instrumentation suites.

Fisheries: Porpoise/Tuna Relationships

To assess the interrelationships of the location, activity, and common prey items between porpoise and tuna. Especially want to monitor vertical migration of prey items in areas of strong thermocline overlaying an oxygen minimum layer.

Point-of-Contact: NMFS, Southwest Fisheries Center

Remarks: Initial feasibility dives with existing submersible to depths of 305 m (1000 ft) off western Mexican coast.

Fisheries: Seamount Ecosystem Study

Seamount ecosystem study to assess the responsibility of oceanic currents in establishment of large aggregations of food fish. Major program in NMFS and would require extensive surveys of the fish colonies and the physical parameters which relate to the ecosystem.

Point-of-Contact: NMFS, Southwest Fisheries Center

Remarks: These Pacific seamount operations will require use of existing subs as well as lockout diving facilities, but these must have 305 m (1000 ft) depth capability.

Fisheries: Northwest Hawaiian Islands Survey

Long-term program to assess terrestrial, near-shore slope, and pelagic sources of the northwest Hawaiian Islands. Studies will include effects of trawling, analysis of substrate, and population dynamics of spiny lobster.

Point-of-Contact: Southwest Fisheries Center

Remarks: Existing submersibles could be utilized.

Fisheries: Shellfish Surveys

Studies related to understanding of existence and ecosystems of deepwater shellfish which are not presently marketed. Understanding of pertinent parameters would lead to utilization of these deepwater species for food.

Point-of-Contact: Alaska Fisheries Center

Remarks: These studies to 915 m (3000 ft) off the northwest and Alaskan coasts could use existing submersibles.

Fisheries: Harvesting Gear Evaluation

Observation of effectiveness of existing bottom harvesting gear in fishing and unharvested areas. Should lead to improved gear and also development of equipment to harvest unexploited species in Alaskan waters.

Point-of-Contact: Alaska Fisheries Center

Remarks: Depths from 30.5 to 610 m (100 to 2000 ft). Weather would severely restrict use of present submersibles.

Fisheries: Fish Distribution, Alaska

Assessment of nursery and spawning areas of ground fish species and the distribution, behavior, and predator-prey relationships of herring along with the correlation of their acoustic signals as an aid in determining accurate biomass and, thus, proper harvest levels.

Point-of-Contact: Alaska Fisheries Center

Remarks: Depths from 55 to 183 m (120 to 600 ft) using existing submersibles.

Fisheries: Fish Migration, Alaska

Study of fish migration and aggregation in Alaskan submarine canyons. Determine feasibility of placing nets at strategic locations in canyons to capture fish.

Point-of-Contact: Northwest Fisheries Center

Remarks: Two- to three-year observational program. Could use existing submersibles.

Fisheries: Black Cod Distribution

Survey, population dynamics, and design of catch gear of black cod in the Gulf of Alaska.

Point-of-Contact: Northwest Fisheries Center

Remarks: Operations required to 549 m (1800 ft).

Fisheries: Coastal Surveys

Development of extensive long-term programs in coastal regions. Would accept proposals from experts in various fisheries fields and integrate them into the overall program. Long-term aspect of program would allow determination of effects of human activities as well as assess cyclic oceanic patterns in relationship to fish stock production.

Point-of-Contact: Northwest Fisheries Center

Remarks: Would want to work in all depths utilizing existing submersibles.

Fisheries: Shellfish Surveys

Survey and study of king crabs and shrimp in early life stages in Alaskan waters.

Point-of-Contact: Northwest Fisheries Center

Remarks: Could use existing submersibles, to depths of 183 m (600 ft).

Fisheries: Walrus/Clam Relationship

Determination of the impact on the expanding clam industry on the population dynamics of Pacific Walrus.

Point-of-Contact: Northwest Fisheries Center

Remarks: These studies in the Bering Sea could utilize existing submersibles.

Geology: Sediment Transport

Survey and examination of large-scale sediment wave patterns. Previous studies have indicated sediment waves up to 30 ft high with wave lengths up to 3 to 4 miles long. Details would have to be studied by submersible during a series of operations extending over several years.

Point-of-Contact: National Ocean Survey

Remarks: These studies to be conducted first off the mid-Atlantic East Coast in depths from 91.5 to 366 m (300 to 1200 ft). Later studies would be conducted in the Gulf of Mexico and off the West Coast.

Geology: Shelf Dynamics

Studies on fluid bed interaction in preparation for construction of offshore facilities. Measurements of sea floor shape, sediment transport, sea floor stability, and factors affecting restabilization after liquefaction. Indirect measurements are misleading; thus in-situ direct measurements must be made.

Point-of-Contact: Office of Sea Grant

Remarks: Studies on both coasts would require mobile autonomous submersible, with capability to hover and to precisely implant instruments on the sea floor.

Geology: Experimental Seismology

Precise emplacement of special instruments on the sea floor in areas in which fault creep is suspected. Would also involve bottom coring and sampling.

Point-of-Contact: Office of Sea Grant

Remarks: West Coast survey, depths to 1220 m (4000 ft). Submersible would require precise maneuvering capability and coring, and sampling capabilities.

Geology: Sediment Investigations

An extensive series of investigations related to sediment substrate inventory, including seismic profiling, coring, and grab sampling with emphasis on sediment transport as it pertains to ocean dumping. Related efforts involve depositional processes in submarine canyons.

Point-of-Contact: Environmental Research Laboratories—Boulder (CO) Headquarters

Remarks: Have used submersibles in past. Study ranges from 27.3 to 274.5 m (90 to 9000 ft) and extensive operations desired.

General Oceanography: Basic Ocean Research

Studies of sediment transport related to activity in the bottom of the water column, internal wave study, and basic study of gravity waves. Major interest is determination of the effects of atmospheric storms on underwater "events."

Point-of-Contact: Environmental Research Laboratories; Atlantic Oceanographic and Meteorological Laboratories

Remarks: Operations could be from 305 to 915 m (1000 to 3000 ft) or beyond. Could utilize existing submersibles, but facilities with greater depth, duration, and refinement required in future.

General Oceanography: Ocean Dumping and Marine Ecosystems

There are several projects related to the observation and assessment of the effects of ocean dumping. These studies relate to most other marine disciplines and could be used as a test bed for equipment and techniques as well as collecting required data.

Point-of-Contact: Environmental Research Laboratories; Marine Ecosystems Analysis

Remarks: Have used submersibles in past. Work in New York Bight could use existing submersibles; would be essentially an extension and refinement of past work.

General Oceanography: Micro-Bathymetry

Study of the origin of microbathymetric features in the shelf and slope environment.

Point-of-Contact: National Ocean Survey

Remarks: Existing minisubmersibles useful as base, but extensive instrumentation (i.e., undersea laboratory) needed.

General Oceanography: Energy Dissipation

Studies on parcelling and dissipation of storm energy on real-time basis. Require capability for real-time in-situ analysis.

Point-of-Contact: Office of Sea Grant

Remarks: Require mobile submersible capable of operation throughout storm conditions. Standard oceanographic sensors.

General Oceanography: Submarine Canyon Currents

Study designed to obtain data on current reversals in submarine canyons and their relationship to dynamics of storm conditions.

Point-of-Contact: Office of Sea Grant

Remarks: Would take place off both U.S. coasts and in the Pacific, where special conditions prevail which affect large weather patterns.

Biology: Precious Coral Survey

Survey of precious coral distribution and density in Alaskan waters below scuba depths. Related to new industry; could be studied coincident with other Alaskan fishery investigations.

Point-of-Contact: Alaska Fisheries Center

Remarks: Depths of 91.5 to 915 m (300 to 3000 ft) using existing submersibles.

Biology: Ecosystem Study

Basic study on biological oceanography and general food webs and the impact of oil spills on the Alaskan marine environment. A three-year study has been initiated.

Point-of-Contact: Northwest Fisheries Center

Remarks: Could utilize existing submersibles.

Biology: Kelp Research

An extended program on kelp with emphasis on the total ecosystem looking into such areas as kelp as a source of methane and other gases.

Point-of-Contact: Office of Sea Grant

Remarks: Could utilize small submersibles or a habitat.

Biology: Galapagos Rift Vent Fish Survey

Study of the biology and geology of seafloor warm water springs with major interest in description of fish populations.

Point-of-Contact: Systematics Laboratory, NMFS

Remarks: These dives to depths of 2500 to 2800 m in the Galapagos Islands would require about a week of dive time and could be a part of the overall Galapagos project.

U.S. Army Corps of Engineers (Department of Defense)

RDT&E: Arctic Ice Scoring Research

Investigations of underwater ice relief and geometry, sub-bottom composition, bottom relief of ice for keel impact probability studies, contemporary ice gouging and scouring processes. This information would be used to determine depths to which pipelines, wellheads, or cables must be buried to prevent destruction by ice movement. Knowledge of the dynamics of gouging and the resultant topographic lows can be applied to the oil pooling potential of these features should subsea blowouts occur.

Point-of-Contact: Cold Regions Research and Engineering Laboratory, Hanover, NH

Remarks: Work would be conducted on Alaska Arctic shelf in depths of 61 m (200 ft). Low level of funding has precluded the use of submersibles to date. Desires use of national facility when available.

Pollution: Effects of Dredge Disposal

Possible investigation of environmental effects of dredge material disposal activities.

Point-of-Contact: Environmental Effects Laboratory, Vicksburg, MS

Remarks: Work is done on a reimbursable basis.

Typically the laboratory has little forewarning of future projects they will be asked to address. At present submersible utilization is remote.

Pollution: Environmental/Ecological Monitoring

Comprehensive studies to evaluate the ocean disposal of dredged sediments. Multidisciplinary investigations to supplement surface sampling and facilitate the determination of benthic communities, textural, topographic, and hydrographic characteristics of potential and historic ocean disposal sites. Investigations would include delimiting biological critical areas and documenting the influence of currents, wave surge, and density-related currents on transport or erosion of dredged spoil mounds, bioturbation, sedimentation, recolonization, and other related phenomenon.

Point-of-Contact: Environmental Analysis Branch, New England Division

Remarks: A singular submersible survey was conducted in the past, but present low funding level has been a factor in eliminating programmed use. Investigator interest has remained high, however.

Department of Energy

Fisheries: Marine Mariculture and Toxicity

There may be requirements for the use of an undersea platform to investigate relationships of toxicity and upwelling in mariculture efforts, especially off the Pacific Coast. At present, use of a habitat appears to be most cost effective.

Point-of-Contact: Solar Applications Group

Remarks: There are no plans to use undersea platforms in the immediate future. Analysis of present studies could specify such a requirement in the coming years. No funds are presently available for use of manned undersea platforms.

Pollution: Seabed Waste Project

These studies involve emplacement of in-situ heater experimental equipment to simulate emplacement of radioactive waste. This study, which would begin in 1981, would require 2 one-week periods of submersible use in the North Pacific in depths to 6000 m. The only support required would be a mother ship. The same type of emplacement of biological effects experiment apparatus would be done in 1982-1983 to study potential interaction of emplaced radiation with the bottom dwelling community. Assuming that the 1981-1983 tests are successful an extension of the study to North Atlantic areas in 4000- to 6000-m depths is intended in 1986.

Point-of-Contact: Seabed Waste Project and Sandia Laboratory

Remarks: Funding has not been allocated for the 1980's field efforts but the planning of the field study (submersible) portion of these studies is underway.

RDT&E: Evaluation of Volatile Sea Floor Constituents

The program would entail measurement and evaluation of volatile seafloor constituents such as mercury, hydrogen sulfide, arsenic, and toxic heavy metals which emanate from volcanos and hot water springs on the sea floor. Would also investigate nutrient and heavy metal fluxes from the seafloor. Results of these studies would describe formation, form, concentration and distribution of heavy metals in the marine environment. Work would be done primarily in areas of submarine volcanos and hot water springs in the Mid-Atlantic Ridge and East Pacific Rise.

Point-of-Contact: Battelle-Northwest, Richland, WA

Remarks: This type of work is being done presently by surface ship. Submersibles would aid in detailed studies if they were available.

RDT&E: Investigation of Energy Production

Studies related to both exploration and production of energy and their effect on the marine environment. For example, monitoring for low-level radioactive wastes in nuclear power plant outfalls; biological effects of petroleum products emanating from drilling or transfer sites; and corrosion/biofouling of intake pipes for OTEC concept. This work would be conducted mainly by small submersible to maximum depths of 300 m. Lockout capability is considered useful.

Point-of-Contact: Battelle-Northwest, Marine Research Laboratory.

Remarks: Sampling and investigation presently conducted from surface ships with onboard or laboratory analysis. Seasonal use of submersible would be particularly effective for monitoring of biota. Presently no funds are available for submersible work.

Department of Health, Education and Welfare

RDT&E: Diver Safety

Project would involve testing of diving tables and all protective and life support equipment used by divers. This could conceivably be performed in conjunction with other ongoing projects that make use of a habitat or lockout submersible to depths of 305 to 610 m (1000 to 2000 ft).

Point-of-Contact: National Institute of Occupational Safety and Health (NIOSH)

Remarks: This program is not presently funded, but funding and diving capabilities are being pursued in conjunction with NOAA and the OCS amendment requirements.

Department of the Interior

Fisheries: Research—Great Lakes

There is departmental interest in solution of a problem related to natural reproduction of lake trout in Lake Michigan. Hatchery-released trout survive to adult stages, but apparently are unable to use deep water "reefs" in the lake for deposition of eggs. The interest is in manual deposition of eggs on the reefs and determination if hatchery fish eggs could survive there.

Point-of-Contact: Office of Fisheries Research

Remarks: This program is not funded, but there is great interest in the project.

Fisheries: Behavioral Studies

Direct observations of the behavior of Great Lakes fish species in the lake environment. These investigations would include: the temporal and spatial aspects of use of reef areas and artificial spawning reefs by spawning lake trout, percoid fishes and their larval and fry stages; diet activity patterns (schooling, resting, feeding behavior); direct observation and sampling of physiochemical conditions associated with eggs and early life history of fry in-situ; and long-term observation of feeding mortality and dispersal during newly planted lake trout fry.

Point-of-Contact: Great Lakes Fishery Laboratory

Remarks: These programs in the management of Great Lakes fishery resources have not used submersibles in the past; however, their potential application as observational platforms for day and night operations is recognized.

Geology: Sand Resources

Investigations of extent and origin of sand resources and development of biological baseline studies in vicinity of these resources.

Point-of-Contact: Office of Marine Geology, Corpus Christi, TX

Remarks: Require submersible with sediment sampling and coring devices. Also require suite of standard instrumentation: current meters, seismic monitors, and soils engineering tools.

Geology: Bottom Stability

Assessment of ocean bottom stability for engineering of pipelines, structures, etc., on shelf and slope areas, and the reaction of bottom sediments to meteorological phenomena.

Point-of-Contact: Office of Marine Geology, Corpus Christi, TX

Remarks: Same comments as immediately above.

Geology: Slump Morphology and Stability

Studies of slump morphology and stability with the prime objectives being the understanding of the dynamics of slumps, their sensitivity to earthquakes, and the influence of rock flour, volcanic ash, etc.

Point-of-Contact: USGS, Menlo Park, CA

Remarks: Submerisbles used for these studies in the Alaska area would be required to carry two observers and a large variety of measuring, sampling, and recording equipment.

Geology: Offshore Background Studies

Long-term studies are needed throughout deeper continental waters. These study requirements are reflective of the national expansion of territorial limits as well as deeper exploitation of mineral and other marine resources offshore. Initial programs are presently needed to define study requirements for future deep sea programs.

Point-of-Contact: USGS, Menlo Park, CA

Remarks: Existing submersibles could be used for specific missions. Greater sustained depth capability will be required in the next decade.

Geology: Soil Engineering Studies

Study of the behavior of marine sediments as a function of the influence of gas, volcanic ash, rock flour, diogenesis, and hydrostatic pressure when samples are brought to the surface. This information is needed for soil engineering as applied to offshore construction.

Point-of-Contact: USGS, Menlo Park, CA

Remarks: Operations to at least 183 m (600 ft); require two observers, good visibility, manipulator and TV and stereo cameras.

Geology: Bedform Dynamics

To obtain information of dynamics and stability of bedforms as a function of tidal currents, sand transport, etc.

Point-of-Contact: USGS, Menlo Park, CA

Remarks: These operations in Alaskan waters would be in depths of 39.5 to 137 m (130 to 450 ft). Would require submersible for two observers and a large array of navigational, sampling and measuring apparatus and equipment.

Biology: Biological Mapping

Submersibles could be used if cost effective for biological mapping activities such as reconnaissance of sea grass or other biological areas.

Point-of-Contact: Bureau of Land Management, New Orleans OCS Office

Remarks: This project has not been funded.

Biology: Arthopod Research

There is interest in developing a study to determine the deepwater migration routes of the Florida spiny lobster.

This work would be done in the Portales Terrace region off southeastern Florida, particularly at depths where surface divers are ineffective.

Point-of-Contact: National Park Service, Resources Branch

Remarks: This project is not funded but would use a small submersible, if available. This agency would consider joint operations with other groups in areas of common interest.

Biology: Trophic Dynamics; Marine Birds and Mammals

A submersible could be utilized in investigations of the availability of food types for marine birds and mammals, their feeding behavior, and behavior to food levels. Surface observations are being made in the Kodiak area in southeastern Alaska, and a submersible, if available, could be used to depths of 400 m.

Point-of-Contact: Fish and Wildlife Service, Office of Biological Services, Anchorage, AK

Remarks: This is an ongoing study. Neither funds nor a submersible have been available for underwater observation or study.

RDT&E: Testing and Evaluation of Neutron Activation Equipment

Group has used neutron activation equipment successfully in on-land borings for identification of coal, uranium, etc. They would like to try the same equipment in bottom borings in the marine environment. The new solid-state equipment and sensors could best be handled by submersible.

Point-of-Contact: USGS Physics Laboratory, Reston, VA

Remarks: USGS presently has capability of boring to about 65.5 m (20 ft) from surface platforms. If undersea facility and funding are available, would like to test new equipment and possibly extend boring depth capability.

General Oceanography: Background Studies

Use of a submersible may be required to conduct detailed environmental or background site surveys at specific sites. These studies are being made more frequently instead of the generalized large-area studies which have been the norm. The purpose of these studies is to provide data for management decisions concerning offshore oil leasing activities.

Point-of-Contact: Bureau of Land Management, Pacific OCS Office

Remarks: No funding has been specifically allocated for background studies which would require the use of a submersible.

Oil Activity Research: Oil Production Monitoring

There is interest in monitoring the environmental effects of ongoing oil production activities in-situ. A habitat could be used to provide a long-term base for observation and measurement of the effect and dispersion of drilling muds. The same effects could be assessed by detailed submersible surveys conducted before, during, and after drilling operations.

Point-of-Contact: Bureau of Land Management, New Orleans OCS Office

Remarks: This type of operation could take place in the Gulf of Mexico or off the Atlantic Coast. As submersibles are made available they would be utilized in this program.

Oil Activity Research: Drilling Effects and Resource Evaluation

Potential program could utilize a submersible for studies of the effect of shunted drilling muds to determine if restrictions imposed on the oil industry are realistic. Other studies would include investigations of demarcation of resources, e.g., drill sites in live bottom sites, etc.

Point-of-Contact: Fish & Wildlife Service, NSTL Station, MS

Remarks: No immediate requirement for submersible, but could be used in the future.

Oil Activity Research: OCS Development Studies

FWS is cooperating with BLM on determination of the effects of OCS development and production. There are several areas of possible investigation: determination of areas with high concentrations of precious corals off Hawaii; determination of distribution of pink coral and productivity of substrates in lease areas off southern California; and observation and monitoring of EPA designated dredge disposal sites. Present interest is mainly in Hawaiian and California waters in depths to 1200 m with average study in depths of 100 m.

Point-of-Contact: FWS, Office of Biological Services, Portland

Remarks: They are not presently funded for submersible projects, but feel that use of undersea facilities would greatly increase their observational study ability.

Oil Activity Research: Oil Lease Management Survey

The Federal Antiquities Act requires that observed bottom anomalies, such as wrecks, be found and classified relative to historical value prior to installation of drilling equipment or pipelines. The same areas are to be monitored during production with respect to the environmental effects of production activities.

Point-of-Contact: Bureau of Land Management, Pacific OCS Office

Remarks: There is a potential requirement for use of submersibles for inspection of sites and environmental monitoring. No funds have been allocated at present.

Oil Activity Research: Effects Investigations

Studies to monitor the localized effects of drilling structures and activities. These investigations include: monitoring bottom conditions (soils foundation parameters) at the site of a working platform, determining the effects of drill cuttings, and observing the bottom processes that occur after a rig leaves the work site.

Point-of-Contact: Bureau of Land Management, Division of Marine Assessments, New York

Remarks: The benefit of submersible utilization for these activities is recognized and may come to fruition unless program direction drastically changes. Most of this field research will probably be performed by USGS with BLM funding.

Inspection: Pipeline and Pipeline Route Survey

There is a growing requirement for detailed pipeline corridor surveys and pipeline inspections. Submersibles would provide effective tool for these surveys.

Point-of-Contact: Bureau of Land Management, Pacific OCS Office

Remarks: This work is not presently funded, and areas of jurisdiction over the problem have not been fully decided. There is a future potential use of submersibles when the program becomes operational.

Inspection: Pipeline and Pipeline Route Survey

There is a growing requirement for detailed pipeline corridor surveys and pipeline inspections. Submersibles would provide effective tool for these surveys.

Point-of-Contact: Bureau of Land Management, Division of Marine Assessment, New York

Remarks: This potential program is identical to the one immediately above except this study would be on the East Coast.

Inspection: Structural Integrity Inspection

There is a possible need for submersible studies for inspection of dams or other fresh water structures for structural integrity and to conduct detailed ecological and environmental sampling surveys.

Point-of-Contact: Bureau of Reclamation, Denver

Remarks: Divers have been used in some studies in the past, but a submersible might be useful for deeper operations if they arise. Presently no requirements.

Coral Harvest: Sustained Yield Studies

Two federal laws prohibit collection of coral on the continental shelf without a Department of Interior permit. To properly assess permit applications, surveys have to be made of coral resources and maximum sustained yields determined. A submersible would be required for this type of survey.

Point-of-Contact: Bureau of Land Management, Pacific OCS Office

Remarks: This program is not presently funded, but commerical pressure will require some sort of action in the near future.

Recreational: Education Facility

There is interest in establishing a means of allowing appropriate interested groups the opportunity of observing and photographing underwater flora, fauna, and geological structures.

Point-of-Contact: Heritage and Recreation Service

Remarks: No funding available or planned. Future potential use only.

U.S. Coast Guard (Department of Transportation)

Inspection: Underwater Safety Program

Plan for safety of civilian undersea activities; maintain knowledge of on-going undersea operations; implement safety regulations and inspection programs as required; and provide/coordinate undersea search and rescue (SAR) services as needed. Manage frequency allocations in the undersea acoustic communication frequency spectrum. Coordinate Coast Guard undersea mission support.

Point-of-Contact: Coast Guard

Remarks: Program may require occasional platform use.

Environmental Protection Agency

Fisheries: Artificial Reef Investigations

Submersibles could be used to determine the effectiveness of artificial reefs as fish propagation sites. The "reefs" were created in the Gulf of Mexico by sinking World War II Liberty ships.

Point-of-Contact: Surveillance and Analysis Division, Region 6

Remarks: No plans for submersible use at present. Could work with other agencies on joint projects.

Pollution: Ocean Spills and Ocean Dumping

Program related to preparation of guidelines and regulations concerning ocean spills and dumping. The interest in submersible work is primarily related to obtaining first-hand data, information, or evidence concerning effects of spills or dumping of hazardous materials.

Point-of-Contact: Oil and Special Materials, Control Division

Remarks: Would essentially want to work with other agencies that utilize submersibles and assist in establish-

ing means of gathering information required for the establishment of regulations.

Pollution: Ocean Dumping & Oil Spill Assessments

This program can visualize the potential for utilization of submersibles to investigate ocean sludge dump sites and their effect on the physical environment and biota and to make oil-spill damage assessments.

Point-of-Contact: Surveillance and Analysis Division, Region 6

Remarks: No plans for submersible use at present. Could work with other agencies on joint projects.

Pollution: Ocean Dumping Research

Program to investigate the effects of dredge spoils and toxic substances on marine organisms. Studies include the emplacement of sterile soils and caged test organisms on the bottom to determine metal fluxes and the reaction of marine life to pollutants. These studies would also include investigation of pollution dispersion rates and dynamics.

Point-of-Contact: ERL, Naragansett

Remarks: Have used submersibles in past. Would be able to utilize submersible as a placement and retrieval device. Could possibly be done in conjunction with other programs.

General Oceanography: Environmental Data Collection

Program could use submersible on case-by-case basis, if required, to assess effects of ocean pollution with regard to legal cases.

Point-of-Contact: National Enforcement Investigation Center

Remarks: Requirements solely dependent on cases. Potential use cannot be predicted.

Oil Activities Research: Observation & Inspection of Oil Drilling Activities on Coral Reefs

This potential program would investigate the effect of drilling processes and the generated sedimentation cloud on live coral reefs. Submersibles would also be a means by which oil wells can be inspected to insure proper blowout prevention devices have been installed.

Point-of-Contact: Surveillance and Analysis Division, Region 6

Remarks: These efforts would require the operation of a manned facility in the immediate vicinity of operating drilling and recovery platforms.

Oil Activity Research: Drilling Monitoring

Assessment of impact of drilling activities around Baltimore Canyon. Jurisdiction has not been settled to date. Studies would involve grabs, trawls, water sampling, and organic analyses in areas adjacent to drilling sites.

Point-of-Contact: EPA Marine Protection Program, Philadelphia

Remarks: Potential requirements for submersible use are not possible to ascertain at the present time.

Smithsonian Institution

Geology: Reef History

Study to reconstruct history of Caribbean reefs by means of underwater drilling, sampling and coring.

Point-of-Contact: Department of Paleobiology

Remarks: Presently using divers; could utilize habitat as base if available.

Biology: Reef Species Behavior

Study to gather data on species, behavior, and distribution of reef fishes in Indo-Pacific areas which are known to support the most diverse fish populations in the world.

Point-of-Contact: Division of Fishes

Remarks: These operations to 93 m (300 ft) would require use of a habitat or a lockout submersible.

Biology: Echinoderm Study

Study of echinoderm density, distribution, and behavior in depths to 3660 m (12,000 ft).

Point-of-Contact: Department of Invertebrate Zoology

Remarks: Have used *Alvin* in past and would like to continue in deeper East Coast waters to depth of 3660 m (12,000 ft).

Biology: Deepwater Scallop Study

Basic studies of deepwater scallops, particularly in areas such as sediment pockets between outcrops, where they cannot be sampled or studied by surface techniques.

Point-of-Contact: Department of Paleobiology

Remarks: Would observe and collect to 1000 m depths mainly off East Coast but also off the Antilles and New Hebrides. Could perform this work while submersible engaged in other activities requiring slow transit and periodic stops.

Biology: General Biology

Study general biology, vertical distribution and in-situ behavior of midwater fishes and the conditions and reason for their bioluminescent characteristics. Investigate the reaction of fish to dump sites. Would operate on East Coast: dump sites, continental slopes, and Bermuda. Requires standard biological sampling and observational capabilities.

Point-of-Contact: Division of Fishes

Remarks: Desires short-term annual diving program. Would frequently operate in midwater; would require good hovering and navigational facilities. Would operate at 183 m (600 ft) and below.

Biology: Cephalopod Study

Study of cephalopods (octopuses and squids) and their bioluminescence. Requires at-sea observation and recording to test laboratory hypotheses. Would operate in midwater in depths to 2000 m or more. Prior work in Hawaii, but could potentially proceed in U.S. tropical waters.

Point-of-Contact: Division of Mollusks

Remarks: Requires submersible for observation, recording, and live sampling of necessary specimens. Would have to be fitted with light intensity meters and standard water column sensors.

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