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**ONR Contract N00014-91-C-0244**
**"Fabrication of a NAVMAP, A Deep-Sea Mapping System, Part 2"**
**Final Technical Report**
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Contract N00014-91-C-0244 supported the second (final) phase of development, fabrication and testing of a deep-sea sonar mapping system by Hawaii Mapping Research Group (HMRG) at University of Hawaii at Manoa. Initial development, including preparation of system specifications, was carried out under ONR grant N00014-90-J-4009. The sonar system was initially (informally) designated "NAVMAP". On completion of testing, the basic system was delivered (June 1992) to the Naval Oceanographic Office (NAVOCEANO) at Stennis Space Center, MS (then Code OW, subsequently reorganized as Code N322) for operation, where it was renamed "SEAMAP". Additional subsystems and documentation were built and delivered to NAVOCEANO prior to June 1994. Through summer 1994, SEAMAP has been successfully used in eight survey operations by NAVOCEANO totalling approximately 200 days of operation in the eastern North Atlantic Ocean and Norwegian Sea. Technical and scientific results of several of those programs have been described in papers and meeting proceedings abstracts included in the publications section at the end of this report. SEAMAP system development included design and fabrication of the following subsystems by HMRG:

- Tow body;
- Sonar transducers;
- Launch/recovery system for operation from ships at sea;
- Subsurface control and transceiver electronics;
- Telemetry system for signal transmission to surface;
- Topside computer-based digital control and acquisition system;
- Digital control, acquisition and display software;
- Various ancillary components to allow field operation; and
- Hardware and software documentation for NAVOCEANO operation and maintenance.

The SEAMAP system design was specified prior to initiation of the present contract, and included as part of the proposal for the present contract. Design specification decisions were made in close consultation among representatives of HMRG, Naval Oceanographic Office (NAVOCEANO) Code OW (now N322), Naval Research Lab (NRL) Code 5110 (now 7420), and the Marine Physical Laboratory of Scripps Institution of Oceanography (SIO/MPL), with which we subcontracted for initial sonar processing software. The basic SEAMAP subsystems are briefly described below. Full system documentation, including all hardware subsystems and software for control, acquisition and display, has been provided to NAVOCEANO Code N322.

Tow body:

Specifications required that the tow vehicle be towed at 8+ kts with less than 2 degrees rms of vehicle pitch and yaw and less than one degree rms of roll; it was required to operate at depths of at least 6000 meters; it was designed to house side-looking sonar arrays (as described below) operating at 11 to 12 kHz with narrow fore-aft beams, requiring that the housed arrays be approximately 4 meters in length; it was designed to float when free of its towing cable and depressor. The tow body was designed by HMRG in cooperation with subcontractor Sound Ocean Systems, Inc., of Redmond, WA. It consists of a syntactic foam body cast in sections, with an outer shell of hard plastic and fiberglass, and with a hydrodynamic shape to allow rapid, stable towing. High density syntactic foam rated for 6000 meter depth operations was used. Housings were included in the tow body for sonar arrays, for pressure cases to house control and acquisition electronics, and for attachment of a neutrally buoyant tether cable, flashing strobe lights, radio beacons, and an acoustic transponder. An extra, empty, flotation section was provided to allow operation with or without additional subsystems (not provided) without causing the tow body to be too buoyant or too heavy. As configured, the tow body weighs approximately 3500 to 4000 kilograms in air when configured normally for operation. It is approximately 5.5 meters long, 1 meter high and 1.3 meters wide.

The tow body, together with the electronics and sonar transducers described below, was operated during sea trials on USNS Silas Bent during spring 1992, and was delivered to NAVOCEANO in time for use in field operations beginning in June 1992.

Sonar transducers:

Sonar transducer specifications included beam pattern and input power requirements, row spacing of separate arrays of two rows of elements each operating on either side of the vehicle, operating frequencies of 11 kHz (port) and 12 kHz (stbd) to reduce sonar crosstalk, and a maximum operating depth of 6000 meters. Electronics for tuning of transmitter electronics with each sonar array was also specified. Subcontractor bids were solicited, and International Transducer Corporation (ITC) of Goleta, CA was selected as the successful bidder. Transducers were delivered to HMRG by ITC in early 1992, where they were integrated with transmit and receive electronics, and used in field trials on USNS Silas Bent that spring. They were delivered to NAVOCEANO in June, and have been operational since that time.

Launch/recovery system for operation from ships at sea:

A hydraulically-controlled system was designed and built for deploying and recovering the SEAMAP tow vehicle from survey vessels. Sound Ocean Systems of Redmond, WA, was the subcontractor for design of the launch/recovery system (LRS), and two of the three major components were built by SOS, with the remaining piece built by University of Hawaii under license. The system includes a hydraulic power pack (SOS-built) operated from ship's electrical power, towing winch (SOS-built), tilting and sliding bed frame (Hawaii-built), plus operator controls and associated hoses and power cables. The main tilting/sliding bed frame is designed with the footprint of a standard shipping container (nominal 20 x 8 feet), and may be welded or bolted to the deck of the ship. All components of the system are designed to allow recovery of SEAMAP from a vessel in moderate sea conditions (sea state 4). The towing winch provides a shallow-towing capability, with drum size limited to 2,000 meters of 0.68" diameter coaxial towing cable; deep operations of SEAMAP require use of a separate winch which was not part of the present contract.

The hydraulic power pack and tow winch were delivered to NAVOCEANO in June 1993, and together with a loaned HMRG sliding/tilting bed system, they were used successfully in field operations that summer on the Norwegian vessel Odin Finder off the coast of Norway. Fabrication of the tilting/sliding bed system and operator controls was completed by HMRG in spring 1994 and delivered in June of that year, and the complete launch/recovery system was used successfully in summer 1994 field operations off Norway by NAVOCEANO.

Subsurface control and transceiver electronics:

Sonar control, transmitter and receiver electronics used in SEAMAP were designed by HMRG; prototype boards were built by HMRG, following which production boards were contracted from National Circuits, Inc., in San Diego, CA. Spare boards of each type were acquired, and artwork for production of additional boards in the future is on file. Full sets of boards for operating SEAMAP were delivered with the system for testing in spring 1992. Updates and revisions to boards have been provided regularly as modifications have been made to improve performance or add functionality; spare boards of most recent revisions have been provided as of summer 1994.

Telemetry system for signal transmission to surface:

Bids were solicited for a telemetry system capable of transmission over 10,000 meters of 0.68" coaxial towing cable, and Colmek, Inc., was awarded a subcontract to provide the topside and subsurface telemetry hardware for SEAMAP. The Colmek system is capable of transmitting SEAMAP sonar data at a rate of 422 kBaud. The system was delivered ahead of testing in spring 1992, although problems with transmission over long cables were apparent. Modifications to telemetry design were made by HMRG, and have been incorporated into the revised design by Colmek.

Topside computer-based control and acquisition system:

SEAMAP was designed to be a fully digital system, controlled from topside by UNIX-based workstations (two Sun SPARCStation 2 computers, one as a redundant "hot spare") which also display and log incoming sonar information, processed to provide backscatter ("side-scan sonar") imagery and swaths of seafloor depth information ("swath bathymetry").

Peripheral instruments with each workstation for system operation were two 8 mm cartridge tape systems (2 each) for realtime data logging, plus two hard disk drives (delivered as 600 Mbyte each), one color plotter for bathymetric data hardcopy display, and one grayscale (thermal) plotter for side-scan sonar hardcopy display. Each workstation also has a Berkeley Engineering board with digital signal processor installed for control of sonar data acquisition.

Digital control, acquisition and display software:

Control and acquisition software, both topside and subsurface, were developed by HMRG and associated groups at University of Hawaii. Initial sonar processing software modules were developed under subcontract by SIO/MPL, and subsequently modified by HMRG and integrated into SEAMAP's master acquisition and display programs. Software for realtime sonar data display was developed by HMRG and associated groups at University of Hawaii, as was software for writing data to 8 mm data cartridges during

Digital signal processors (DSPs) are used in both the topside (board-mounted in the SPARCStation computer) and the subsurface (one each for port and starboard) for primary sonar acquisition control, control of telemetry, and base-band filtering of raw sonar signals (digitally) in the subsurface. Boards and development kits were acquired from Berkeley Camera Fr[illegible]ng, Inc., and DSPs were programmed and integrated into the sonar control and acq[illegible] system by HMRG and associated groups at University of Hawaii.

SEAMAP documentation:

A complete set of documentation describing hardware and software for SEAMAP, as well as operating manuals, was delivered to NAVOCEANO Code N322 prior to June 1994. Updates and corrections are provided as they become available.

Presentations and publications related to development and use of SEAMAP system:

1991:

Whittaker, C.C., M. Rognstad and A. Shor, 1991. NAVOCEANO's new swath bathymetric and imaging system. Proceedings of Marine Technology Society, September 1991 meeting in New Orleans, LA.

1992:

Halter, E.F., A.N. Shor, S.H. Zisk, and M.R. Rognstad, 1992. HAWAII MR1 and SEAMAP: Two new systems for sea floor surveying. American Geophysical Union, 1992 Fall Meeting Abstract Supplement, p. 543.

Rognstad, Mark R., 1992. Hawaii MR1: A new underwater mapping tool. International Conference on Signal Processing Applications and Technology (Proceedings of meeting in Boston, MA in November, 1992), p. 900-905.

Shor, A.N., M.R. Rognstad and S.H. Zisk, 1992. HAWAII MR1: A new tool for mapping in the EEZ. Pacific Congress on Marine Science and Technology (Abstracts). OST-3/1.

1993:

Appelgate, B., A.N. Shor, D. Chayes, L.E. Johnson, and P.R. Vogt, 1993. Axial structure of the Kolbeinsey Ridge seafloor spreading center. American Geophysical Union, Spring Meeting Abstract Supplement, p. 307.

Appelgate, B., and A.N. Shor, 1993. Spreading center morphology of the Kolbeinsey Ridge. InterRidge symposium on Mid-Ocean Ridge Segmentation, University of Durham, England, September 21-22, 1993.

Davis, R.B., and others, 1993. Hawaii Mapping Research Group bathymetry and sidescan data processing. Oceans '93 (Proceedings, meeting in Vancouver, British Columbia), v. 2, p. 449-453.

Davis, R.B., M.H. Edwards, S.H. Zisk, A.N. Shor and E. Halter, 1993. New techniques for interactively processing and mosaicking various bathymetric and backscatter datasets. American Geophysical Union, Spring Meeting Abstract Supplement, p. 307.

Gardner, J.M., A.N. Shor, P.R. Vogt, and J. Herring, 1993. Late Quaternary sediment transport on the Upper Bear Island Fan: Recent SEAMAP side-scan sonar and bathymetric surveys off Norway. American Geophysical Union, Fall Meeting Abstract Supplement, p. 343.

Johnson, L.E., P.R. Vogt, D. Chayes, B. Appelgate, L. Kajiwara and A.N. Shor, 1993. Geophysical studies of the Jan Mayen Ridge, 70.16$^{o}$-67.75$^{o}$N. American Geophysical Union, Spring Meeting Abstract Supplement, p. 307.

Joseph, D., A.N. Shor, E. Halter, C. Nishimura, M. Czarnecki, P. Vogt, C. Jones and D. Chayes, 1993. SEAMAP investigation of the Gulf of Cadiz and Gorringe Bank: The search for the boundary between the African and Eurasian plates. American Geophysical Union, Spring Meeting Abstract Supplement, p. 307.

1994:

Appelgate, B., A.N. Shor, and M.H. Edwards, 1994. A comparison of axial structural characteristics between the obliquely spreading Reykjanes Ridge and the orthogonal Kolbeinsey Ridge. American Geophysical Union, Fall Meeting Abstract Supplement, in press (for presentation at 12/94 meeting).

Lingsch, S., 1994. A comparison of SEAMAP and SeaBeam bathymetry on the Jan Mayen Ridge. Marine Technical Society (Proceedings, meeting in Washington, D.C. Fall 1994).