

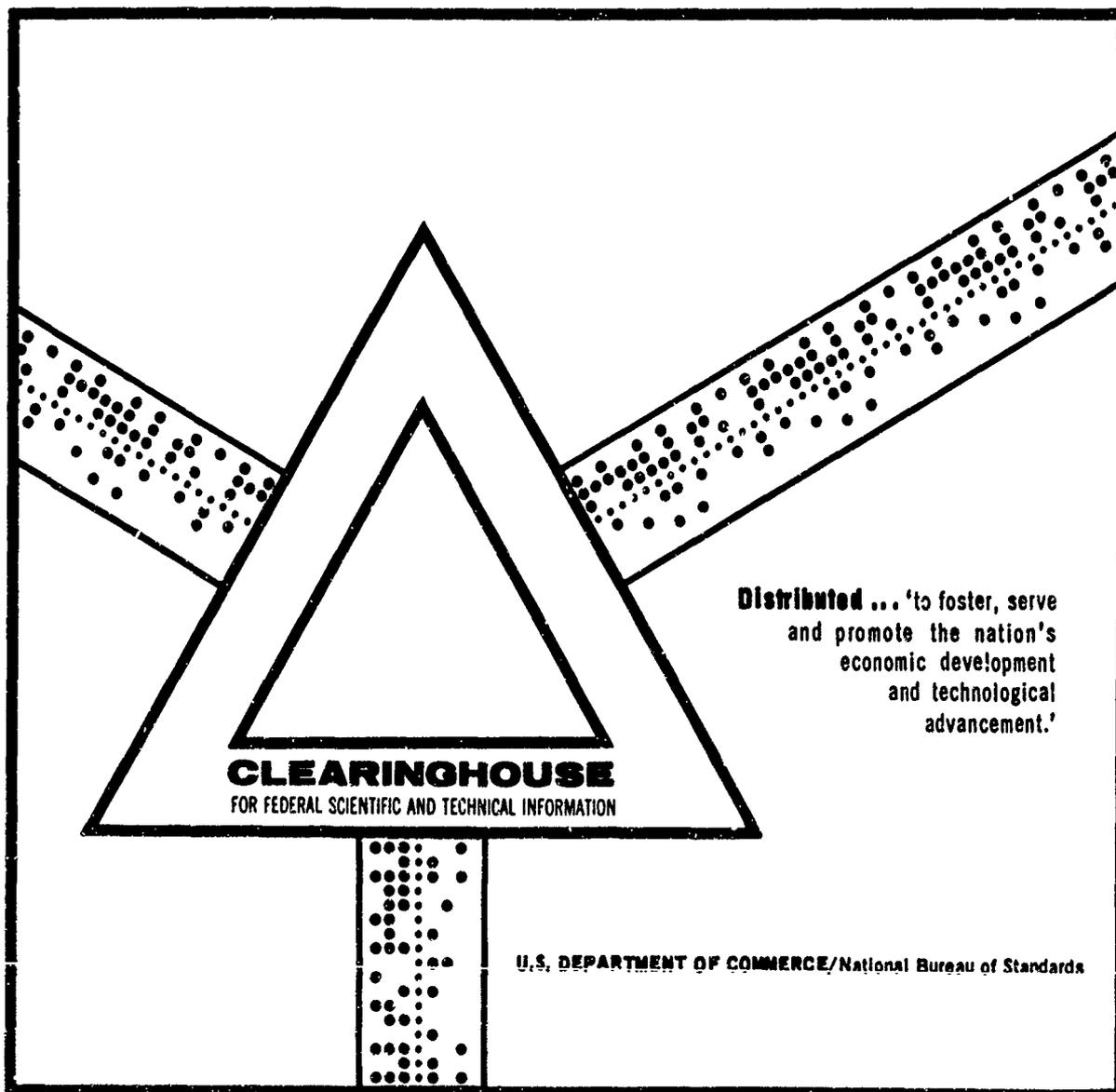
AD 696 537

FINAL REPORT OF CONTRACT NONR-2866 INCLUDING A HISTORY OF THE CONTRACT AND A BIBLIOGRAPHY OF SCIENTIFIC CONTRIBUTIONS SUPPORTED BY THE CONTRACT AT THE WOODS HOLE OCEANOGRAPHIC INSTITUTION FROM MARCH 1, 1959 TO JUNE 30, 1969

John C. Beckerle

Woods Hole Oceanographic Institution  
Woods Hole, Massachusetts

June 1969



**Distributed ...** 'to foster, serve  
and promote the nation's  
economic development  
and technological  
advancement.'

**CLEARINGHOUSE**  
FOR FEDERAL SCIENTIFIC AND TECHNICAL INFORMATION

U.S. DEPARTMENT OF COMMERCE/National Bureau of Standards

This document has been approved for public release and sale.

WOODS HOLE OCEANOGRAPHIC INSTITUTION  
Woods Hole, Massachusetts

REFERENCE NO. 69-51

Final Report of Contract Nonr-2866 including  
a History of the Contract and a Bibliography  
of Scientific Contributions Supported by the  
Contract at the Woods Hole Oceanographic In-  
stitution from March 1, 1959 to June 30, 1969.

by

John C. Beckerle

June 1969

TECHNICAL REPORT

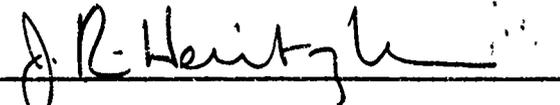
*Submitted to the Office of Naval Research as  
the FINAL REPORT under Contract Nonr-2866(00)  
NR 287-004.*

*Reproduction in whole or in part is permitted  
for any purpose of the United States Govern-  
ment. In citing this manuscript in a bibli-  
ography, the reference should be followed by  
the phrase: UNPUBLISHED MANUSCRIPT.*

*This document has been approved for public  
release and sale; its distribution is unlimited.*

NOV 18 1969

Approved for Distribution



J. R. Heirtzler, Chairman  
Department of Geology and Geophysics

## ABSTRACT

This is the final report of Contract Nonr-2866(00) including a history of the contract and a bibliography of scientific contributions supported by the contract at the Woods Hole Oceanographic Institution from March 1, 1959, to June 30, 1969. The contract was initiated as a project to provide basic environmental measurements in a broad ocean area between Bermuda and the Antilles that would limit the specifications and the performance of a large long range underwater acoustics system known as Project ARTEMIS. From the beginning in late 1958 until the present the research program included sound transmission studies, temperature and sound velocity measurements, studies of currents in the deep ocean and studies of the bottom conditions. This program of research has brought about better understanding of the ocean movements and reflecting properties of the ocean bottom in the Bermuda-Antilles area. A reliable environmental ocean measuring system was developed under this contract and put to use to determine spatial and temporal variations in the acoustic structure in the ocean.

## INTRODUCTION

The Geophysics Department at the Woods Hole Oceanographic Institution has been responsible for a portion of the environmental research in the ocean in support of Project ARTEMIS under Contract Nonr-2866(00) since the contract was initiated late in 1958. This report will be a final report of the research into the ocean environmental factors that influence underwater acoustic propagation and pertinent to the needs in the development of an advanced acoustics system. As such it will contain a brief history of the research work and a bibliography.

Late in 1958, when Project ARTEMIS began, it was recognized that such a large scale feasibility study would require the cooperation of some twenty laboratories, frequent coordinating, planning and review conferences, and a major research effort to uncover the environmental factors that would limit the specifications and performance of the system. The research area in the ocean chosen for this large scale feasibility study was situated between Bermuda and the Antilles. J. B. Hersey, who was the principal investigator, in the Department of Geophysics for the Office of Naval Research contract with the Woods Hole Oceanographic Institution, set forth four categories that required an extensive research effort. These were: sound transmission studies, water structure studies, water current studies, and studies of bottom conditions. It was the considerable experience in the basic factors about the sound transmission medium and its boundaries that affect long range sound transmission, gained by the research efforts of the Geophysics Department of this Institution since 1953 and before, that helped immeasurably in the delineation of the important areas of research needed. Although there was a goodly amount of scientific knowledge available about the areas mentioned above, as well as specialty fields such as signal processing and the design of large sound transducers, the scale of the ARTEMIS feasibility study required

a considerable extrapolation of the state of the knowledge at that time. For instance, there was a great deal known about environmental variations in the sea but a considerable lack of the detailed knowledge required to make a prediction about the limitations of the system concept. We now recognize more fully the serious limitations placed on the performance of the ARTEMIS system, as initially conceived, by fluctuations in the ocean and by sound transmission loss and scattering due to bottom reflections. Indeed, the scale of the research effort into environmental factors undertaken has only recently provided a grasp of the complexity of ocean processes. The enormity of the ocean's environmental problem in long range underwater sound transmission, particularly when one is pushing to get the very most from an advanced systems development program, is beginning to be appreciated. Even to this day, questions such as how large one can make an underwater hydrophone array and achieve considerable gain cannot be answered simply. An answer to such a question requires measurements of the spatial and temporal coherence of acoustic signals in the ocean, the reflecting properties of the ocean floor and the sublayers below, and measurements of the noise distribution. All of these factors vary with location in the ocean. It is interesting, in retrospect, that the basic limitations of the ARTEMIS system were foreseen to be environmental in character and that a program of research into all of the above areas was carried out.

In the early years of this program extensive expeditions were undertaken to obtain pertinent information regarding sound transmission characteristics. Particularly, information was vital with respect to sound transmission loss on a year round basis. Therefore, measurements of transmission loss were conducted in the winter, as well as in the spring, summer, and fall. This kind of information was essential in considerations of the level of the source design and the amount of signal processing that would be required under the system's concept. There are a number of reports describing this research contained in the bibliography. Moreover, extensive studies of the bottom of the ocean, detailed site surveys, bottom photography, seismic studies of reflectors underneath the bottom

which could produce destructive as well as constructive interference in the frequency ranges of interest were all part of the systematic investigation of the ARTEMIS area carried out by the Department of Geophysics. Considerable effort went into the identification of sound paths and some of these sound paths have been given extensive study with regard to wavefront fluctuations by the research group of the Bell Telephone Laboratories and the scientists of Hudson Laboratories in efforts to optimize beam-forming.

The sound velocity structure in the region was studied extensively by the Geophysics Department. Members of this department were the first to employ the National Bureau of Standards sound velocimeter to the ocean environment problem in the ARTEMIS area. The environmental system used for this work from the Institution's research ships has undergone development throughout the contract periods even up to this present time. Some brief description of the present capabilities that have resulted from this development program will be mentioned later. Both acoustic and oceanographic cruises were carried out by the Geophysics Department in an effort to identify reliable sound paths. Water structures near the surface were studied with the thermistor chain on long traverses of the ARTEMIS area in 1961 in order to determine the scale of the fluctuations and to determine the likelihood of multiple bottom reflections as opposed to sound channel and surface reflected type transmission. Thermistor chain observations gave considerable insight into the character of the ocean's fluctuations in the vicinity of the sea surface and it became obvious from these records that there were many scales of inhomogeneities affecting sound transmission. Any examination of these records at such an early date gave the impression that the internal motions of the ocean were overwhelmingly complex. It was clear from these research efforts that many years of study of this complex phenomenon of internal ocean movements would be required before a meaningful grasp of the processes involved could be established. Moreover, the very complexity of the records and the lack of adequate theories of turbulence precluded the possibility of any direct approach using the measurements in the prediction of acoustical fluctuations.

Indeed, even to this present day, although some real progress has been made, there is a real problem in trying to correlate oceanographic fluctuations and acoustical transmission fluctuations.

In the early and middle years of the contract period very little was known about deep currents in the ocean. Swallow float measurements were just beginning to be made and members of the Geophysics Department conducted drogue measurements to obtain estimates of the current flow with some emphasis on the vicinity of the proposed receiver array location. Transient currents were observed in the very deep ocean and there was concern as to how ocean currents might affect the lifetime of undersea equipment. There are several reports which describe efforts to obtain information about deep ocean currents. The difficulties of measuring ocean currents and of interpreting the results of such measurements is now well appreciated by oceanographers. The need for continued research into deep ocean currents is more fully appreciated. The lifetime and the complexity of the in-water ARTEMIS system has demonstrated that careful planning and design with enough thought to the ocean problems in the vicinity can provide a reasonably long life. However, many of the engineering problems associated with long life underwater installations have not been solved.

In the middle 60's extensive oceanographic cruises were taken by the Geophysics Department to make systematic measurements of sound velocity, temperature, salinity, and other variables in the ocean. The scale of these cruises over the ARTEMIS area was enlarged whenever the research could be sponsored jointly by other contracts held by the Institution.\* After the realization that small scale internal wave fluctuations, known to have an important effect on sound transmission, could not be understood adequately without a study of large scale phenomena, the research

---

\* Progress reports of some of the work on this contract were issued periodically in WHOI reports in view of their pertinence to another contract, Nonr-4029(00). These brief accounts are cited in the bibliography in the semi-annual reports of Oceanographic and Underwater Acoustic Research.

program entered into a study of large scale Rossby waves. A major cruise of ATLANTIS II-22 in June 1966 was undertaken to learn about the ocean area and to study the thermal front region which passed through the area from west to east and may extend as far east as the mid-Atlantic ridge. Several reports on this work have been completed. They reveal that the Sargasso Sea is a very complicated region of eddies of different sizes and intensities which vary with depth. It is likely that the movement of these eddies have an influence on the smaller scale internal gravity waves and on acoustical fading phenomena.

During this period the Sylvania Applied Research Laboratory in Waltham, Massachusetts offered considerable assistance to the Institution in the development of an on-line sound velocity profiling system. A report on this work prepared by them is cited in the bibliography. During this period the Institution entered in closer cooperation with acoustical studies in progress by the Bell Telephone Laboratories. Many sound velocity profiles were obtained by the Institution's cruises to the area along sound transmission bearings from Argus Island, off Bermuda. These studies showed that thermal characteristics that occur near the ocean surface, particularly in the thermal front region, extend very deep into the ocean. Some ray computations were undertaken in order to study the influence of this thermal front region on sound transmission.

The purpose of CHAIN Cruise 67 was to study the thermal front region and to supply environmental measurements necessary to assist in the interpretation of acoustical studies. The acoustical measurements were carried out by the Bell Telephone Laboratories group under the guidance of Howard Broek. The results of this effort to relate environmental variations directly to acoustical fluctuations indicated some correlation with the longer scale ocean movements. However, it is clear that environmental measurements along a transmission run need to be obtained with relatively permanent installations in the water in addition to ocean measurements from ships.

An evaluation of the final sound velocity profiling system that was developed during this contract occurred on CHAIN Cruise 89 which took place during March and April of this year. This system plotted in final form during the cruise many of the sound velocity profiles, temperature, and other variables measured. The in-water sensor package that was designed for this system can handle up to 7 oceanographic sensors. Each are sequentially sampled. A hydrophone could also be included for continuous monitoring of the sound field. The depth of the instrument is obtained using an inverted echo sounder and a computer aboard the ship calculates from the measurements the depth of the instrument and the sound velocities to be associated with that depth. The information was displayed on teletype output and on graphs and stored on digital magnetic tape. The results of that cruise have been analyzed and several reports have been completed. We believe this demonstrates a technical capability that the Geophysical Department has been striving for in this area of oceanographic measurements, namely, to provide reliable oceanographic measurements pertinent to acoustic transmission during and shortly following the completion of a cruise.

In summary, Contract Nonr-2866(00) was initiated as a project to provide basic environmental measurements in a broad ocean area between Bermuda and the Antilles that are related to the performance of a large long range underwater acoustic system known as Project ARTEMIS. From the beginning in 1958 until the present the research program included sound transmission studies and extensive studies of the ocean environment for acoustics. This program of research has brought about a better understanding of the ocean movements and reflecting properties of the ocean bottom in this large ocean area between Bermuda and the Antilles. The basic nature of the findings in this area establish a base from which continued studies in this and adjoining areas can be fruitfully developed. Also during this contract period a reliable environmental ocean measuring system has been developed. This system is very useful in obtaining information about the spatial and temporal variations in the acoustic structure of the ocean.

BIBLIOGRAPHY OF SCIENTIFIC CONTRIBUTIONS PREPARED UNDER  
CONTRACT Nonr-2866 BETWEEN MARCH 1, 1959 and JUNE 30, 1969

- 1959 Hersey, J. B. ARTEMIS VI: Cruise Plans for CHAIN Cruise #9, September - October 1959. Tech. Memo No. 8-59 dtd September 1959. (Also Contract Nonr-1367).
- 1959 Hersey, J. B. Letter to Dr. R. A. Frosch dtd September 22, 1959. Summary of a series of discussions and correspondence relative to the WHOI survey plans in the Bermuda area for late September and October relative to Project ARTEMIS. (Confidential).
- 1959 Hersey, J. B. Preliminary report on an ocean bottom survey on Plantagenet or Argus Bank (U). WHOI Ref. No. 59-61 dtd November 1959. (Confidential).
- 1959 Voorhis, A. D. and L. Baxter, II. Sound transmission measurements for Project ARTEMIS November 1958 - February 1959 (U). WHOI Ref. No. 59-41 dtd August 1959. (Confidential).
- 1960 Baxter, Lincoln, II. Sound transmission research in the western North Atlantic Ocean (U). WHOI Ref. No. 60-14 dtd February 1960. (Confidential).
- 1960 Bruce, John G. Cruise plans for ATLANTIS Cruise #257, July - August, 1960. Tech. Memo 9-60 dtd July, 1960.
- 1960 Bruce, John G., Jr. Current studies off Plantagenet Bank, Bermuda (U). WHOI Ref. No. 60-23 dtd May 1960. (Confidential).
- 1960 Foster, D. B. Letter to Mr. Joseph F. McGrath (ONR) concerning progress dtd August 3, 1960. (Confidential).

- 1960 Hersey, J. B. Letter to Dr. R. A. Frosch reporting activities at Woods Hole and of other cooperating groups in the studies of environmental problems dtd May 13, 1960. (Confidential).
- 1960 Hersey, J. B. Status of Current Activities under Contract Nonr-2866 prior to June 1, 1960 (U). WHOI Ref. No. 60-34 dtd June 1960. (Confidential).
- 1960 Pratt, Richard M. Cruise plans for ATLANTIS Cruise #260, October - November, 1960. Tech. Memo No. 10-60 dtd October 1960. (Also Contract Nonr-1367).
- 1960 Stetson, Thomas. Preliminary results of ATLANTIS Cruise #259, October 4 - 6, 1960. Tech. Memo No. 11-60 dtd October 1960.
- 1960 Voorhis, A. D. Measurements of acoustic energy at Bermuda during the ARTEMIS IV Exercise (U). WHOI Ref. No. 60-39 dtd August 1960. (Confidential).
- 1961 Baxter, Lincoln II and Helen S. Graham. Seasonal variations in acoustic transmission losses in long paths in North American Basin (U). WHOI Ref. No. 61-26 dtd July 1961. (Confidential).
- 1961 Beckerle, J. C. Fluctuations in long range transmission of sound between a fixed source and fixed receivers. U. S. Navy Jour. of Und. Acous., 11, 719-732. (Confidential) (Done at Bell Telephone Laboratories).
- 1961 Bruce, John. Cruise plans for ATLANTIS Cruise #274, October 17 - December 3, 1961. Tech. Memo No. 9-61 dtd October 1961.
- 1961 Bruce, John G., Jr. Current studies off Plantagenet Bank. WHOI Ref. No. 61-17 dtd June 1961.
- 1961 Johnson, H. R. Sound transmission between proposed source-ship and receiving-array sites (U). WHOI Ref. No. 61-15 dtd May 1961. (Confidential).

- 1962 Baxter, Lincoln II. Detailed path identification program. Hudson Laboratories Status Rpt. No. 5, ARTEMIS Rpt. #26, pp. 150-153, May 31, 1962.
- 1962 Baxter, L., II and H. S. Graham. Correlated time functions of sound energy received at Bermuda in summer and winter from explosive sources (U). Hudson Laboratories ARTEMIS Rpt. No. 25 and WHOI Ref. No. 62-26. (Confidential).
- 1962 Caulfield, David D. and J. B. Hersey. Cruise plans for CHAIN Cruise #29, July - August 1962. WHOI Tech. Memo No. 3-62.
- 1962 Hersey, J. B. VII. Environmental research. Hudson Laboratories Status Rpt. 5, ARTEMIS Rpt. No. 26, pp. 113-123. (Confidential).
- 1962 Pratt, Richard M. Report on ATLANTIS Cruise #260, 11 October - 7 November 1960. WHOI Ref. No. 62-19 dtd May 1962. (Also Contract Nonr-1367).
- 1962 Reitzel, John. Cruise plan for ATLANTIS #282, July 5 - August 13, 1962. WHOI Tech. Memo No. 1-62 dtd June 1962.
- 1963 Baxter, L., II, H. S. Graham and D. D. Caulfield. Acoustic path identification in the deep sea. (U). (Abstract). Jour. Und. Water Acous. 13(1):224-225. January 1963. (Confidential).
- 1963 Birch, F. S., J. S. Reitzel and J. B. Hersey. Variation of sound velocity in the ocean area between Bermuda, the Bahamas and the Greater Antilles. (Abstract). Jour. Und. Water Acous. 13 (1):224.
- 1963 Hersey, J. B. Specifications for sound velocimeters to be mounted in the modules to be installed this year in the ARTEMIS array area. Memo to Dr. Warren A. Tyrrell dtd February 20, 1963.

- 1963 Hersey, J. B. Contribution to report on acoustic navigation entitled "The Need for Acoustic Navigation in the ARTEMIS Environmental Research Program". Letter to Raymond Hasse, USNUSL dtd February 21, 1963.
- 1963 Nalwalk, A. J. and J. K. Hall. Track charts, bathymetry, and location of observations. CHAIN Cruise No. 29, July 29 - August 14, 1962; CHAIN Cruise No. 30, August 22 - 30, 1962; CHAIN Cruise No. 31, September 4 - 7, 1962. North Atlantic Ocean. WHOI Ref. No. 63-25. (Also Contract Nonr-4029).
- 1963 Reitzel, John. Letter to Dr. R. A. Frosch, Hudson Laboratories, reporting ARTEMIS work performed on the second half of Cruise #1 of R/V ATLANTIS II dtd May 24, 1963. (Confidential).
- 1964 Backus, Richard H. Chapter I - Environment. Biological Considerations. (For ARTEMIS Handbook).
- 1964 Beckerle, John C. Chapter I - Environment. Sound Velocity Conditions. (For ARTEMIS Handbook).
- 1964 Beckerle, John C. Cruise plans for ATLANTIS II Cruise No. 11. 17 June - 10 August 1964. WHOI Tech. Memo No. 10-64 dtd June 1964. (Also NSF Grant GP-1123).
- 1964 Beckerle, John C. Environmental Measurements. ARTEMIS Annual Report.
- 1964 Bruce, John G., Jr. Current studies south of Bermuda. WHOI Ref. No. 64-5 dtd February 1964.
- 1964 Bruce, John G., Jr. Deep current measurements north of Puerto Rico. ARTEMIS Report No. 38 and WHOI Ref. No. 64-34.

- 1964 Hays, Earl E. Microbathymetric Survey. WHOI Ref. No. 64-13, ARTEMIS Report No. 36 dtd March 1964. (Confidential).
- 1964 Voorhis, A. D. and J. B. Hersey. Oceanic thermal fronts in the Sargasso Sea. Jour. Geophy. Res., Vol. 69, No. 18, pp. 3809-3814. (Also Contract Nonr-4029 and 2196).
- 1965 Baxter, Lincoln, II, Helen S. Graham and David D. Caulfield. Some long-range experiments on sound transmission correlation and reverberation for Project ARTEMIS. U.S.N. Jour. of Und. Acous., Vol. 15, No. 1, pp. 15-40, January 1965. (Confidential).
- 1965 Beckerle, J. C. Cruise plans for CHAIN Cruise #47. Woods Hole to Woods Hole, 19 April - 11 May 1965. WHOI Tech. Memo No. 6-65 dtd March 1965. (Also Contract Nonr-4029).
- 1965 Beckerle, J. C. CHAIN Cruise #47. In Oceanographic and Underwater Acoustics Research conducted during the period 1 November 1964 - 30 April 1965, pp. 13-15. WHOI Ref. No. 65-46 dtd June 1965.
- 1965 Beckerle, J. C. Study of sound velocity profiles - Thermal fronts and internal waves southwest of Bermuda in Oceanographic and Underwater Acoustics Research conducted during the period 1 November 1964 - 30 April 1965, pp. 15-16. WHOI Ref. No. 65-46 dtd June 1965.
- 1965 Dunkle, William M. Track charts, bathymetry and location of observations. CHAIN Cruise #47, North Atlantic Ocean, April 20 - May 11, 1965. WHOI Ref. No. 65-27 dtd June 1965. (Also Contract Nonr-4029).
- 1965 Knott, S. T. Bathymetric and seismic reflection studies of the ARTEMIS environs (U). WHOI Ref. No. 65-2, and ARTEMIS Report No. 40 dtd February 1965. (Confidential).

- 1965 Payne, R. E. Track charts, bathymetry and location of observations. ATLANTIS II Cruise No. 11, North Atlantic Ocean, June 8, 1964 - August 8, 1964 dtd April 1965. WHOI Ref. No. 65-18. (Also NSF Grant GP-1123).
- 1965 Payne, R. E., J. C. Beckerle and S. Stillman. Velocimetry, in Oceanographic and Underwater Acoustics Research conducted during the period 1 May - 31 October 1964, pp. 55-56. WHOI Ref. No. 65-12 dtd March 1965.
- 1965 Pratt, R. M. and W. M. Dunkle. Track charts, bathymetry and location of observations. ATLANTIS Cruise No. 260. North Atlantic Ocean. Hydrographer Canyon - Muir Seamount surveys. October 11, 1960 - November 7, 1960. WHOI Ref. No. 65-15 dtd March 1965. (Also Contract Nonr-1367).
- 1965 Reitzel, J. S. Track charts, bathymetry and location of observations. ATLANTIS Cruise No. 282. North Atlantic Ocean. July 7, 1962 - August 11, 1962. WHOI Ref. No. 65-14 dtd March 1965. (Also Contract Nonr-1367).
- 1966 Beckerle, John C. Acoustical and environmental fluctuations (U). Proc. of the Third U. S. Navy Symp. on Military Oceanography, Vol. I, pp. 331-339. (Confidential).
- 1966 Beckerle, J. C. Evidence of internal waves in crossing the thermal front region in Oceanographic and Underwater Acoustics Research conducted during the period 1 May - 31 October 1965, pp. 14-17. WHOI Ref. No. 66-11 dtd April 1966.
- 1966 Beckerle, J. C. The ray theory of internal waves and temperature measurements in the ocean in Oceanographic and Underwater Acoustics Research conducted during the period 1 May - 31 October 1965, p. 18. WHOI Ref. No. 66-11 dtd April 1966.

- 1966 Beckerle, J. C. Cruise plans for ATLANTIS II, Cruise No. 22. WHOI Tech. Memo No. 3-66 dtd June 1966. (Also Contract Nonr-4029).
- 1966 Beckerle, J. C. and R. E. Payne. Sound velocity contours northeast of the Bahamas in Oceanographic and Underwater Acoustics Research conducted during the period 1 May - 31 October 1965, pp. 13-14. WHOI Ref. No. 66-11 dtd April 1966.
- 1966 Beckerle, J. C., R. E. Payne, S. W. Bergstrom, and S. Stillman. Comparison of sound velocimeter with hydrographic measurements made on the same lowering in Oceanographic and Underwater Acoustics Research conducted during the period 1 November 1965 - 30 April 1966, pp. 28-30. WHOI Ref. No. 66-43 dtd July 1966.
- 1966 Kean, William F., Jr. and Thomas E. Pease. Track charts, bathymetry and location of observations. ATLANTIS II Cruise No. 22. North Atlantic Ocean, June 10, 1966 - August 3, 1966. WHOI Ref. No. 66-54 dtd October 1966. (Also Nonr-4029).
- 1966 Payne, R. E. and J. C. Beckerle. Sound velocity profiles between Bermuda and the Antilles. WHOI Ref. No. 66-52 dtd August 1966. (Also Contract Nonr-4029).
- 1966 Press, M., J. Teixeira, K. Westlund and J. Storer. A Real-time processing system for oceanographic velocity profiles. Applied Research Laboratory (Sylvania Electronic Systems). Rep. No. 518 dtd December 1966.
- 1967 Beckerle, J. C. Cruise plan for CHAIN No. 67, 10 May - 10 June 1967. WHOI Tech. Memo No. 2-67 dtd May 1967.
- 1967 Beckerle, J. C. Deep towed temperature sensor observations in Oceanographic and Underwater Acoustics Research conducted during the period 1 May - 31 October 1966, p. 25. WHOI Ref. No. 67-3 dtd March 1967.

- 1967 Beckerle, J. C. Test measurements of internal wave fluctuations with sound velocity profiling system - Yo-Yo- Experiment in Oceanographic and Underwater Acoustics Research conducted during the period 1 May - 31 October 1966, pp. 25-27. WHOI Ref. No. 67-3 dtd March 1967.
- 1967 Beckerle, J. C. Test measurements of internal wave fluctuations with sound velocity profiling system - Yo-Yo-Experiment in Oceanographic and Underwater Acoustics Research conducted during the period 1 November 1966 - 30 April 1967, pp. 18-19. WHOI Ref. No. 67-65 dtd October 1967.
- 1967 Beckerle, J. C. and S. W. Bergstrom. Analysis of CHAIN 47 sound velocity data in Oceanographic and Underwater Acoustics Research conducted during the period 1 May - 31 October 1966, pp. 22-24. WHOI Ref. No. 67-3 dtd March 1967.
- 1967 Beckerle, J. C. and S. W. Bergstrom. Analysis of sound velocity profiles from ATLANTIS II Cruise 22 in Oceanographic and Underwater Acoustics Research conducted during the period 1 November 1966 - 30 April, 1967, pp. 17-18. WHOI Ref. No. 67-65 dtd October 1967.
- 1967 Beckerle, J. C. and W. Dow. On-line sound velocity profiling system in Oceanographic and Underwater Acoustics Research conducted during the period 1 November 1966 - 30 April 1967, p. 19. WHOI Ref. No. 67-65 dtd October 1967.
- 1967 Beckerle, J. C. and R. E. Payne. Analysis at sea of a line of sound velocity profiles southwest of Bermuda in Oceanographic and Underwater Acoustics Research conducted during the period 1 May - 31 October 1966, p. 24. WHOI Ref. No. 67-3 dtd March 1967.

- 1967 Beckerle, J. C. and R. E. Payne. ATLANTIS II Cruise #22 in Oceanographic and Underwater Acoustics Research conducted during the period 1 May - 31 October 1966, pp. 12-14. WHOI Ref. No. 67-3 dtd March 1967.
- 1967 Beckerle, J. C., J. L. Wagar and R. D. Worley. Underwater acoustic wavefront variations and internal waves in Oceanographic and Underwater Acoustics Research conducted during the period 1 November 1966 - 30 April 1967, p. 20. WHOI Ref. No. 67-65 dtd October 1967.
- 1967 Bowin, C. O., R. L. Chase and J. B. Hersey. Geological applications of sea-floor photography in: Deep-Sea Photography, J. B. Hersey, ed., Johns Hopkins University Press, pp. 11 - 140. (Also Nonr-1367 and NSF Grant GP-2370).
- 1967 Bruce, John G., Jr. and Edward M. Thorndike. Photographic measurements of bottom currents. In: Deep-Sea Photography, J. B. Hersey, ed., Johns Hopkins University Press, pp. 107-111. (Also Contract Nonr-4029 and Nonr-1367).
- 1967 Delnore, V. E., J. C. Beckerle and R. E. Payne. Surface layer temperature structure and Rossby waves in Oceanographic and Underwater Acoustics Research conducted during the period 1 November 1966 - 30 April 1967, p. 20. WHOI Ref. No. 67-65 dtd October 1967.
- 1967 Dimock, Alan. The crown monitor, Model 3, Variable monitoring amplifier. WHOI Tech. Memo No. 7-65. (Also Contract Nonr-4029).
- 1967 Hays, H. C. CHAIN Cruise No. 67. Summary cruise report prepared by Chief Scientist<sup>e</sup>. Track charts, bathymetry, and location of observations. North Atlantic Ocean, southwest of Bermuda. 10 May - 9 June 1967. WHOI Ref. No. 67-63 dtd August 1967.

- 1967 Hersey, J. B. The manipulation of deep-sea cameras. In: Deep-Sea Photography, J. B. Hersey, ed., Johns Hopkins University Press, pp. 55-67. (Also Contract Nonr-4029 and 1367).
- 1967 Hoskins, Hartley. Seismic reflection observations on the Atlantic continental shelf, slope and rise southeast of New England. Jour. of Geol., Vol. 75, No. 5, pp. 598-611. (Also Contract Nonr-1367 and Nonr-4029 and NSF Grants GP-822 and GP-1123).
- 1967 Payne, R. E., J. C. Beckerle, S. W. Bergstrom and V. Lowell. Data reports on sound velocity measurements in Oceanographic and Underwater Acoustics Research conducted during the period 1 November 1966 - 30 April 1967, p. 19. WHOI Ref. No. 67-65 dtd October 1967.
- 1967 Wood, L. and J. C. Beckerle. An optical analog experiment of an ideal underwater acoustic experiment in Oceanographic and Underwater Acoustics Research conducted during the period 1 November 1966 - 30 April 1967, p. 11. WHOI Ref. No. 67-65 dtd October 1967.
- 1968 Beckerle, John C. (In preparation). A report on ATLANTIS II Cruise 22. June, July and August 1966. PART I - The dynamics of ocean movements in the Sargasso Sea revealed by sound velocity and temperature measurements. WHOI Ref. No. 68-66 dtd October 1968. (Also Contract Nonr-4029).
- 1968 Beckerle, John C. A report on ATLANTIS II Cruise 22. June, July and August 1966. PART II - Sound velocity profiles. WHOI Ref. No. 68-67 dtd October 1968. (Also Contract Nonr-4029).
- 1968 Beckerle, J. C. Successful prediction of current meter measurements on buoy "P" at 30°N70°W in Oceanographic and Underwater Acoustics Research conducted during the period 1 May - 31 October 1967, pp. 24-26. WHOI Ref. No. 68-6 dtd February 1968.

- 1968 Beckerle, J. C. and E. J. Katz. CHAIN Cruise 67 in Oceanographic and Underwater Acoustics Research conducted during the period 1 May - 31 October 1967, pp. 10-11. WHOI Ref. No. 68-6 dtd February 1968.
- 1968 Beckerle, John C., John S. Reitzel, Richard E. Payne and J. B. Hersey. LECTURES GIVEN AT AGU, April 20, 1966. Variations in sound velocity profiles in the ocean between Bermuda and the Antilles. Trans. Amer. Geophys. Un., v. 47, No. 1, p. 109. (Also WHOI Ref. No. 68-19).
- 1968 Beckerle, John C. Detection of internal waves from doppler shift observations. Trans. Amer. Geophys. Un., v. 47, No. 1, p. 110. (Also WHOI Ref. No. 68-19).
- 1968 Beckerle, J. C. and A. Suarez. Doppler shifts and internal waves at the thermal front in Oceanographic and Underwater Acoustics Research conducted during the period 1 May - 31 October 1967, pp. 26-27. WHOI Ref. No. 68-6 dtd February 1968.
- 1968 Beckerle, J. C., J. L. Wagar and R. D. Worley. Underwater acoustics wavefront variations and internal waves. J. Acous. Soc. of Am., Vol. 44, No. 1, 295-296. (Also WHOI Ref. No. 67-53) (Also Contract Nonr-3275 with Western Electric Co., Inc.).
- 1968 Katz, E. J. and J. C. Beckerle. Oceanic front and sound velocity in Oceanographic and Underwater Acoustics Research conducted during the period 1 May - 31 October 1967, pp. 22-24. WHOI Ref. No. 68-6 dtd February 1968.
- 1969 Beckerle, J. C. Spatial correlation of ocean movements and sound velocity fluctuations. Jour. Acous. Soc. of Am., Vol. 45, No. 4. pp. 1050-1051, April 1969.
- 1969 Beckerle, John C. The dynamics of the Sargasso sea as revealed by temperature and sound velocity measurements. 5th U. S. Navy Symposium on Military Oceanography (3 May 1968).

- 1969 Beckerle, J. C. and E. O. LaCasce, Jr. A report on Cruise 67 of R/V CHAIN, May and June 1967. A study of acoustical fluctuations and ocean movements. WHOI Ref. No. 69-39 dtd June 1969.
- 1969 Brockhurst, R. R. and E. J. Katz (in press). Sound transmission in the presence of an oceanic front (Sargasso Sea). U.S.N. Jour. Und. Acous.
- 1969 Dow, Willard and Thomas Whalen. Deep instrument packages WHOI Ref. No. 69-27 dtd May 1969.
- 1969 Katz, Eli Joel. Further study of a front in the Sargasso Sea. Tellus, Vol. 21, No. 2, 259-269.
- 1969 LaCasce, E. O., Jr. and J. C. Beckerle. A report on a preliminary study for acoustically monitoring large-scale internal ocean movements. WHOI Ref. No. 69-4 dtd June 1969. (Also Nonr-4029).
- 1969 LaCasce, E. O., Jr., T. L. Whalen and J. C. Beckerle. A report on R/V CHAIN Cruise 89, March and April 1969. Sound velocity profiles. WHOI Ref. No. 69-26 dtd May 1969. (Also Nonr-4029).
- 1969 LaCasce, E. O., Jr., C. M. Wooding and J. C. Beckerle. Sound velocity characteristics in the Sargasso Sea based on observations on cruise 89 of R/V CHAIN. WHOI Ref. No. 69-38 dtd June 1969. (Also Nonr-4029).

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D		
<i>(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)</i>		
1 ORIGINATING ACTIVITY (Corporate author)		2a REPORT SECURITY CLASSIFICATION
WOODS HOLE OCEANOGRAPHIC INSTITUTION Woods Hole, Massachusetts 02543		UNCLASSIFIED
		2b GROUP
3 REPORT TITLE		
FINAL REPORT OF CONTRACT Nonr-2866 INCLUDING A HISTORY OF THE CONTRACT AND A BIBLIOGRAPHY OF SCIENTIFIC CONTRIBUTIONS SUPPORTED BY THE CONTRACT AT THE WOODS HOLE OCEANOGRAPHIC INSTITUTION FROM MARCH 1, 1969 TO JUNE 30, 1969		
4 DESCRIPTIVE NOTES (Type of report and inclusive dates)		
Technical Report		
5 AUTHOR(S) (Last name, first name, initial)		
Beckerle, John C.		
6 REPORT DATE	7a TOTAL NO OF PAGES	7b NO OF REFS
June 1969	18	94
8a CONTRACT OR GRANT NO	9a. ORIGINATOR'S REPORT NUMBER(S)	
Nonr-2866; NR 287-004	WHOI Reference No. 69-51	
b PROJECT NO.		
c.	9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d		
10 AVAILABILITY/LIMITATION NOTICES		
This document has been approved for public release and sale; its distribution is unlimited.		
11 SUPPLEMENTARY NOTES		12 SPONSORING MILITARY ACTIVITY
		Office of Naval Research Washington, D.C.
13 ABSTRACT		
The Contract was initiated as a project to provide basic environmental measurements in a broad ocean area between Bermuda and the Antilles that would limit the specifications and the performance of a large long range underwater acoustics system known as Project ARTEMIS. From the beginning in late 1958 until the present the research program included sound transmission studies, temperature and sound velocity measurements, studies of currents in the deep ocean and studies of the bottom conditions. This program of research has brought about better understanding of the ocean bottom in the Bermuda-Antilles area. A reliable environmental ocean measuring system was developed under this contract and put to use to determine spatial and temporal variations in the acoustic structure in the ocean.		

DD FORM 1473  
1 JAN 64

UNCLASSIFIED

Security Classification

1. Project ARTEMIS KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
2. Final Report						
3. Sound Transmission						
4. Environmental Measurements						

**INSTRUCTIONS**

1. **ORIGINATING ACTIVITY:** Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (*corporate author*) issuing the report.
- 2a. **REPORT SECURITY CLASSIFICATION:** Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.
- 2b. **GROUP:** Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.
3. **REPORT TITLE:** Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.
4. **DESCRIPTIVE NOTES:** If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.
5. **AUTHOR(S):** Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.
6. **REPORT DATE:** Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.
- 7a. **TOTAL NUMBER OF PAGES:** The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.
- 7b. **NUMBER OF REFERENCES:** Enter the total number of references cited in the report.
- 8a. **CONTRACT OR GRANT NUMBER:** If appropriate, enter the applicable number of the contract or grant under which the report was written.
- 8b, 8c, & 8d. **PROJECT NUMBER:** Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.
- 9a. **ORIGINATOR'S REPORT NUMBER(S):** Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.
- 9b. **OTHER REPORT NUMBER(S):** If the report has been assigned any other report numbers (*either by the originator or by the sponsor*), also enter this number(s).
10. **AVAILABILITY/LIMITATION NOTICES:** Enter any limitations on further dissemination of the report, other than those

imposed by security classification, using standard statements such as:

- (1) "Qualified requesters may obtain copies of this report from DDC."
- (2) "Foreign announcement and dissemination of this report by DDC is not authorized."
- (3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through \_\_\_\_\_."
- (4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through \_\_\_\_\_."
- (5) "All distribution of this report is controlled. Qualified DDC users shall request through \_\_\_\_\_."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. **SUPPLEMENTARY NOTES:** Use for additional explanatory notes.

12. **SPONSORING MILITARY ACTIVITY:** Enter the name of the departmental project office or laboratory sponsoring (*paying for*) the research and development. Include address.

13. **ABSTRACT:** Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as (TS), (S), (C), or (U).

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. **KEY WORDS:** Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical content. The assignment of links, roles, and weights is optional.