



Acoustic Monitoring of Global Ocean Climate

ACOUSTIC THERMOMETRY OF OCEAN CLIMATE
GLOBAL ACOUSTIC MAPPING OF OCEAN TEMPERATURE





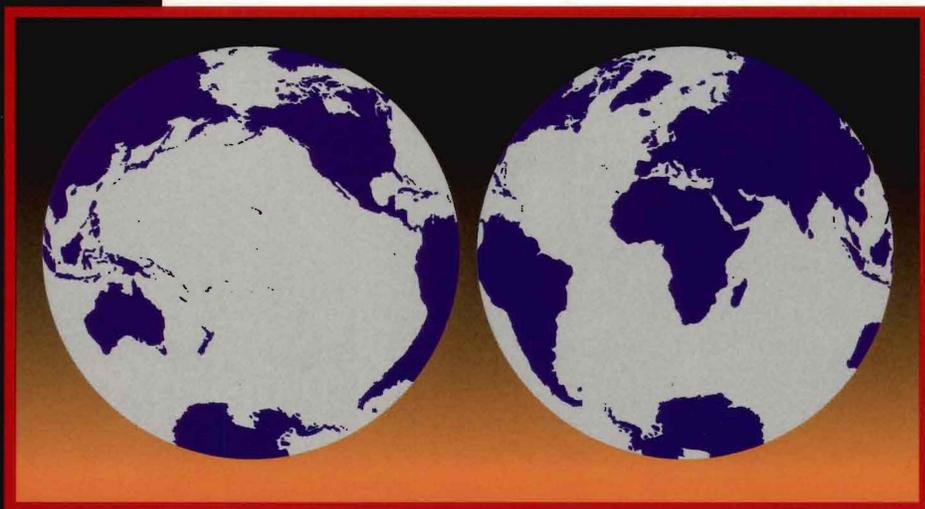
ACOUSTIC MONITORING OF GLOBAL O

Funded by the Strategic Environmental Research and Development Program (SERDP) and sponsored by the Advanced Research Projects Agency (ARPA), the Acoustic Monitoring of Global Ocean Climate Program is the definitive experiment to accurately measure ocean temperature on a global scale which can provide direct evidence of the rate of global climate change. This 30-month research and engineering initiative will use acoustic thermometry to form the basis for a global network involving many international collaborators. The experiment, primarily focused in the Pacific Ocean basin, will resolve outstanding scientific issues in the use of acoustics for basin scale temperature trend monitoring.

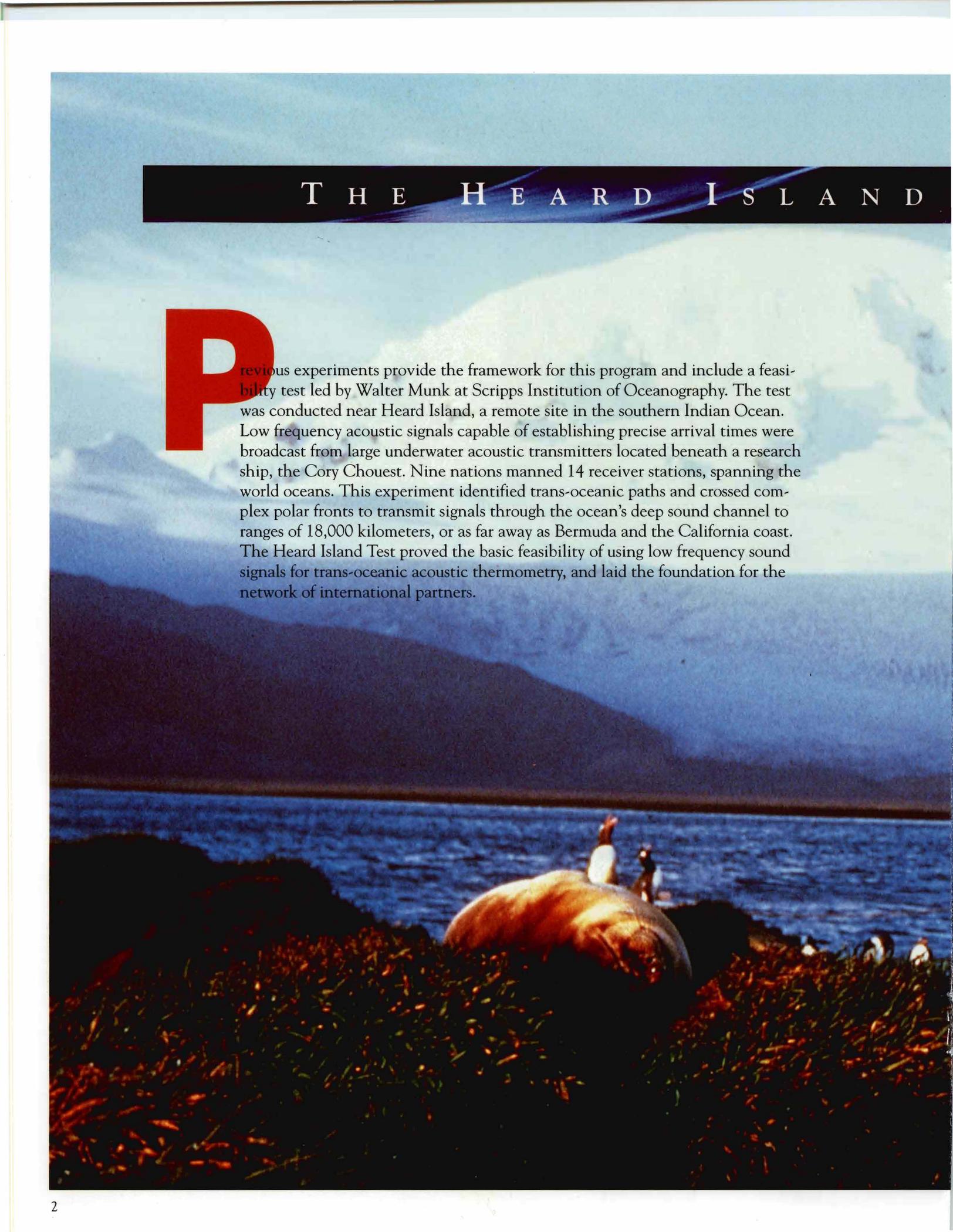
OCEAN CLIMATE

CLIMATE CHANGE: EFFECT OF THE OCEANS

Oceans cover three-quarters of the earth and are vast reservoirs of heat and carbon dioxide build-up from our industrialized world. An accurate measure of ocean temperature on a global scale can provide direct evidence of the rate of global climate change caused by greenhouse gases. Acoustic thermometry measures the transmission time of acoustic pulses from source to receiver, deriving the temperature along the transmission path from the speed of sound in the ocean. This method provides temperature measurement over large ocean expanses and can shorten the time scale for characterizing greenhouse trends to a decade, far shorter and more affordable than methods of atmospheric measurements.



(Left) The initial network consists of acoustic sources deployed near California and Hawaii. The receiver sites include existing U.S. Navy facilities, several fixed Vertical Line Arrays (VLAs), and drifting Surface Suspended Acoustic Receivers (SSARs). Partnerships with Russian and Japanese scientific organizations are also being pursued for sources in the northwest Pacific Ocean. Other receivers may be deployed in collaboration with international partners in the southern Pacific Ocean. (Cover and inside front cover globe graphic by D. Dickinson, SAIC) (Above) Long-lead planning is underway to expand the acoustic network to the Indian and southern Atlantic Oceans with cooperation of bordering nations.



T H E H E A R D I S L A N D

Previous experiments provide the framework for this program and include a feasibility test led by Walter Munk at Scripps Institution of Oceanography. The test was conducted near Heard Island, a remote site in the southern Indian Ocean. Low frequency acoustic signals capable of establishing precise arrival times were broadcast from large underwater acoustic transmitters located beneath a research ship, the Cory Chouest. Nine nations manned 14 receiver stations, spanning the world oceans. This experiment identified trans-oceanic paths and crossed complex polar fronts to transmit signals through the ocean's deep sound channel to ranges of 18,000 kilometers, or as far away as Bermuda and the California coast. The Heard Island Test proved the basic feasibility of using low frequency sound signals for trans-oceanic acoustic thermometry, and laid the foundation for the network of international partners.



THE ATOC NETWORK

Scripps Institution of Oceanography's program, Acoustic Thermometry of Ocean Climate (ATOC), calls for installation of a network of acoustic transmitters and receivers over trans-Pacific paths, using coupled ocean-atmospheric circulation models and extensions of acoustic propagation models to aid in acoustic network design. ATOC studies of acoustic travel-time variability along fixed ocean paths are designed to expose and accurately characterize seasonal trends. Other paths in the network are being tailored to best avoid seasonal "noise". The data collected are being studied for evidence of new, large ocean variability and underlying global scale temperature trends. With relatively few sources and receivers, ATOC will characterize heat distribution of the Pacific circulation system for gyre and basin scales, while suppressing ocean "weather" and smaller scale disturbances.

With the support of the U.S. Navy, technology is now ready for affordable and reliable sound sources, large hydrophone arrays, and seabed signal processors and recorders. ATOC acoustic sources are planned for installation in waters off the Hawaiian Islands and northern California. The U.S. Navy will also provide extensive access for special ATOC diagnostic receivers at their existing undersea facilities at sites throughout the north Pacific. A data network will process and consolidate special acoustic signals for access by project scientists and researchers through the program's international network.

(Above) **ATOC Network configuration shows sources at Kauai and Monterey. Receivers are VLA's at Monterey, NZ and Emperor Seamounts; AVATAR's in the Gulf of Alaska, Rarotonga, and NAVFACS at Guam, and around the north Pacific Rim. Map is Semtner-Chervin mesoscale resolving ocean with temperature shaded in color to depict a typical turbulent eddy field. (Network graphic by M. Dzieciuch, SIO).**

(Left and bottom) **A scene off Heard Island. Research vessel, The Cory Chouest.**

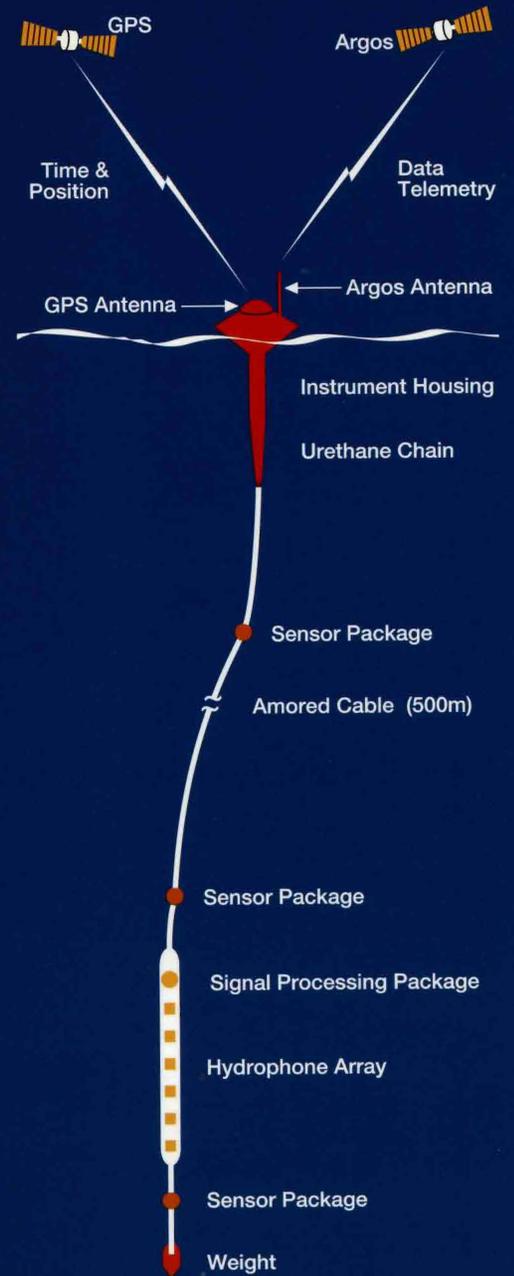


Heard Island photo by H. Milburn

ACOUSTIC INSTRUMENT

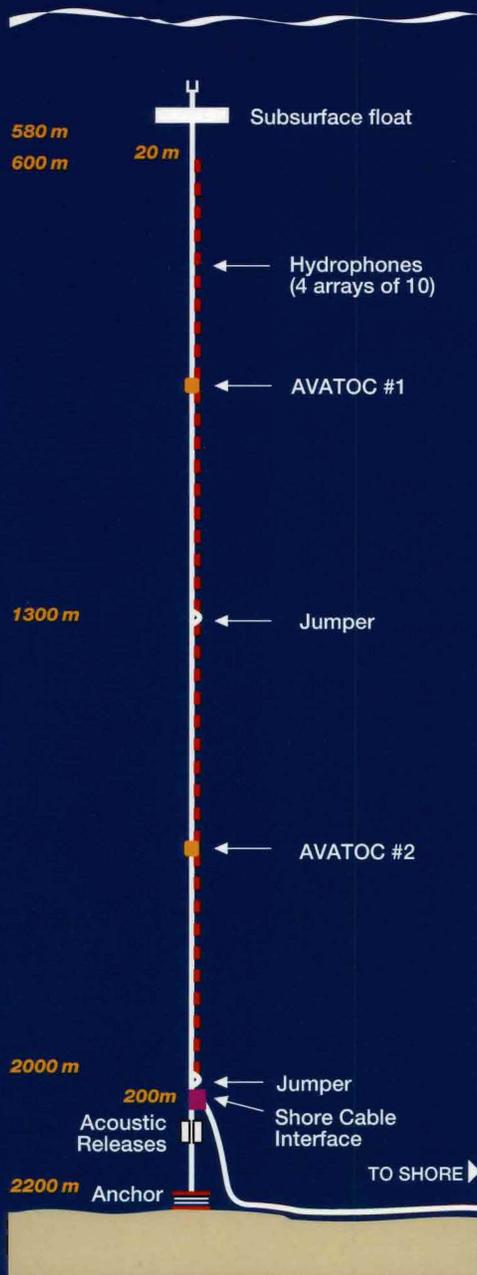


Surface Suspended Acoustic Receiver (SSAR)



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AVATOC Point Sur Cable to Shore



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he program combines existing and new hardware sources and receiver technology. New acoustic sources and vertical line arrays are being designed, developed and procured for this program. Vertical line arrays (AVATOC) with 1380 meter aperture are being developed and installed at key ATOC nodes to spatially separate the modal structure of acoustic arrivals. These systems will help determine the impact of seasonal, gyre and larger scale ocean dynamics on the detectability of the global climate change signal. Advanced technology in acoustic transducers is being incorporated into ATOC sources to provide high reliability for the current program and to test new technology sources for long term monitoring.

THE GAMOT CONTRIBUTION

A second consortium called the Global Acoustic Mapping of Ocean Temperature (GAMOT) led by Woods Hole Oceanographic Institution and Pennsylvania State University is contributing to this program by developing a unique Surface Suspended Acoustic Receiver (SSAR) which has the potential for mapping global oceans in near-real time using state-of-the-art electronics and signal processing techniques. Additionally, a group headed by Florida State University researchers will use advanced ocean models to study climate variability for the Pacific equatorial latitudes.

DATA MANAGEMENT

Digital signals collected from the global network are processed, archived and disseminated by the ATOC Data Center, located at Scripps Institution of Oceanography. Time and development costs have been minimized by adaptation of existing data management software provided by the government.

Raw data in the form of acoustic signals, ocean temperatures and currents are transmitted to the data center directly or by tape. Data are converted to a common format for scientific analyses.

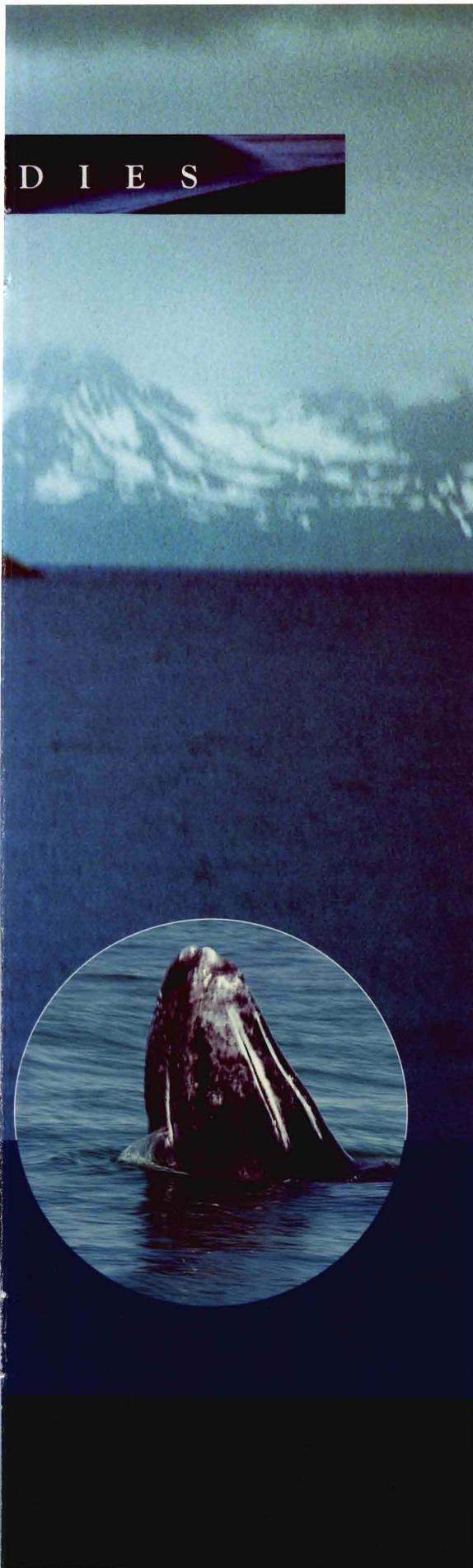


M A R I N E M A M M A L S T U

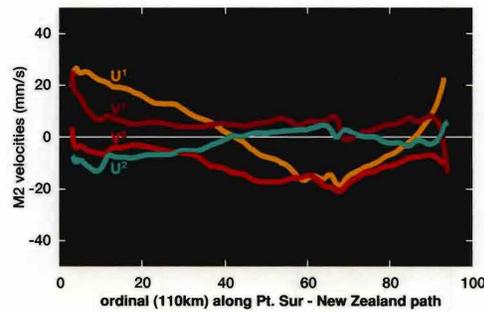
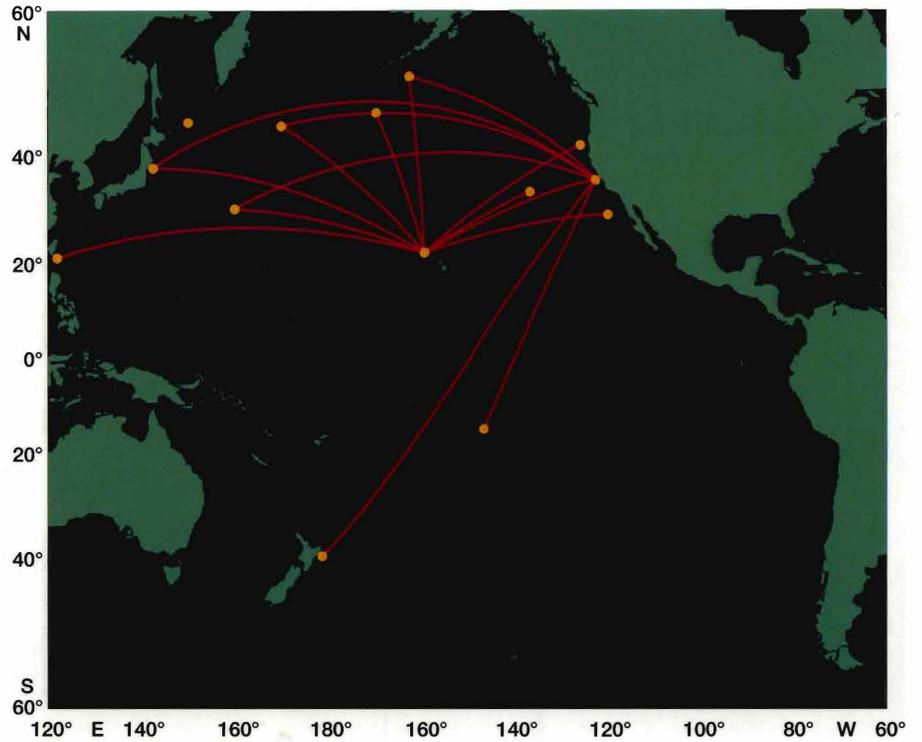
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tudies of the effect of acoustic “noise” on the behavior of marine mammals is an important part of this effort. The program monitors the effects of sounds from acoustic sources on habituation patterns of larger cetaceans and identifies the range of signals causing minimal disturbance.

This research program begins with surveys and observations to develop a baseline. Acoustic tracking, species distribution surveys, and behavioral monitoring are used to assess the effects of man-made noise on behavioral patterns of marine mammals over long periods of time.



Whale photos courtesy of Hubbs - Sea World Research Institute, S. Leatherwood.



Tidal Prediction Models

D. Cartwright

GLOBAL CLIMATE AND ACOUSTIC MODELS

Global Climate Models (GCMs) are being studied and refined to characterize ocean temperature fields and long-term trends. Through computer models of the earth's climate, these data aid in the prediction of global warming trends and acoustic travel time trends to be tested against measurements. Both long-range acoustic propagation and ocean climate models provide a better understanding of the effects of seasonal and other natural variability of ocean temperatures.



PARTNERS

The Acoustic Monitoring of Global Ocean Climate team includes leading U.S. oceanographers, scientists and researchers and international partners from Australia, Canada, China, France, Japan, New Zealand, Russia and South Africa.

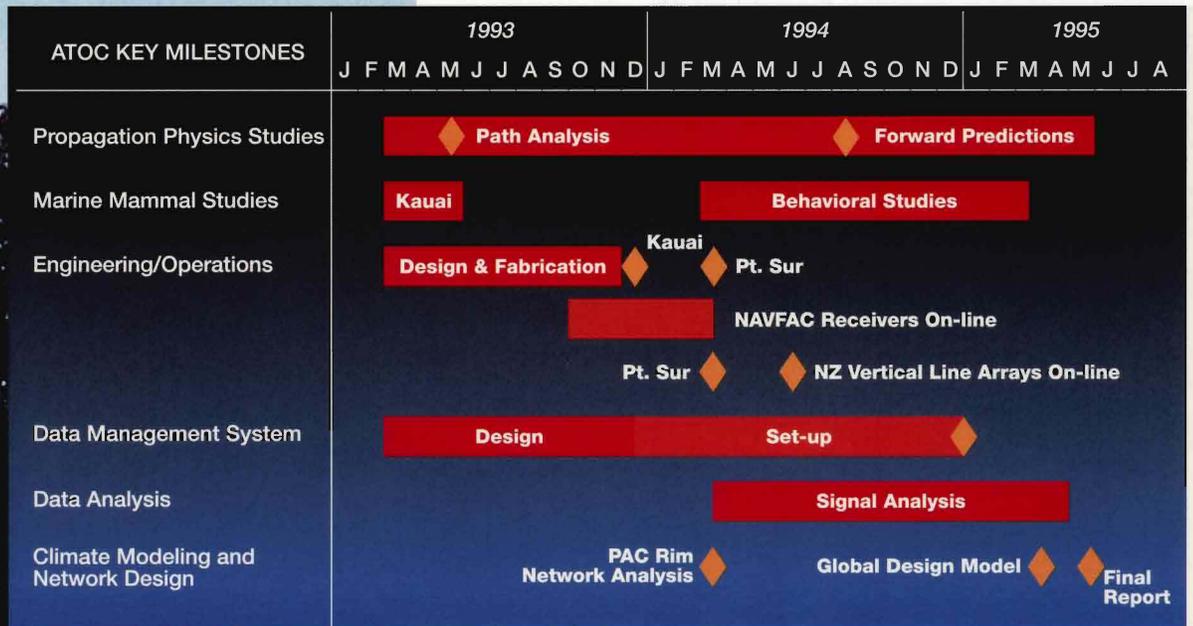
ATOC research institutions and industrial partners are led by Scripps Institution of Oceanography and include Applied Physics Laboratory at the University of Washington; University of Michigan; Massachusetts Institute of Technology; Woods Hole Oceanographic Institution; Science Applications International Corporation; Cornell University; Hubbs-Sea World Research Institute; and key investigators from CSIRO of Australia; University of Miami; NOAA's Florida and Colorado laboratories; Naval Postgraduate School; and Hamburg University.

The GAMOT consortium, led by Woods Hole Oceanographic Institution and Pennsylvania State University, collaborates with ATOC and includes researchers from Florida State University; Naval Research Laboratory, Stennis; and University of Alaska, Fairbanks.

Mississippi State University will contribute advanced computer visualization. Mission Research, Inc. will perform supporting data analyses. Research Planning, Inc. is providing technical support to ARPA. The U.S. Navy Undersea Surveillance Office and the Commander Undersea Surveillance, Pacific Operations is affording access to key operational facilities and technologies from existing undersea research and development programs.

EXECUTIVE DIRECTION AND MILESTONES

The Executive Committee, comprised of senior members of the scientific community, guides this program under the direction of Dr. Ralph W. Alewine, Director of ARPA's Nuclear Monitoring Research Office and Walter Munk of Scripps Institution of Oceanography, University of California, San Diego.



Propagation and GCM-based analyses will drive the ATOC network design. Ocean instrumentation is being developed and installed during the first year. Data are then collected and interpreted with advanced acoustic instruments to be tested in the second year. The GCM-based analyses will lead to a global network plan.

EXPECTATIONS

This 30-month research and engineering initiative probes innovative concepts, embraces and extends the latest technology and involves the world's leading researchers who are strongly committed to its success. This initiative is designed to produce the models and techniques on which to base a global network involving many international collaborators.



Scripps Pier, La Jolla, CA (Photo by Susan R. Green, SIO Photo Lab)



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