CONTENTS

CONTENTS (continued)

INTRODUCTION

As the *Ocean State*, Hawaii has been a leader in ocean-directed research for many years. In the late 1960's, for instance, the study, *Hawaii and the Sea*, highlighted research areas to be pursued by government, academic, or commercial organizations. Hawaii's mid-Pacific location is unique and allows extraordinary access to a variety of ocean environments–particularly the deep ocean–in a climate generally mild enough for year-round, at-sea activity.

Department of Defense (DoD) ocean-related activities, facilities, and assets in Hawaii are also numerous, exceptional, and long standing. Recent DoD emphasis has focused on providing advanced technology to both war-fighting and support units, while emerging DoD programs seek to increase use of commercially developed advanced within DoD systems and system-development cycles. Hawaii provides an ideal location for a federally supported state program to develop ocean technologies for DoD applications.

CONGRESSIONAL ACTION

The National Defense Center of Excellence for Research in Ocean Sciences (CEROS) was created by congressional action. House Bill 8761, published in the September 18, 1992, *Congressional Record*, contained a section entitled *Research, Development, Test, and Evaluation, Defense Agencies* and provided for

> ". . .an additional amount for RESEARCH, DEVELOPMENT, TEST AND EVALUATION, DEFENSE AGENCIES, $74,800,000, to remain available for obligation until September 30, 1993. Provided that $5,000,000 of the funds appropriated in this paragraph shall be made available only for a National Defense Center of Excellence for Research in Ocean Sciences to be established through cooperation between the Defense Advanced Research Projects Agency (DARPA) and the Hawaii High Technology Development Corporation (a government entity) for the purpose of conducting research and development (R&D) activities of interest to the Department of Defense on such topics as ocean environment preservation technology, new ship hull design concepts, shallow water and surveillance technologies, ocean measurement instrumentation, and the unique properties of the deep ocean environment."

NATIONAL DEFENSE CENTER OF EXCELLENCE FOR RESEARCH IN OCEAN SCIENCES (CEROS)

Background

In February 1993, DoD technical needs, combined with ocean technology capability in Hawaii, yielded the National Defense Center of Excellence for Research in Ocean Sciences (CEROS). CEROS was established through a grant from the Defense Advanced Research Projects Agency (DARPA) to the High Technology Development Corporation (HTDC), an agency of the State of Hawaii attached to the Department of Business, Economic Development and Tourism (DEBDT). CEROS was funded

> ". . . for the purpose of conducting research and development activities of interest to the Department of Defense . . . and . . . to support and stimulate a broad spectrum of research in ocean science in the State of Hawaii."

DARPA Grant No. MDA 972-93-1-0008

DARPA awarded Grant No. MDA 972-93-1-0008 for $5,000,000 to HTDC for CEROS in February 1993. This grant supported a core program of eleven projects involving twelve prime contractors during CEROS FY93. Technical work was complete for this grant by December 1997, and the final grant report was delivered to DARPA in September 1998.

DARPA Grant No. MDA 972-94-1-0010

DARPA awarded Grant No. MDA 972-94-1-0010 to HTDC for CEROS in May 1994. This grant, with total funding of $18,737,796, supported a core program of thirty-nine projects involving nineteen prime contractors during CEROS FY94, FY95, and FY96. Technical work was complete for this grant by June 1999, and the final report was delivered to DARPA in September 1999.

DARPA Cooperative Agreement No. MDA972-97-2-0001

DARPA awarded Cooperative Agreement No. MDA972-97-2-0001 to the Natural Energy Laboratory of Hawaii Authority (NELHA) in September 1997. This agreement, with total funding of $31,707,564, supported a core program of eighty projects involving thirty-five prime contractors during CEROS FY97, FY98, FY99, FY00 and FY01. Contract details are listed in Table 1. This report describes the work done under the 1997 agreement.

The purpose of the grant is

> ". . . to support a broad spectrum of research in Ocean Sciences in the State of Hawaii and to provide support for CEROS. This effort shall be carried out as set forth in this article to this Cooperative Agreement, and the Awardee's proposal entitled 'CEROS Procurement Plan: February 1997'. . ."

State Oversight and Interaction

The State of Hawaii and DBEDT recognize that building and reinforcing a competitive ocean research and development (R&D) community with guided networking, marketing, and new business interchanges are important functions of CEROS. When CEROS was created, it was administered by the State of Hawaii through HTDC. In December 1995, CEROS was transferred to the Natural Energy Laboratory of Hawaii Authority (NELHA), another State of Hawaii agency.

Program Summary

CEROS advances the state's goals of expanding technology-based industries by encouraging the participation of Hawaii companies that have special expertise of interest to DoD. The NELHA Board of Directors set broad goals, developed policy, and provided guidance for the general management and direction of CEROS under Cooperative Agreement No. MDA972-97-0001. As CEROS grantor, DARPA reviewed and evaluated CEROS programs and management to assure grant conformance and consistency with congressional intent.

The CEROS Technical Director is the agreement's Principal Investigator and is responsible for technical program development and execution. The Technical Director impanels a research advisory board to provide functional oversight, guidance, and advice throughout the CEROS source-selection process and to plan and implement strategic development. As a condition of funding, CEROS programmatic goals and managerial approaches are presented to DARPA annually as an operational plan.

Program Objectives

The purpose of CEROS is to solicit and support innovative technology development for national maritime military applications and sustained technology-based economic development in Hawaii. This is to include demonstrating capabilities and building residual benefits.

The CEROS technical program seeks to identify leading-edge, value-added technologies that support DoD requirements, use facilities, and infrastructure in Hawaii, and foster potential commercial development. The technical topic areas addressed by the CEROS program were identified in the congressional legislation as

- Ocean environmental preservation technology
- New ocean platform and ship concepts
- Shallow water surveillance technologies
- Ocean measurement instrumentation
- Unique properties of the deep ocean environment.

Program Scope

CEROS supports R&D projects that are intended to produce measurable results or products within 12 months. Procurement is based on priorities that are issued in published solicitations, emphasizing near-term results. Proposals can include options for an extended period of performance. However, incremental or follow-on funding of any such option is not guaranteed.

If a project is proposed that probably cannot be procured within time or budget limitations, the CEROS Technical Director and the CEROS Research Advisory Board will try to reduce the risks and consequences of postponing, scaling, or not funding. Trade-offs among cost, performance, and schedule are evaluated relative to programmatic goals and planned procurement schedule and appropriate risk-reduction strategies are identified and implemented.

Procurement

CEROS solicits proposals for concept development and demonstration of ocean technologies and applied ocean sciences for military maritime purposes through annual Broad Agency Announcements (BAAs). An offeror must be a commercial enterprise to be eligible for consideration. CEROS selects and supports technical projects that conform to its mission. CEROS procures R&D based on programmatic priorities and goals; the resultant procurement contracts include terms and schedules for delivery. The selection process emphasizes technology development in Hawaii and the Pacific without eliminating applicable projects of merit with a focus elsewhere. CEROS determines best value through technical and

programmatic evaluations that match proposed efforts with DoD technology needs and CEROS programmatic objectives within funding constraints. As a condition of funding, DARPA approves CEROS contract policy and procedures and assures that they are consistent with applicable federal acquisitions regulations and guidelines.

The BAA for each year covered under this agreement was published in the Commerce Business Daily as follows:

YEAR	SOLICITATION	RELEASE DATE
FY97	BAA-CEROS-97-01	December 11, 1996
FY98	BAA-CEROS-98-01	October 10, 1997
FY99	BAA-CEROS-99-01	October 2, 1998
FY00	BAA-CEROS-2K-01	October 1, 1999
FY01	BAA-CEROS-01-01	October 2, 2000

TABLE 1
CEROS PROJECTS – FY97 THROUGH FY01

Contractor	Year	Project	Amount	Contract No.
Aquaculture Technology Incorporated	97	Continuous Production of Marine Algae Chaetoceros Spp. In an Open System	$440,000	42803
Band, Lavis & Associates, Inc.	97	Application Techniques & Comparative Effectiveness of Non-Toxic Anti-Fouling Surfaces to Immersed Nettings Used in Naval and Aquaculture Industries	$225,483	42982
BBNT Solutions LLC (formerly BBN Corporation)	99	Hydrofist: A Non-Explosive Means for Generating Intense and Focused Underwater Shock Waves (Phase 1)	$999,819	45694
	00	Hydrofist: A Non-Explosive Means for Generating Intense and Focused Underwater Shock Waves (Phase 2)	$800,000	47343
	01	A Proposal to Implement and Demonstrate Antisub-marine Warfare (ASW) Targeting and Weapon Control Using Non-Organic Sensors: Netted Combat Control System (Netted CCS) Phase 1	$1,112,450	48213
Black Pearls, Inc.	97	Probiotic Bacteria: The Key to Expanded Use of Deep Seawater In Tropical Aquaculture and the Solution to a Growing Industry Problem	$121,392	42839
	00	Deep Seawater Use in a Photobioreactor; More Efficient Microalgal Production and Broader Deep Seawater Applications	$173,201	46762
	01	Development of a Sensitive, Sessile Monitor for Non-Point Source Heavy Metal Pollution for Tropical and Sub-Tropical Indo-Pacific Waters	$138,097	48210
Cox Environmental Systems	00	Water Properties Sensor Project	$215,004	46763
Detection Limit Technology, Inc.	97	Solution+ In-Situ Ocean Sediment Chemical Analyzer	$360,000	42887
	98	Polychlorinated Biphenyl (PCB) Analyzer for Shallow Ocean Water	$380,000	44524
	00	Surface-Enhanced Raman Spectroscopy (SERS) Immunoassay Detection System: "Dog Nose" Sensor for TNT Detection and Detection of an Aquaculture Virus	$439,937	47339
Dynamics Technology, Inc.	00	Analysis of Synthetic Aperture Sonar (SAS) Data for Geological Surveys	$98,239	47258
Edward K. Noda & Associates, Inc.	98	Modeling of Hurricane-Induced Coastal Flooding for the Hawaiian Islands	$182,345	44370
Gateway Technologies International, Inc.	98	Personal Emergency Lifesaving System (PELS)	$240,920	44023

TABLE 1
CEROS PROJECTS – FY97 THROUGH FY01

Contractor	Year	Project	Amount	Contract No.
GuideNet, Inc.	98	Using Software Agents to Acquire and Visualize Environmental Information for Antisubmarine Warfare (ASW) Surveillance (Phase 1)	$305,000	44404
	99	Using Software Agents to Acquire and Visualize Environmental Information for Antisubmarine Warfare (ASW) Surveillance (Phase 2)	$360,000	45513
	00	Workflow Paradigm for Antisubmarine Warfare (ASW) by Reliable Meteorology and Oceanography (METOC) Data and Tasks	$397,050	46676
Innovative Technical Solutions, Inc. dba NovaSol	01	Temporally Enhanced Adaptive Multi-Spectral (TEAMS) System for Detection of Underwater Objects	$34,953	48580
Knapp Engineering, Inc. dba Structural Solutions	97	3-D Finite Element Design of Cables	$190,000	43109
	98	A Probe for In Situ Characterization of Marine Carbonate Sands and Other Sediments	$220,000	44748
	98	SMART SCUBA (Phase 1)	$319,000	44751
	99	SMART SCUBA (Phase 2)	$312,000	46008
	00	Modeling of Cable Fatigue	$190,000	47073
	01	Experimental Investigation of Cable Fatigue	$192,000	48488
Makai Ocean Engineering, Inc.	98	An Internet-Enabled Engineering Tool for Dynamic-ally Analyzing and Planning World-Wide Subsea Cable and Array Installations (Phase 1)	$379,985	44303
	00	Remote Monitoring and Expert Control of Submarine Cable and Array Installations	$345,737	46765
	00	Improving Flow From Deep Water Pipelines	$388,950	47072
Neptune Technologies, Inc.	97	Diver Homing Device Product Improvement (Phase 2)	$39,300	42967
Nextwave Engineering	01	Snap-To Amphibious Footwear System	$75,700	48002
Ocean Engineering Consultants, Inc.	00	Small Water Plane Area Twin Hull (SWATH) Ship Software and Verification	$164,954	46684
Oceanic Imaging Consultants, Inc.	98	The ROVER's Eye Terrain Database Visualization as an Aid to ROV Navigation (Phase 1)	$239,652	44366
	99	The ROVER's Eye Terrain Database Visualization as an Aid to ROV Navigation (Phase 2)	$275,482	46005
The Oceanic Institute	99	Cultured Fish as Biological Indicators of Pollution	$216,766	45852
Oceanit Laboratories, Inc.	97	Computational and Physical Modeling of the Hurricane Tower Desalination	$150,000	43162
	01	Three-Dimensional Cloud Height Indicator for Marine Application (3D-CHIMA)	$400,000	48216
Oceantek, Inc.	99	An Ocean Bottom Span Analyzer for Survey Planning and Installations of Submarine Cables	$188,000	45770

TABLE 1
CEROS PROJECTS – FY97 THROUGH FY01

Contractor	Year	Project	Amount	Contract No.
Oceantronics, Inc.	99	Electronic Charting Display and Information System (ECDIS-N) with Special Emphasis on Submarine Navigation - Hi Plot	$393,000	45300
ORINCON Corporation	97	Antisubmarine Warfare Commander's Workstation Upgrades & ARTS	$500,000	42705
	97	An Improved Acoustic Intercept Receiver for Submarine Applications (Phase 1)	$450,000	42703
	97	An Integrated System for Detection, Classification, Localization, Multisensor Tracking and Reporting of Submarine Contact Data	$700,000	43055
	98	Situation Awareness System (SAS) Processor for Submarine Applications, Phase 2	$171,777	44367
	98	Upgraded Advanced Real-Time Sensor (ARTS) Processor for Maritime Patrol Aircraft Applications	$373,000	44368
	98	An Improved Acoustic Intercept Receiver for Submarine Applications (Phase 2)	$560,000	44369
	99	Automation and Integration of Environmental Factors Into ASW Tracking	$497,415	45290
	99	At-Sea Evaluation of the Situation Assessment System Processor	$775,864	45812
	00	Mission Reconfigurable Signal Processing System	$749,504	46675
	01	Theater-Wide Situational Awareness For Decision Wall	$150,000	48163
	01	Passive Assured Access (PAA) System	$749,203	48390
Pacific Environmental Technologies	99	Mass Spectrometer Using Rotating Fields for Exploratory Research (Mass SURFER) Phase 1	$141,743	45291
	00	Mass Spectrometer Using Rotating Fields for Exploratory Research (Mass SURFER) Phase 2	$171,864	46821
Pacific Marine & Supply Company, Ltd.	97	Computational Fluid Dynamics (CFD) Code Validation and Improvement Using Large Scale Tests	$663,300	42787
	98	Development of a Patentable Combination Propeller-Pump Jet Integrated Propulsion Pod with Boundary Layer Suction	$300,000	43959
	99	Fabrication and Demonstration of a Patentable Combination Propeller Pump Jet Integrated Propulsion Pod with Boudary Layer Suction Designed Under a CEROS 98 Grant	$1,019,000	45496
	00	Large-Scale Producibility Demonstration of 3-D Lifting Bodies	$980,000	47257
	01	Flapping Foil Technology for Motion Stabilization of Novel High-Speed Vehicles	$250,000	48211

TABLE 1
CEROS PROJECTS – FY97 THROUGH FY01

Contractor	Year	Project	Amount	Contract No.
Raytheon Company	97	Integrated Sensor System for Search and Classification of Subbottom	$753,008	43320
	98	Multispectral, Interferometric, Synthetic Aperture Sonar System (SAS)	$550,034	44414
	99	Frequency Agile Sequential Transmission Synthetic Aperture Sonar (FastSAS) Risk Reduction Technology Demonstration for NetTORP -- TERMINATED	$119,976	45773
Science & Technology International, Inc.	98	Undersea Fanbeam Spectral Imaging (FSI) Risk Reduction Technology Demonstration	$398,895	44304
	98	Patuxent River Dual Camera HSI System	$565,498	45125
Science Applications International Corporation	99	Web-Based Processing for State-of-the-Art Large Aperture Multidimensional (SLAM) Array	$500,000	45772
	00	Web-Based, Propagation and Noise Effects on Signal Processing (Phase 2)	$670,000	47316
	01	Web-Based Simulation, Modeling and Signal Processing	$399,868	48575
Scientific Solutions, Inc.	01	Implementation of an Ocean Acoustic Laboratory at Pacific Missile Range Facility (PMRF)	$150,392	48389
Sea Engineering, Inc.	97	On Site, Preliminary Analysis of Sediment Core Samples (Phase 2)	$102,650	42849
	97	Development of a 3-D, Forward/Aft Sweeping, High Resolution Buried Object Imaging System (Phase 1)	$388,660	42913
	98	Development of an Ultra-High Resolution Stress Detection System for Marine Application	$319,154	44632
	98	Dev of a 3-D, Forward/Aft Sweeping, High Resolution Buried Object Imaging System, Phase 2	$421,200	44801
	99	Development of an Enhanced Resolution Filter for Improving Sonar Imagery	$148,287	45514
SEE/Rescue Corporation	98	LIFE/FLOAT The One-Person Survival Craft	$70,000	44373
	00	Compact-Inflatable-Mobile Survival Platform for Military/Special Forces and Commercial Applications (Phase 2)	$120,000	47505
STI Services, Inc. (TerraSystems, Inc.)	01	vSAR: Video Search And Rescue	$337,123	48214
	01	Reconnaissance of Mines and Obstacles in the Surf Zone (SZ)	$34,999	48574
Synthetic Technology Corporation	97	Bioactive Marine Isonitrile Compounds from Hawaiian Sponges as Models	$300,033	43313
TerraSystems, Inc.	98	Development of an Underwater Compositional Mapping (UCM) System	$351,177	44002
	99	Enhanced Sea & Land Rescure Visibility Systems	$253,839	45292

TABLE 1
CEROS PROJECTS – FY97 THROUGH FY01

Contractor	Year	Project	Amount	Contract No.
Trex Enterprises	00	Development of a Sensor for Pesticide Monitoring Based on a Porous Silicon Optical Biosensor	$537,000	46764
	01	Porous Silicon Biosensor	$499,826	48215
Varian Associates, Inc.	97	Laser Heterodyne Imaging for Littoral Water Surveillance (Phase 2)	$395,435	43314

FISCAL YEAR 1997 CORE PROJECTS

Continuous Production of Marine Algae *Chaetoceros Spp*. in an Open System

Aquaculture Technology, Inc. (ATI), Honolulu, HI
Contract No. 42803 (FY97 Core) for $240,000

PERIOD OF PERFORMANCE: October 15, 1997 to May 18, 2000

OBJECTIVE: Develop and demonstrate an efficient, open, and continuous process to produce kilogram quantities of the marine algae *Chaetoceros spp*.

BACKGROUND: In previous work sponsored by CEROS, ATI showed that the marine algae *Chaetoceros spp*. contains certain polyunsaturated fatty acids that were found to be effective against S*taphylococcus spp*. and other known antibiotic-resistant bacteria. Military and civilian populations are endangered when bacteria develop resistance to drugs because death from infection can result when effective treatment against bacteria is lacking. Because the algal fatty acids with antibacterial properties are difficult to synthesize chemically, a special system is needed to produce large quantities of algae as a natural source for antibacterial fatty acids. Photobioreactors are chambers where *seed* algae and nutrients are mixed with sea water and exposed to illumination. Large-scale photobioreactors use solar illumination to produce algae and other valuable products; e.g., food additives, pharmaceuticals, nutritional supplements, pigments, and biosurfactants. Surfactants also have many uses in products such as adhesives, emulsifiers, detergents, and industrial reagents.

RESULTS: ATI developed a production system consisting of eight fractionating photobioreactors. The photobioreactors are both growth chambers and harvesting units for the microalgae. ATI tested harvested algae and isolated several fractions that showed strong biosurfactant activity (foaming). ATI perfected a foam fractionation system that used the natural foaming material for efficient harvest of *Chaetoceros* cells from the photobioreactors. The new system improved cell yield significantly.

ATI also upgraded the laboratory equipment and protocols for the production of the antibiotic compounds from the *Chaetoceros* extracted from the photobioreactors. A vacuum dryer proved particularly effective in speeding the extraction process and preventing compound degradation. ATI increased the efficiency of the final purification stage by adding large capacity chromatographs and automated samplers to the process.

U.S. Patent No. 5,866,150 entitled *Antibacterially Active Extracts from the Marine Algae Chaetoceros and Methods of Use* was issued in February 1999 to ATI.

SIGNIFICANCE: The process, procedures and equipment developed by ATI can support high-volume production, harvest, and separation of various marine natural products for a variety of uses such as pharmaceuticals, food pigments, and biosurfactants. These products have billion dollar world markets.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Application Techniques and Comparative Effectiveness of Nontoxic Anti-Fouling Surfaces to Immersed Nettings Used in Naval and Aquaculture Industries

Band, Lavis & Assoc.(BLA), Severna Park, MD
Contract No. 42982 (FY97 Core) for $225,483

PERIOD OF PERFORMANCE: October 15, 1997 to June 14, 1999

OBJECTIVE: To

- Confirm that silicone-coated netting reduces biofouling accumulation and reduces work required to clean biofouling accumulation on submerged netting
- Develop a cost-effective means of producing silicone-coated netting
- Develop a cost model that can be used to predict the benefits of implementing the use of coated net in a particular aquaculture facility

BACKGROUND: A need exists in the commercial aquaculture industry and the military to solve biofouling problems on submerged netting. Biofouling of net pens and net panels represents one of the severest operational and maintenance problems in marine aquaculture.

RESULTS: BLA conducted extensive research in many geographical areas in both aquaculture and military environments. BLA developed an automated process to coat nets with silicone, which is technically significant. Of four aquaculture facilities, three showed economic benefit of using silicone-coated net systems. The research and development effort showed that silicone-coated nets are

- Less expensive, suited to automated processing, are effective biofouling inhibitors, and have superior mechanical properties
- Beneficial in several geographic locations in both sub- and full-scale applications.
- More beneficial in severe biofouling.

SIGNIFICANCE: Although the research and development objects were met, further full-scale testing is required to fully define the benefits of using silicone-coated net. Nevertheless, BLA conducted a market study and developed a business plan in support of full commercialization of silicone-coated net systems. In 2002, treated netting was installed at the Biosciences Division animal enclosures at the SPAWAR Systems Center in San Diego and remains in service.

Probiotic Bacteria: The Key to Expanded Use of Deep Seawater in Tropical Aquaculture and the Solution to a Growing Industry Problem

Black Pearls, Inc., Halualoa, HI
Contract No. 42839 (FY97 Core) for $121,392

PERIOD OF PERFORMANCE: October 1, 1997 to September 20, 1998

OBJECTIVE: To expand the use of ocean thermal energy conversion-related deep sea water (DSW) for culture of tropical invertebrates and other organisms at the Natural Energy Laboratory of Hawaii Authority (NELHA) and improve the hatchery and nursery production of pearl oysters in Hawaii and the other United States-affiliated Pacific.

BACKGROUND: The objectives for this research were developed because it could lay a foundation for increased understanding of probiotic principals, which could lead to use of probiotics or their bio-active products in energy, engineering, and human medicine fields. Probiotics could serve as antibiotics, pesticides, and antifouling in the aquaculture area, commercial maritime industry, and military applications.

RESULTS: Work with evaluating various bacteria for probiotic use was seriously complicated and compromised by water quality problems associated with the NELHA delivery system. Larvae performed better using seawater bucketed out of nearby tide pools compared to NELHA surface seawater (SSW). Despite several attempts at solution, including Black Pearls, Inc. installing its own SSW, the problem of biofouling buildup inside the pipes continued. Whatever the problem, apparently probiotic use of beneficial bacteria is not the solution. A strain that works well during one larval cycle might have no effect when used in the next cycle. Currently for Black Pearls, Inc.'s production system, antibiotics are the best option for reliability.

SIGNIFICANCE: The viability of Black Pearls, Inc., and perhaps other present and future tenants, depends on a high level of water quality, or at least the ability to counteract any deficiencies. Until the problem is better understood, it will be difficult to devise a plan to overcome it. Further investigation into this situation is very important to everyone at the NELHA site.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Solution to *In-Situ* Ocean Sediment Chemical Analyzer

Detection Limit Technology, Inc. (DLT), Kailua, HI
Contract No. 42887 (FY97 Core) for $360,000

PERIOD OF PERFORMANCE: October 1, 1997 to April 30, 1999

OBJECTIVE: To

- Develop a sensor for detecting and identifying benzene, toluene,, ethylbenzene, xylene (BTEX) in groundwater; sensor will add on to existing *Solution*$^+$s system and show sensitivity below 12 ppm
- Develop software partial least squares (PLS) methods to online detect and identify BTEX and nitrates
- Design and manufacture house for *Solution*$^+$ probe for field use
- Demonstrate *Solution*$^+$ for the state.

BACKGROUND: Traditional approach to site characterization hampers remediation because of uncertainty regarding field samples, time requirements, and cost. In a past CEROS-supported effort, DLT performed research to detect and identify chlorinated hydrocarbons, particularly tricholoethylene (TCE), and heavy metals. The resultant device currently outperforms existing technology in sensitivity and accuracy with the advantage of reversibility, and the ability to measure multiple volatile organic compounds (VOCs) and metals simultaneously. Using *Solution*$^{+'}$s portable Raman spectrometer with attached sensors, DLT has demonstrated detection and identification of TCE to 10-ppm levels, and heavy metals; e.g., Cd^2+ to 50 ppB in real-life groundwater samples from known contaminated sites. This method is inexpensive, selective, sensitive, repeatable, and has a long life. Also, it can be used for quantification as well as identification between chlorinated hydrocarbons. .

RESULTS: The development of the BITEX sensor particular for ethylbenzene, exceeded estimated sensitivities to 100 ppb incorporating a new development in colloidal surface enhanced Raman spectroscopy (SERS). This development eliminates the problem of inconsistencies between sensors and localized heating. It enhances signals through use of magic-sized particles and has developed a new research direction into immunoassay.

A new bundled fiber-optic Raman probe was manufactured and tested providing throughputs equal to previous working-distance probes. The probe represents a breakthrough in Raman monitoring in adverse environments including autoclaves, undersea applications, space applications, as well as in-line process control.

In developing the nitrate sensor, a two-pronged approach used published literature to produce a sensor that detected nitrate down to 50 ppb, but not without pretreatment of the sample to promote adsorption onto the detector. The high-risk approach generated a new development in creating the sensor molecule preorganized for nitrate. The yield for this key step was improved to more than 40 percent, giving a complete yield of almost 10 percent, which compares to less than 0.3 percent using previous art methods.

SIGNIFICANCE: This research is the key to nitrate detection and is resulting in several published papers, a new tool for many chemical applications, as well as a high commercial potential for a patentable nitrate-detection device.

3-D Finite Element Design of Cables

Knapp Engineering doing business as Structural Solutions, Inc., Aiea, HI
Contract No. 43109 (FY97 Core) for $190,000

PERIOD OF PERFORMANCE: January 1, 1998 to December 30, 1999

OBJECTIVE: To develop software for 3-D finite element design, analysis, and simulation testing of oceanographic cables.

BACKGROUND: Structural Solutions based the CableCAD® software package on its existing CableLab design software. CEROS supported cable design and analysis software development at Structural Solutions in FYs 96 and 97. Structural Solutions estimates that several hundred cable and rope manufacturers or users will have immediate interest in the CableCAD® software product. Structural Solutions sold approximately twenty licenses since the CableCAD® product was released in mid-1999. The project was delayed when the project's software engineer ended his Structural Solutions affiliation.

RESULTS: Structural Solutions developed the CableCAD® software package for computer-aided cable design and analysis. CableCAD® operates on a personal computer running the Microsoft Windows 95 or Windows NT system. Three modules comprise the CableCAD® code—(1) finite layer solver; (2) finite element solver, and (3) interactive graphical processor—simplifies creation of finite element cable models. The graphical database provides libraries of wire geometries and user-defined components. The graphical environment accelerates the modeling process and improves the accuracy of results. The CableCAD® postprocessor produces plots of cable reactions and deformations that provide insight into cable design and potential performance. CableCAD® software is produced and sold from Hawaii for $7,495 per license.

SIGNIFICANCE: In a relatively short time, this project produced the first commercially available cable design and analysis tool based on finite element analysis. CableCAD® can model diverse structures such as helical cable, wire ropes, and flexible pipe for defense, scientific, and commercial applications. Sales of CableCAD® software are generating positive cash flow for Structural Solutions.

Diver Homing Device Product Improvement
Phase 2

Neptune Technologies, Inc.,
Contract No. 42967 (FY97 Core) for $39,300

PERIOD OF PERFORMANCE: November 1, 1997 to July 31, 1998

OBJECTIVE: To further test and improve a prototype electro-acoustic system that allows a diver to home in on an ultra-sonic transmitter.

BACKGROUND: In an earlier CEROS-sponsored project, Neptune designed, built, and tested the diver homing device (DHD), which consists of a transmitter, receiver and the SCUBA diver. A particular feature of the DHD uses the diver's body and equipment as an acoustic shield to increase directionality. The DHD met or exceeded all performance requirements and contract specifications. Neptune Technologies received a U.S. patent for the DHD.

RESULTS: Operational testing was completed and results have been incorporated into improved transmitters and receivers. Prototypes were modified to implement the improvements. Other tests were successfully conducted to evaluate specific changes in the hardware or processing. A demonstration was conducted successfully for Navy SEALs at Pearl Harbor. The SEAL unit has HDH units to use for more testing and evaluation.

SIGNIFICANCE: In addition to receiving the patent, Neptune Technologies has completed an operational handbook, promotional flyer, warranty/registration card, and business plan. Further, Neptune Technologies plans to open a research and development and small production facility in Honolulu.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Computational and Physical Modeling of the Hurricane Tower Desalination

Oceanit Laboratories, Inc., Honolulu, HI
Contract No. 43162 (FY97 Core) for $150,000

PERIOD OF PERFORMANCE: January 1, 1998 to December 31, 1998

OBJECTIVE: To develop two models (computational and physical) to analyze, design, optimize, and predict full-scale Hurricane Tower desalination system performance.

BACKGROUND: The 1996 Water Desalination Act mandated efforts into research and development of innovative desalination technologies to convert salt and brackish water into fresh water. There is a need for a simple and efficient method to utilize abundant and cheap natural resources found in the very environment where military forces are deployed. Under contract with the National Science Foundation (NSF) and in cooperation with Common Heritage Corp., Kona, Hawaii, Oceanit successfully demonstrated that a secondary vortex, inherent to a hurricane system, could be useful in water desalination. The result was called Hurricane Tower desalination system. The Hurricane Tower system uses deep, cold seawater as the condensing agent to extract water evaporated from warm surface seawater heated in a solar pond. The tower uses a central rotor and rotating disk to create primary and secondary circulatory flows that enhance thermodynamic processes.

RESULTS: The computational model was written in a C-based graphical programming language, with a user-friendly graphical user interface (GUI). The program incorporates theoretical thermodynamics with empirical fluid mechanic results taken from the physical model. The computational model is designed for analyzing and designing full-scale Hurricane Tower performance.

The physical model, measuring 2 ft in diameter with an adjustable height of up to 4 ft, was used to test the performance of the system for varying parameters, including rotor/disk RPM, aspect radio, rotor size, and water flow rates. Testing protocol, along with a test matrix, was developed and executed. Results and optimization analyses were used to identify tower parameters for optimum larger-scale system operation. The advantage of the physical model is the relative ease in adjusting system subcomponents and run settings. Results of the model were used to calibrate computational model parameters, including thermodynamic efficiencies, and fluid mechanic circulatory constants.

SIGNIFICANCE: The models developed provide valuable tools to design, optimize, and demonstrate Hurricane Tower system performance. The models can also be used to develop, design, and test related hybrid desalination systems and technologies to enhance water production and efficiency. For marketing and commercialization purposes, the models will also be used as technology demonstrators.

Antisubmarine Warfare (ASW) Commander's Workstation Upgrades and Advanced Real-Time Sensor (ARTS)

ORINCON Hawaii, Kailua, HI
Contract No. 42705 (FY97 Core) for $500,000

PERIOD OF PERFORMANCE: September 10, 1997 to September 9, 1998

OBJECTIVE: To develop and implement enhancements to the ADM-3 workstation to increase operational functionality; to adapt processing algorithms from the ARTS processor to support processing of sonobuoy data from maritime patrol aircraft (MPA).

BACKGROUND: Under the FY95 CEROS program, Orincon installed an ADM-3 workstation at Commander Combined Task Force Twelve (CTF-12) to provide multisensor fusion, localization, and optimization capabilities for basin-wide ASW command and control. For FY97, CTF-12 requested several enhancements to the ADM-3 workstation to increase operational functionality, enhance modeling and display capabilities, improve on-line training and user assistance functions, and develop networking capabilities to provide system products to fleet users.

CTF-12 also requested a modified ARTS processor to provide automated target detection and other ASW capabilities for a maritime patrol aircraft (MPA). Orincon developed the ARTS processor under CEROS support in FYs 95 and 96. The ARTS processor provides a reliable, automated system for detection of acoustic signatures from potentially hostile submarines, as well as a multichannel, automated, real-time alerting and display capability for signals of interest.

RESULTS: Five enhancements were added to the ADM-3 workstation—(1) screen decluttering function that allows the operator to choose, by name, the tracks that are displayed; (2) overlay feature that allows the operator to create and display exercise-area boxes on the tactical display screen; (3) extended "HELP" files that included standard operating procedures for the CTF-12 command; (4) "Publish" button to automatically record a selected geographic display, convert the selection to ".gif" format, and place the "snapshot" on the CTF-12 website; and (5) advanced hypothesis generation system that added environmental information to line-of-bearing reports for enhanced target track localization.

The MPA ARTS processor was configured to process data from up to 32 sonobuoy channels. The system hardware was packaged in a ruggedized commercial off-the-shelf (COTS) chassis with a 19-in. color monitor, keyboard, and trackball. Two system tests were successfully conducted during RIMPAC 98 exercises.

SIGNIFICANCE: This project addressed two high-priority requests from the CTF-12 to enhance antisubmarine warfare capabilities in the Pacific. The enhancements to the ADM-3 workstation provided a greater functionality for the ASW commander at CTF-12. The MPA ARTS processor provided a significantly enhanced ASW capability of the CTF-12 MPA.

Improved Acoustic Intercept Receiver for Submarine Applications
Phase 1

ORINCON Hawaii, Kailua, HI
Contract No. 42703 (FY97 Core) for $450,000

PERIOD OF PERFORMANCE: November 17, 1997 to February 16, 1999

OBJECTIVE: To develop, demonstrate, and evaluate an improved intercept receiver (IAIR) processor onboard an operational submarine of the Pacific fleet.

BACKGROUND: Localization of active sonar emitters is accomplished by mapping the time-delay measurements, obtained by coherent processing of time-series data from multiple sensors, into an estimate of the emitter's position. This technology is often referred to as wide-aperture array, interarray, or wave-front curvature processing. Better data processing techniques are needed so the U.S. Navy can increase its capabilities to utilize sonar data during operations.

RESULTS: ORINCON developed a prototype system, running on workstation hardware, to automatically correlate broadband sonar emissions from surface ships and submarines, particularly active acoustic waveforms from surveillance and tactical sonar systems. This IAIR system utilizes omnidirectional and noise-monitoring hydrophones that are mounted along the length of the submarine. Input from the bow-mounted spherical sonar is also used in the processing algorithms to take advantage of the array gain available from that sensor. Correlation of input from the tracker beam and omnidirectional hydrophones enables the system to operate effectively on sources at greater range than that from correlating omnidirectional hydrophones alone.

Furthermore, the ORINCON improvements include wavefront curvature processing to improve target localization capabilities for IAIR systems. ORINCON intends to apply this build, test, build procedure during Phase 2 (FY98) to determine the number of bands needed to cover the emitters of interest to fleet submarines.

SIGNIFICANCE: This project answered a request from the Commander, Submarine Force, U.S. Pacific Fleet (COMSUBPAC). When Phase 2 (FY98) is completed, equipment will be installed on a Pearl Harbor-based submarine.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

An Integrated System for Detection, Classification, Localization, Multisensor Tracking and Reporting of Submarine Contact Data

ORINCON Hawaii, Kailua, HI
Contract No. 43055 (FY97 Core) for $700,000

PERIOD OF PERFORMANCE: November 17, 1997 to February 16, 1999

OBJECTIVE: To develop and demonstrate a submarine situation awareness system (SAS) to automatically detect, classify, and fuse submarine detection data with all-source data and report specific information to the on-scene commander and maritime patrol aircraft.

BACKGROUND: Under CEROS support in FYs 95 and 96, Orincon developed the advanced real-time sensor (ARTS) processor to provide automated target recognition capability to support tactical antisubmarine warfare (ASW). The ARTS processor provides quick response across a broad spectrum of advanced signal and information processing applications. Under CEROS support in FY95, Orincon and Sippican Corp. showed that a submarine-launched, two-way, fiber optics-linked disposable communications buoy is feasible using existing technology and components. Tests of the AN/BRT-6 antenna demonstrated a receiving capability for both satellite and line-of-sight operations. The SAS applies art and technology from the ADM-3/ASW commander workstation projects funded by CEROS in FYs 95 and 97; the system detects, fuses, classifies, localizes, and tracks surface and subsurface targets in littoral and deep-water.

RESULTS: Four automated detection and classification algorithms were developed and incorporated into the ARTS processor. The ARTS processor was installed on *USS Louisville* in July 1998 according to a temporary alteration (TEMPALT) secured by SUBPAC. An antenna/float assembly was developed and tested to provide transmit/receive capability for the AN/BRT-6 submarine-launched communication buoy. Measurements taken at the ARCH facility at the Naval Undersea Warfare Center, Newport, Rhode Island, indicated that the modified antenna met the receive/transmit antenna requirements for the submarine-launched, two-way, fiber optic-linked communications buoy. The SAS processor integrated information from the improved ARTS processor and the two-way, fiber optics-linked communications buoy. Also, the SAS processor incorporated advanced multihypothesis, multiple target tracking, and correlation algorithms with multisensor data measurements to form fused target tracks. The operator-machine interface (OMI) includes a comprehensive suite of interactive displays that present the derived tactical scene to support analysis, measurements, tracking, and tactical decisions.

SIGNIFICANCE: This project addressed a high-priority request from SUBPAC for an advanced automated system for surface/subsurface target detection, classification, localization, data fusion, situation assessment and reporting. The project leveraged results from previous CEROS-supported projects to demonstrate a feasible way for undersea platforms to communicate with war fighting commanders and other Navy (surface and air) elements while remaining at operating depth.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Computational Fluid Dynamics (CFD) Code Validation and Improvement Using Large-Scale Tests Optimization of Design for High Froude Number Underwater Body Operating Near Surface (*Midfoil* and *Slice*); and Subsequent Construction and Testing of Optimized Underwater Body

Pacific Marine & Supply Co., Ltd., Honolulu, HI
Contract No. 42787 (FY97 Core) for $663,300

PERIOD OF PERFORMANCE: September 15, 1997 to May 14, 1999

OBJECTIVE: To consider the effects of thickness ratio on hydrodynamic performance for three different aspect ratios.

BACKGROUND: Pacific Marine combined funds from CEROS, the Hawaii Electric Vehicle Development Program and MARITECH of DARPA to design, test, and build a manned model of a new ship design called MidFoil. Rather than a traditional v-hull or even a catamaran-style small water plane area twin hull (SWATH), the MidFoil has a foil-shaped body placed amidships to provide displacement. CEROS supported the computerized design and testing with CFD, small-scale physical model tests, and construction of the unique foil for the 65-ft manned model. The 50-ton vessel was launched in Honolulu Harbor and ran successfully. The vessel exhibits and extremely smooth, stable ride even in rough seas and at speeds over 20kt. The design can be scaled up to 10,000 tons for various DOD and commercial applications; e.g., shipping and ferries. Results have direct application to DARPA and ONR advanced fast-ship programs. Benefits from the Tri-Strut effort were applied to the Pacific Marine SLICE program.

Earlier work involved with the development of low-drag underwater bodies led to the paraboloid and H body forms. Since then the J-2 body has been developed, which has some drag advantages over the paraboloid body. The objects of the study were the H and J-2 bodies. As with earlier studies, the CFD code used is Analytical Methods, Inc.'s VSAERO/FSWAVE.

RESULTS: No attempt was made to offset sinkage, other than setting camber and angle of attack at nominal values of 2% and 1 deg, respectively. Experience with MidFoil and earlier analyses indicate that sinkage can be controlled and therefore, dynamic lift was not specifically addressed. The aspect ratios studied were

- Displacement/drag
- Wetted areas versus displacement/drag
- Cavitation

SIGNIFICANCE: Investigators concluded that thicker bodies have better displacement/drag ratios than thinner bodies. For a specific application, bodies with the highest thickness ratio should be used, which satisfies other design considerations; e.g., speed (cavitation) and draft. Flow over the bodies appears well behaved and there are no indications of separation; cavitation is not a significant problem. Examination of friction along streamlines indicates that improvements to these bodies are possible. Additional shaping could be introduced to mitigate localized friction.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Integrated Sensor System for Search and Classification of Subbottom Objects

Raytheon Systems Co., Mukilteo, WA
Contract No. 43320 (FY97 Core) for $758,000

PERIOD OF PERFORMANCE: January 15, 1998 to December 30, 1999

OBJECTIVE: To develop and test an integrated bottom-penetrating synthetic aperture sonar system that can search, detect, image, and classify objects and bottom topography.

BACKGROUND: In FY94, CEROS funded Alliant Techsystems to develop and demonstrate a bottom-penetrating, synthetic aperture sonar (SAS) system for environmental survey and underwater ordnance remediation. The project leveraged considerable DARPA support for advanced SAS technology and included the Hawaii Mapping Research Group (HMRG) of the University of Hawaii (UH), School of Ocean & Earth Science & Technology as a significant principal subcontractor and partner. Raytheon eventually subsumed the SAS development work started by Alliant. Since FY94, CEROS provided about $5.1 million for bottom-penetrating SAS development; nearly half the funding went to HMRG. The SAS development team initially upgraded UH's MR1 bottom-mapping sonar to support hardware and signal processing development for the bottom-penetrating system. Subsequent years brought considerable convergence between the DARPA- and CEROS-sponsored efforts and emphasis on real-time data processing for classifying buried objects.

RESULTS: Towfish was stable at speeds of 2 to 5 kts. Thirty sets of image data were collected from diverse targets in downlooking and various side-looking aspects. Buried mines were detected when they occurred within the swath of the system. Synthetic apertures were limited to about 4 m for runs over featureless bottoms. Bottom features; e.g., burial scars, were important for image classification with the system.

SIGNIFICANCE: The SAS techniques demonstrated are novel, but the images produced are not clear enough for definitive classification of unknown buried ordnance-sized objects. Furthermore, after 5 years of development, full real-time data processing has not been demonstrated. The upgraded MR1 remains UH property and enables HMRG to secure profitable commercial contracts and research grants. Under contract with Pacific Marine & Supply of Honolulu, Raytheon used the *R/V SLICE* advanced technology vessel, which proved an excellent working platform for the sea tests, in Hawaii and California.

On-Site, Preliminary Analysis of Sediment Core Samples
Phase 2

Sea Engineering, Inc. (SEI), Waimanalo, HI
Contract No. 42849 (FY97 Core) for $102,650

PERIOD OF PERFORMANCE: October 1, 1997 to April 30, 1999

OBJECTIVE: To develop a miniaturized field-screening system that would enable users to conduct rapid, economical, on-site chemical screening of potentially contaminated dredge sediments.

BACKGROUND: The research conducted during this project was based on two existing technologies—x-ray fluorescence and silicon carbide hydrocarbon (SiC) sensor. The SiC sensor had been previously developed at Jet Propulsion Laboratory (JPL), Pasadena, California, and its ability to distinguish among simple compounds was demonstrated. This project involved working with more complex organic compounds. The specific goals of Phase 1 were to conduct the research required to demonstrate the applicability of the two technologies to sediment testing, determine the detection limits for the various chemical constituents, and develop the design criteria for a prototype instrument. Proof-of-concept testing was successful. Instrument sensitivity can be increased by utilizing a higher-powered source and replacing the single detector with an array of detectors. These approaches would increase the sensitivity of the instrument by a factor of approximately 400, bringing the detection limit down to about 0.25 ppm.

RESULTS: Incorporation of catalysts into the sensor was investigated early. Addition of catalyst to the sensor was required because initial testing did not show sufficient separation between the electrochemical responses of the classes of compounds of interest. After literature was surveyed, nickel was selected as a potential catalytic material. As a result of initial tests, noise in the sensors became an increasingly larger proportion of the signal. Although obvious sensor-contact problems were resolved and data were reviewed and reanalyzed, the problem remained. The objective was then shifted to identifying the reasons for the reproducibility problem, which had to be resolved before continuing the detection limit tests. Two new sensors—one catalyzed and one uncatalyzed—were constructed using a modified contact geometry. The approach reduced the noise but there were more reproductibility issues in both the new sensors. The objectives for the SiC sensor were not met, but the investigators illustrated that organic compounds react on the sensor surface and members of the same class have similar responses.

SIGNIFICANCE: The project identified other issues in basic research that need to be resolved to apply this technology as originally proposed. JPL intends to conduct fundamental studies of the mechanism of operation of the SiC sensor. If understanding of the operation of the sensor leads to a solution of the reproducibility problems, a portable, economical, chemical screening system for marine sediments could be achievable.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Development of a 3-D, Forward/Aft-Sweeping, High Resolution Buried Object Imaging System
Phase 1

Sea Engineering, Incorporated (SEI), Waimanalo, HI
Contract No. 42913 (FY97 Core) for $388,660

PERIOD OF PERFORMANCE: November 1, 1997 to April 30, 1999

OBJECTIVE: To design and demonstrate a portable, high-resolution sonar that will detect buried objects in real time and produce 3-D images that provide burial depth, location, and target size.

BACKGROUND: Many marine projects in Hawaii and the Pacific Basin require location and discrimination of buried objects; e.g., cables that cannot be towed, pipelines, unexploded ordnance (UXO) hazardous waste containers, and miscellaneous debris. SEI has been involved in many of these projects. The only practical technologies available are towed magnetometers and diver hand-held metal detectors that are unable to discriminate between metallic debris and the objects of interest. Phase 1 involved designing and constructing a sonar capable of forward/aft and port/starboard beam steering, developing software to perform the beamforming and match filtering in a postprocessing mode, investigating image visualization techniques, and collecting acoustic data and generating images of buried objects. The project provided the following results:

- 32-channel imaging sonar produced images of most objects buried in the test field
- Steering angle of 12-deg optimized buried-object imaging
- Coefficient filter-enhanced relative strength of coherent reflections from targets
- 3-D image of a target was demonstrated using surface rendering

RESULTS: SEI and Precision Signal, Boca Raton, Florida, developed and tested a sonar processing system comprising a sonar control computer and four additional computers in the topside processor. The sonar has a steerable transmission beam to minimize scattering noise and illuminate targets at various aspect angles. Images of cable and pipe sections, ordnance and cylinders buried 1 ft in sand were generated during testing at Makai Pier, Oahu. The effort produced the following results:

- System detected and imaged targets and displayed the target field in real time
- Tests demonstrated importance of fore/aft beam steering for target detection in sand
- Processing algorithms were optimized to enhance image quality and simplify data interpretation.
- Dimensions of linear objects were accurately imaged.
- Sonar effectively located and mapped buried UXO and pipe and cable sections.

SIGNIFICANCE: This two-phase project developed and proved a subbottom imaging technology for finding certain classes of buried objects and reporting target information in real time. This is the first sonar capable of forward/aft and port/starboard sweeping of transmission and reception beams. The sonar showed the importance of forward/aft beam steering for detecting objects buried in sand. The sonar is a useful adjunct to SEI for near-shore geophysical cable routing surveys in Hawaii and throughout the Pacific Basin.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Bioactive Marine Isonitrile Compounds from Hawaiian Sponges as Models for Synthetic Nontoxic Antifoulant and Antibiotic Agents III. Product Optimization and Field Validation

Synthetic Technology Corp., Honolulu, HI
Contract No. 43313 (FY97 Core) for $300,033

PERIOD OF PERFORMANCE: January 1, 1998 to December 31, 1998

OBJECTIVE: To test isonitrile compounds, natural products as extracted from the sponges *Ciocalypta sp.*, and synthetic, as antifoulants first in laboratory bioassays with the larvae of the common biofouling polychaete tubeworm *Hydroides elegans*, then in field trials after incorporation into paint coatings.

BACKGROUND: Biofouling of ships is a critical economic and tactical problem for naval and commercial shipping operations. The most common solution has been to incorporate toxic metal ions, copper or tin, into ship coatings. Fouling is especially well controlled by tributylin (TBT), but that remains toxic in waters and sediments and bioaccumulates, causing reproductive problems and developmental defects in marine animals. Copper can replace TBT but is also toxic. Nontoxic alternatives are needed that can be as effective as toxic metal ions. This report summarizes Synthetic Technology's investigation of antifouling agents based on the sponge isonitrile compound isocyanopupukeanane (ICP)

RESULTS: ICP was identified in Hawaii from the sponge *Ciocalypta* and a nudibranch, *Phyllidia sp.* that feeds on the sponge. Results show that low concentrations of ICP inhibit the settlement and metamorphosis of larvae of *Hydroides elegans* in laboratory bioassays. Nudibranches are known for sequestering biologically active natural products from food sources. Synthetic Technology has been testing products from another nudibranch, *Phestilla sibogae*, which feeds on the coral *Porites compressa*. *Hydroides elegans* is the most troublesome fouler in Hawaii and occurs throughout tropical and warm, temperate seas. The potential was for use of unique natural products derived from nudibranches and their food sources was demonstrated. Synthetic Technology tested three different types of paint as carriers for isonitrile additives and found that silicone coatings are superior to epoxy or polyester resins for this purpose.

SIGNIFICANCE: Since the amount of material that can be obtained from sponges or nudibranches is limited, the use of synthetic products will be an important step in making practical use of this discovery. Further research is indicated as to the optimal formulation of isonitrile and formamide derivatives that could be used as antifoulants.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Laser Heterodyne Imaging for Littoral water Surveillance
Phase 2

Varian Associates, Inc., Palo Alto, CA
Contract No. 43314 (FY97 Core) for $395,435

PERIOD OF PERFORMANCE: February 1, 1998 to April 30, 1999

OBJECTIVE: To develop the coherent-turbid water imaging system technology (C-TWIST) imaging system for object identification in highly scattering coastal, river, and lake waters with low visibility (optimized for operation at distances of less than 3 ft).

BACKGROUND: This project was a cooperative effort between Varian Associates and Detection Limit, Inc., Kailua, Hawaii. The system uses coherent detection, coherence gating, and long-wavelength illumination, all of which are novel techniques in underwater imaging. The C-TWIST system has unique capacity for imaging in turbid coastal water and can operate with many different laser sources. The performance of the proof-of-concept system assembled in Phase 1 exceeded the range and resolution of all existing optical systems available for imaging in high-turbidity waters.

RESULTS: The laser source used in Phase 2 was a compact 500-mW, 683-nm semiconductor laser with 5-W power consumption. Because the manufacturer of this laser discontinued production, Phase 2 data were obtained using two other laboratory systems. In Phase 2, the researchers upgraded, modularized, and fitted the system with a synchronous raster scanning capability and a simple-to-use dedicated user interface. The system was optimized for imaging in waters with less than 1 m of visibility where it outperforms all existing optical imaging systems. Moreover, its superior detection system can be used for imaging at longer ranges with equal effectiveness. C-TWIST has demonstrated the highest possible signal-to-noise ratio performance for any underwater imaging system, within 20 dB of the theoretical limit. The system also boasts immunity to sunlight-level ambient light, which would blind other imagers, as well as a natural immunity to fluorescent signals that would prove confusing to many other systems.

SIGNIFICANCE: This is the first reported demonstration of coherent image acquisition under water. C-TWIST's system design and prototype assembly need no further development. The next stage of evolution is to customize it to particular applications. The laser source and optical scanner are the key components whose selection and configuration will depend on the exact operating environment of C-TWIST. Other system components are modularized and interconnected by optical fiber and can be configured to fit most requirements.
.

FISCAL YEAR 1998 CORE PROJECTS

Polychlorinated Biphenyl (PCB) Analyzer for Shallow Ocean Water

Detection Limit Technologies, Inc. (DLT), Kailua, HI
Contract No. 44524 (FY98 Core) for $380,000

PERIOD OF PERFORMANCE: July 1, 1998 to September 30, 1999

OBJECTIVE: To demonstrate that an *in-situ* instrument based on surface effect raman spectroscopy (SERS) can detect and measure (PCB) compounds in marine sediments.

BACKGROUND: PCB compounds are harmful to human and animal health. PCBs were used widely in electrical devices for many years before their harmful effects were recognized. Leaked or spilled PCBs are persistent environmental contaminants and PCB-contaminated sites are found on military and nonmilitary sites. Approximately 20 percent of the total PCBs produced now reside in the open ocean, and 11 percent reside in coastal sediment. Existing instruments to detect and quantify PCB compounds are not field-portable and laboratory processing of field samples can take hours orweeks to complete. An analyzer that can measure PCB compounds in the field could greatly reduce the costs and time required for characterization and remediation of contaminated sites. Since FY93 (with CEROS support), DLT developed and applied the SERS technique to a variety of instrument and measurement problems.

RESULTS: DLT developed an instrument based on SERS technology that detected PCB compounds in *clean* water, in sediment preparations, and directly in ocean sediments. DLT demonstrated that the instrument-detected PCB compounds in water at concentrations as low as 126 ppt within 10 sec, and in sediment extracts at 800 ppt . DLT developed a special probe for the instrument and demonstrated direct, quantitative measurement of PCB compounds in wet ocean sediment in less than a minute. DLT combined four technologies to achieve the results: (1) conventional Raman spectroscopy, (2) SERS, (3) a colloidal medium for SERS, and (4) surface attraction using immunoassay techniques. Also, DLT obtained two provisional patents for technology developed during this project.

SIGNIFICANCE: DLT demonstrated that a Raman-based instrument could provide quick, on-site measurements of PCB compounds and produce more detailed chemical analyses than existing methods. The DLT SERS instrument is relatively inexpensive and can be used by a minimally trained technician in the field. Existing alternatives are less sensitive and results require hours of laboratory chemical analysis by a trained expert. DLT has spunoff several companies and received several patents for Raman-based spectroscopic instruments and techniques. DLT companies have also received nearly $2 million in FY98 and FY99 Small Business Innovation Research (SBIR) funds.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Modeling of Hurricane-Induced Coastal Flooding for the Hawaiian Islands

Edward K. Noda and Associates, Inc., Honolulu, HI
Contract No. 44370 (FY98 Core) for $182,345

PERIOD OF PERFORMANCE: August 1, 1998 to December 31, 2000

OBJECTIVE: To develop a new numerical modeling methodology to accurately determine near-shore wave characteristics and coastal flooding for island coastal areas caused by hurricanes.

BACKGROUND: Wave setup over shallow reef areas can exceed the storm surge effects caused by hurricane wind stress and inverted barometer effects. Therefore, spatial modeling (both on and offshore) of the wave transformation processes is important to accurate determination of inundation effects at the shoreline. An integrated hydrodynamic model is required to characterize the spatial 2-D variability of the near-shore wave field, the subsequent rise in mean water level, and the spatial characteristics of coastal flooding effects. The integrated model was developed for practical application to specific sites using PC systems. However, with CEROS support, Version 1.0 of the software was calibrated and verified for the south shore of the island of Kauai.

RESULTS: An integrated numerical model, Hurricane-Induced Coastal Inundation Program (HICUP™) a PC-based modular program for Windows 95/98 operating system that enables real-time forecasting of hurricane-generated waves and coastal inundation. HICUP™ enables the user to predict the hurricane-generated waves and coastal inundation from an approaching hurricane at site-specific locations in real time. HICUP™ 2.1 is programmed with three sites in the Hawaiian Islands: (1) Kukuiula-Poipu area south shore Kauai, (2) Makaha-Waianae area southwest shore Oahu, and (3) Maalaea Bay south shore Maui. HICUP™ program modules numerically model wave transformation and wave setup in a 2-D numerical grid of the near-shore and shoreline regions of a selected area and predict the spatial extent of coastal inundation. Results are plotted over a USGS map of the selected coastal reach. Future development work on HICUP™ will expand the application to other site-specific coastal areas.

SIGNIFICANCE: As the first of its kind program, HICUP™

- Enables real-time predictions of Hawaiian island inundation caused by an approaching hurricane
- Is unique in the 2D formulation for modeling wave-induced setup
- Was developed specifically for use by nonengineers

Personal Emergency Lifesaving Systems (PELS)

Gateway Technologies International, Inc. (GTII), Honolulu, HI
Contract No. 44023 (FY98 Core) for $240,920

PERIOD OF PERFORMANCE: June 30, 1998 to December 29, 1999

OBJECTIVE: To construct a prototype personal emergency lifesaving system (PELS) that will alert a ship if a man goes overboard (MOB), and provide position locations of the MOB for rescue and lifesaving.

BACKGROUND:. This project seeks to prevent loss of life at sea. If a ship knows immediately that there is a MOB and is able to locate him quickly, the chances of survival are much greater.

RESULTS: GTII, constructed a prototype PELS. The primary components are a packet-data transceiver, GPS receiver, and laptop computer. The MOB unit has a transceiver and a GPS receiver. The host unit has a transceiver, a GPS receiver, and a laptop computer that sets up, controls, logs operations, displays data records, and saves data in a file for postdemonstration analysis. The prototype PELS tracked a MOB with range up to 1800 yd and gave accurate bearing to the MOB. The overboard detection feature was not implemented in this phase of development.

SIGNIFICANCE: While the prototype functioned reasonably well under test conditions, the cost of GPS receivers and other components is prohibitive. Therefore, GTII currently cannot produce and market PELS for the target price of $100 per unit.

Using Software Agents to Acquire and Visualize Environmental Information for Antisubmarine Warfare (ASW) Surveillance
Phase 1

Guide.Net, Inc., Honolulu, HI
Contract No. 44404 (FY98 Core) for $305,000

PERIOD OF PERFORMANCE: August 1, 1998 to December 31, 1999

OBJECTIVE: To develop software to automatically retrieve oceanographic and meteorological (METOC) data from the Internet. To enhance Navy capability to produce timely METOC reports and plans.

BACKGROUND: Guide.Net is an Internet software company specializing in interactive websites. This project marked Guide.Net's entry into application development and workflow analysis for DOD. The project was closely coordinated with the command and staff of the Navy Pacific Meteorology and Oceanography Center (NPMOC) at Pearl Harbor. NPMOC has a clear need to augment and automate data acquisition and handling in support of fleet operations throughout the Pacific command. For example, one staff meteorologist at Pearl Harbor had book marked 142 Internet sites as sources of METOC data, but lacked an automated system to query and display specific data from these multiple sources. Guide.Net headed a team that included coinvestigators from the Universities of Washington, Massachusetts, and Hawaii.

RESULTS: Guide.Net developed software routines (webcrawlers) to retrieve METOC data over the Internet. Also developed was display interface for collected data. A detailed workflow analysis of data collection process was produced at NPMOC. Utility of routines were demonstrated using high seas wave data in the Pacific. A demonstration of the system, named SmartBuoy, is available on the Guide.Net website under METOC products.

SIGNIFICANCE: The NPMOC Chief Scientist endorsed this initial step to automate and improve METOC planning operations. The workflow tool is built upon the lightweight extensible information framework (LEIF) client and agent architecture. LEIF was developed for the Navy and used by Guide.Net in this project so the resultant capabilities could be easily applied for fleet use. The Space and Naval Warfare System Command (SPAWAR) identified the LEIF METOC workflow system as a noteworthy development at the METOC facility in San Diego. SPAWAR provided funds to Guide.Net for further implementation of LEIF. The workflow analysis was also adopted by the Office of Naval Research (ONR) for improved METOC support of air-strike mission planning. Guide.Net is developing licensing and marketing plans for the workflow routines. Follow-on development resulting from this project received CEROS funds in FY99 and FY00.

A Probe for *In Situ* Characterization of Marine Carbonate Sands and Other Sediments

Knapp Engineering., Inc. dba Structural Solutions, Aiea, HI
Contract No. 44748 (FY98 Core) for $220,000

PERIOD OF PERFORMANCE: November 1, 1998 to January 31, 2000

OBJECTIVE: To develop and demonstrate a new ocean tool for *in-situ* measurement of engineering properties of seabed sand and soils.

BACKGROUND: The Hawaiian Islands' and other tropical islands' beaches need sources of sand for beach replenishment so off-shore (100-m water depth) deposits need to be located and characterized. A sediment probe would meet this need using an internal video camera that could be deployed from a ship without anchoring and without a heavy winch.

RESULTS: The square-shaped working prototype of the probe was equipped inside with an underwater video camera (rated to 750m) to record the sediments through a quartz window. A pneumatic hammer was attached to drive the probe into the sediments. Field tests were conducted on land from the Makai Pier and from a 32-ft Boston whaler off Waikiki in 40 ft of water (both located off the island of Oahu). Although buoyant in the water, the exhaust hose required for the pneumatic hammer was bulky on deck, which probably limited the penetration depth. Future models would use an electric or hydraulic percussive hammer to alleviate these problems. However, good video images were captured by all tests. Deep Sea Power & Light now has a color video camera that will improve the information gathered from the images. Color is important for beach applications.

SIGNIFICANCE: This project confirmed the potential of the sediment probe to function as proposed and suggests continued development toward a commercial product. Markets could include onshore and shallow water surveys for geophysical and mining companies.

SMART SCUBA™
Phase 1

Knapp Engineering, Inc. dba Structural Solutions, Aiea, HI
Contract No. 44751 (FY98 Core) for $319,000

PERIOD OF PERFORMANCE: November 1, 1998 to April 30, 2001

OBJECTIVE: To design a robust, low-cost, fiber-optic sensor system, consisting of an optical-fiber sensor embedded in the wall of a filament-wound composite tank, an optical connector, and hand-held optical instrumentation that reads light power attenuation as a function of tank internal pressure. With design of the composite tank and sensor system interrelated, a simple, low-cost microbend intensity sensor will be used.

BACKGROUND: U.S. pressurized cylinder manufacturers are developing composite Self-Contained Underwater Breathing Apparatus (SCUBA). Preliminary market research indicates that U.S. manufacturers alone produce more than 1 million composite pressure tanks each year. However, none has Department of Transportation (DOT) approval. Operational safety must be addressed first—specifically, ability to monitor structural integrity. Several firms indicate that they would be willing to evaluate SMART SCUBA™, and if it performs as claimed, would be interested in incorporating the technology. SMART SCUBA™ technology is expected to have an immediate and very broad market.

RESULTS: In this initial phase, a pressure test was conducted on Prototype 1 to measure the response of the fiber-optic sensor to a change in internal pressure. Test results prove that the concept of using an optical-fiber sensor wrapped in overlapping helical curves and embedded in a composite overwrap functions as a nearly linear pressure transducer. These results were anticipated but are not necessarily negative. The desired result is a sufficiently large signal to measure the change of tank volume (or internal pressure), and a much larger signal is wanted when structural degradation; e.g., delamination or fiber breakage, occurs.

SIGNIFICANCE: SMART SCUBA™ has been funded for FY99 by CEROS. In the follow-on investigation, the issue of defect detection will be addressed. Also to be studied is the possibility of increasing the microbend sensor sensitivity by reducing the structural bond between crossed fibers. Before any design changes are made, a known structural defect into the composite overwrap of Prototype 2 will be introduced. Also, the fiber-optic connector design will be simplified. The greatest challenge is developing a manufacturing approach that requires only minor changes to techniques now used by tank fabricators. If Structural Solutions can accomplish this in the follow-on effort, it is believed that the composite gas cylinder industry will support its efforts to commercialize this new technology.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

An Internet-Enabled Engineering Tool for Dynamically Analyzing and Planning World-Wide Subsea Cable and Array Installations
Phase 1

Makai Ocean Engineering, Inc., Kailua, HI
Contract No. 44303 (FY98 Core) for $379,985

PERIOD OF PERFORMANCE: July 1, 1998 to March 31, 2000

OBJECTIVE: To develop, test, and validate a user-friendly, Internet-enabled engineering tool for the simulation, feasibility evaluation, and planning of subsea cable and complex submarine array installations.

BACKGROUND: Located on Oahu, Makai is a world leader in the field of submarine cables from lay planning to installing where monitoring and control of the lay are critical. Installing submarine fiber-optic cables is a thriving global business with approximately 100,000 route-km of submarine fiber-optic cable installed each year. In addition to communications, there is a large demand for complex subsea cables and cable arrays to satisfy the needs of marine oil surveying, military surveillance/training arrays, and seismic warning systems. Current state-of-the-art for planning and monitoring cable lays lags behind the rest of the field. A poorly planned or executed cable lay can lead to millions of dollars of avoidable expenditures. Previously, CEROS funded Makai for related work in FYs 94 and 96.

RESULTS: Makai developed MakaiPlan™, a software product that can be used for a variety of submarine cable-laying tasks. These tasks include route planning and editing, cable characterization, cable-lay simulation, route positioning and diagramming, and cost estimation. MakaiPlan™ is a complete package for planning installation of a submarine cable along a particular route. Makai has also developed a commercial version of MakaiPlan™.

MakaiPlan™ allows multiple planners and designers to interactively work on a cable installation with easy access to and exchange of project data. During the project, Makai learned that probable customers for MakaiPlan™ favored a PC-based, stand-alone system rather than remote Internet to access the UNIX-based system at Makai headquarters. Therefore, the software runs on Windows 95/98 or NT operating systems. An extensive user manual was developed to accompany MakaiPlan™.

SIGNIFICANCE: From September 1999 through June 2000, Makai sold 44 copies of MakaiPlan™ on the international market, which represent significant revenue. An improved version of MakaiPlan™ 1.1 was developed for release in June 2000. MakaiPlan™ and the new software are designed to work together as a seamless cable lay planning, simulation, and deployment package. CEROS provided follow-on funds in FY00 with $345,737.

The ROVer's Eye™ Terrain Database Visualization as an Aid to ROV Navigation
Phase 1

Oceanic Imaging Consultants (OIC), Honolulu, HI
Contract No. 44366 (FY98 Core) for $239,652

PERIOD OF PERFORMANCE: September 1, 1998 to December 31, 2001

OBJECTIVE: To create virtual reality software to allow a remotely operated vehicle (ROV) to be successfully operated in low- to zero-visibility conditions.

BACKGROUND: ROVs have many applications; e.g., military, medical, search and recovery. All applications have problems; e.g., poor light and water clarity. OIC wanted to create an on-the-fly virtual reality model derived from sonar sources. Specifically, it sought to provide a high-fidelity representation of the physical relationship between the ocean bottom representation derived from multibeam sonar and a texture image that is overlaid on the ocean-bottom structure. Phase 1 was to consist of two subprojects—(1) component specification/acquisition and user interface development, and (2) component integration and field testing. Commercial off-the-shelf (COTS) packages were selected for virtual reality modeling and on-land testing. In addition, COTS multibeam systems were used that met the forward-looking requirement.

RESULTS: By the end of 1999, OIC had a prototype of ROVer's Eye™, which would communicate with GeoDAS to receive an initial model, and vehicle navigation. ROVer's Eye™ could load a .dxf file of a vehicle, attach a navigation feed (mouse, joy stick, or GeoDAS) and render both *wing man* and *bird's eye* views of the seafloor or given model, showing both the terrain and the texture overlay. CEROS is funding a follow-on project in FY99.

SIGNIFICANCE: OIC registered ROVer's Eye as a trademark; it is investigating patent possibilities. OIC has contracted with Johns Hopkins University Applied Physics Laboratory to sell two systems.

Situation Awareness System (SAS) Processor for Submarine Applications
Phase 2

ORINCON Hawaii, Inc., Kailua, HI
No. 44367 (FY98 Core) for $171,777

PERIOD OF PERFORMANCE: August 1, 1998 to July 31, 1999

OBJECTIVE: To improve and automate on-board tactical data fusion and display for on-scene submarine commanders.

BACKGROUND: The Navy seeks wide-band communications capability that would enable undersea platforms to communicate with surface, air, and command elements while operating at depth. The SAS processor provides multisource data fusion and processing capabilities to support localizing and tracking surface and subsurface targets. Data input paths to the SAS processor include the existing communications antenna for *offboard* sources and own-ship sources; e.g., adapt advanced real-time sensor (ARTS) and the sphere and towed-array sonar systems. For this effort, ORINCON focused on improving the submarine's onboard processing, data fusion, and tactical scene presentation capability. Thus, the SAS processing and presentation capability would be available for multisource data as submarine tactical connectivity improves.

RESULTS: ORINCON developed an advanced automated system for surface/subsurface target detection, classification, localization, data fusion, situation assessment, and tactical information display. Furthermore, ORINCON defined and developed communication interfaces to support reception and fusion of selected sensor data via several input paths. Interactive graphic displays in the postprocessing tactical scene presentation improved sonar operators' ability to effectively track multiple targets.

SIGNIFICANCE: This project addressed a high priority request from the Commander, Submarine Force, U.S. Pacific Fleet (COMSUBPAC). In response, ORINCON successfully transitioned data fusion and display technologies from the CEROS-funded $(CM)^2$-DF system at Commander Combined Task Force-12 (CTF-12) to the SAS test bed. This transition provided onboard tactical data analysis and display capabilities common to those at COMSUBPAC.

Upgraded Advanced Real-Time Sensor (ARTS) Processor for Maritime Patrol Aircraft (MPA) Applications.

ORINCON Hawaii, Inc., Kailua, HI
No. 44368 (FY98 Core) for $373,000

PERIOD OF PERFORMANCE: August 1, 1998 to March 31, 2000

OBJECTIVE: To adapt ARTS signal processing technology to support automated antisubmarine warfare (ASW) from MPA.

BACKGROUND: This is a continuation of CEROS FY97 effort, which developed the MPA ARTS processor to support data processing within an integrated sonobuoy field. ORINCON developed and demonstrated automated target detection and signal processing with the ARTS processor for submarines with CEROS support in FY95-97. The ARTS processor provides sonar operators with reliable, automated detection and alerting capability against a variety of submarine-generated acoustic signatures. The ARTS processor is a sonar operator's tool for Navy submarines that was adapted for use on Navy aircraft. With ARTS, naval submarines can operate more effectively in littoral waters. Commander Combined Task Force Twelve (CTF-12) requested that ORINCON explore modifying the ARTS processor to improve and automate ASW capabilities for maritime patrol aircraft.

RESULTS: ORINCON's *build-test-build* approach to system development produced additional autodetector, target localization, and tracking algorithms that were integrated into the airborne test bed for the ARTS processor. The ARTS processor enhances the ability of a sonar to process large amounts of sonar data in *noisy* acoustic environments with few false alarms. ORINCON adapted the ARTS processing architecture to MPA requirements and addressed the need for automated tools for airborne ASW operations.

SIGNIFICANCE: The airborne and submarine-based ARTS processors are meeting immediate Navy needs for advanced operational tools. In August 1998, the Navy selected several of ORINCON's signal processing algorithms as the principal automated alerting applications for the advanced processor build program, a Navy-wide upgrade of sonar processors.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

An Improved Acoustic Intercept Receiver (IAIR) for Submarine Applications
Phase 2

ORINCON Hawaii, Kailua, HI
Contract No. 44369 (FY98 Core) for $560,000

PERIOD OF PERFORMANCE: August 1, 1998 to November 30, 1999

OBJECTIVE: To develop, demonstrate, and evaluate an improved intercept receiver (IAIR) processor onboard an operational submarine of the Pacific fleet.

BACKGROUND: Localization of active sonar emitters is accomplished by mapping the time-delay measurements, obtained by coherent processing of time-series data from multiple sensors, into an estimate of the emitter's position. This technology is often referred to as wide-aperture array, interarray, or wave-front curvature processing. Better data processing techniques are needed so the U.S. Navy can increase its capabilities to utilize sonar data during operations.

RESULTS: During Phase 1 (FY97), ORINCON developed an IAIR processing prototype system that provides automated broadband correlation of active sonar emissions from surface ships and submarines. The systems detects and classifies active acoustic waveforms from surveillance and tactical sonar systems installed on US Navy submarines. During the Phase 2, ORINCON implemented the IAIR algorithms in a real-time system using commercial off-the-shelf hardware. ORINCON applied this build-test-build procedure to determine the number of bands needed to cover the emitters of interest to fleet submarines. Also, an operator machine interface was developed and integrated into the prototype system. This system was installed on a Pearl Harbor-based submarine and evaluated during an at-sea test.

SIGNIFICANCE: This project answered a request from the Commander, Submarine Force, US Pacific Fleet (COMSUBPAC), and equipment was installed on a Pearl Harbor-based submarine. This submarine used the IAIR during WESTPAC.

Development of a Patentable Combination Propeller-Pump Jet Integrated Propulsion Pod with Boundary Layer Suction

Pacific Marine & Supply Co., Ltd. (Pacific Marine), Honolulu, HI
Contract No. 43959 (FY98 Core) for $300,000

PERIOD OF PERFORMANCE: June 15, 1998 to June 14, 2000

OBJECTIVE: To research, design, engineer, and develop a high-performance podded propulsor applicable to high-speed craft.

BACKGROUND: The benefits of podded electric motor propulsion include design flexibility in the placement of main engines and generators, increased internal space, and high propulsive efficiency over a wide thrust range. Pacific Marine has extensive experience in the design, development, and construction of advanced ship hull forms. As a spin off from the *RVs SLICE* and *MIDFOIL* research, Pacific Marine invented a patentable podded propulsion design that is applicable to all podded propulsors but especially applicable to high-speed crafts.

RESULTS: Pacific Marine conceptualized and initiated the design of an advanced electrical integrated propulsion pod system that was demonstrated in its *WestFoil* hydrofoil ferry. Engine power output was shown to be close to the theoretical maximum values, but propeller performance was substantially below the design characteristics.

SIGNIFICANCE: Future work includes measurement of the pressure distribution and boundary layer profile over the main foil, and also the laminar-to-turbulent transition point. CEROS provided follow-on funding in FY00 to complete final construction drawings and specification for the integrated propulsion pod.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Multispectral Interferometric Synthetic Aperture Sonar (SAS)

Raytheon Systems Co., Mukilteo, WA
Contract No. 44414 (FY98 Core) for $550,034

PERIOD OF PERFORMANCE: August 1, 1998 to February 29, 2000

OBJECTIVE: To upgrade the SAS test bed (developed under Contract No. 41401) to provide multispectral, three-dimensional (3-D) images using SAS interferometry over the frequency range of 10 to 20 kHz.

BACKGROUND: Under CEROS funding (Contract Nos. 43320 and 38107), Raytheon validated the resolution and contrast improvements claimed for the side-looking sonar (SLS) with SAS processing used in the detection of bottom and subbottom objects. In previous CEROS-supported work, Raytheon modified the Hawaii MR1 sonar platform owned by the Hawaii Mapping Research Group (HMRG) at the University of Hawaii. Under CEROS Contract Nos. 39570 and 41401, Raytheon designed, assembled, and tested a purpose-built SLS system; a stable, towed SLS platform (*test bed*); and created signal-processing techniques and algorithms that define postprocessing capable of producing high-resolution images of objects in and on the sea bottom.

RESULTS: For this contract, the Raytheon team added multispectral interferometric SAS processing schemes to the system to enhance the detection and classification of bottom and subbottom objects. The effort ultimately showed that interferometric SAS processing is possible in shallow water (<150m) environments, and that multibeam processing could enhance production of quality target-elevation data. However, certain environmental processing or hardware limitations prevented full exploitation of the techniques during this contract period. Consequently, the results presented are more promising than definitive. Raytheon also concludes that motion compensations and autofocusing techniques are largely unnecessary for synthetic aperture formation for shallow water, bottom-penetrating operation because of the short ranges involved. Data sets analyzed under this contract were collected off Waikiki and San Diego from *RV Slice*.

SIGNIFICANCE: Raytheon and HMRG demonstrated that interferometric SAS processing is possible in shallow water, but hardware and environmental limitations remain to be fully addressed. The project was a unique use for *MV Slice*; the advanced technology demonstration vessel was a suitable platform for the tests.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Undersea Fanbeam Spectral Imaging (FSI)
Risk Reduction Technology Demonstration

Science and Technology International (STI), Honolulu, HI
Contract No. 44304 (FY98 Core) for $398,895

PERIOD OF PERFORMANCE: August 1, 1998 to January 1, 2000

OBJECTIVE: To examine deep and shallow water surveillance missions and develop system requirements for an FSI system. To define the functional requirements and design constraints of an FSI system for both commercial and military applications.

BACKGROUND: Underwater imaging is used to monitor a variety of targets on the ocean floor. Imaging is used for military, scientific, and environmental purposes. Underwater imaging systems must be maximized to discriminate targets of interest. State-of-the-art optical systems in this class presently use laser line scan (LLS) configurations, in which monochromatic laser illumination is combined with common path-point imaging using *flying spot* scanning to provide the lateral field of regard. In contrast, the FSI system provides very wide swath illumination (fanbeam), reduced common-path imaging, and hyperspectral visible fluorescence acquisition.

Pushbroom imaging spectrometers form images by assembling sequential lines of spectral data as the sensor moves at a constant velocity relative to the target. As the pushbroom scans the bottom, the image of the entire scene is serially constructed to develop a full spectral image cube. The FSI underwater remote-sensing system acquires 3-D spatiospectral data at a high rate. The FSI features a modular approach that uses separated illumination and detector units to reduce backscatter from the common volume.

RESULTS: FSI is the world's first underwater reflectance and fluorescence hyperspectral imaging system. FSI illuminates the bottom with a very wide and thin fanbeam using an incoherent *white light* source (mercury-xenon lamp) with a pushbroom imaging spectrometer receiver pointed at the same line as the transmitter. The desired modularity and sensitivity required novel optical and system design solutions. STI constructed a prototype system and conducted preliminary laboratory and field tests that demonstrate the system.

SIGNIFICANCE: Existing (and competing) underwater LLS systems provide high area coverage rates and good discrimination for some targets of interest. However, the LLS systems are commonly limited to monochromatic data acquisition. The FSI system will enhance target detection and characterization by using both reflected and fluoresced hyperspectral images. The FSI system thus promises to expand the utility of LLS underwater imaging. STI now has a new capability to apply to military, scientific, and environmental problems.

Patuxent River Dual Camera HSI System

Science and Technology International (STI), Honolulu, HI
Contract No. 45125 (FY98 Core) for $565,498

PERIOD OF PERFORMANCE: February 18, 1999 to April 17, 2000

OBJECTIVE: To provide operational dual camera HSI system to the Patuxent River Naval Warfare Center, Maryland.

BACKGROUND: STI developed this technology with CEROS funding in previous fiscal years. Under CEROS Article XIII, CEROS may manage contracts for follow-on work even when the funds come from a source outside the CEROS budget. The Patuxent River Naval Warfare Center, Maryland, purchased an STI dual camera HSI system to fly on aircraft in support of reconnaissance missions. The dual mode fluorescence imager/hyperspectral imager (DFI/HSI) consists of a passive hyperspectral imaging system combined with an active laser system. Both systems are integrated into one package that can be installed in a variety of aircraft. Typically, the DFI/HSI instrument is flown at altitudes between 1,000 and 6,000 ft, resulting in ground resolutions from 0.29 to 1.73m, respectively. DFI/HSI instruments may be used for mapping of coral reefs and land vegetation, surveillance, or other specialized imaging requirements.

RESULTS: The final flight and subsequent data processing demonstrations were conducted February 15-18, 2000, in Honolulu, Hawaii. The sensor completed the mission with no downtime. The instrument and operator's manuals were shipped to Patuxent River Naval Warfare Center in April 2000.

SIGNIFICANCE: In addition to this being the first contract managed under CEROS Article XIII, the U.S. Navy purchased and put into operation a dual camera hyperspectral imaging system developed with CEROS funds.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Development of an Ultra-High Resolution Stress Detection System for Marine Application

Sea Engineering, Inc. (SEI), Waimanalo, HI
Contract No. 44632 (FY98 Core) for $319,154

PERIOD OF PERFORMANCE: November 1, 1999 to October 31, 2000

OBJECTIVE: To develop a practical prototype stress measurement system based on low frequency voltage fluctuations (LFVF) phenomena. In particular, to explore and demonstrate the ability to measure stress directly in materials and structures in the marine environment using LFVF techniques.

BACKGROUND: In 1995, scientists at the University of Hawaii (UH) at Manoa discovered that the spectral characteristics of naturally occurring LFVF change when the material is placed under stress. LFVF occur when a direct current passes through a conductive material. Early experiments using small diameter wire indicated that the LFVF technique was as much as 1 million times more sensitive to stress than conventional piezoresistive techniques. UH was awarded a U.S. patent for proposed nondestructive measurement technique based on the results of the early LFVF experiments. SEI teamed with the Hawaii Natural Energy Institute of the UH School of Ocean and Earth Science and Technology to explore potential applications of LFVF sensors to structures and materials in the marine environment.

RESULTS: Initial experiments used wires to characterize the effect of material composition and wire diameter on the LFVF signal. Results showed that the LFVF signal became weaker, relative to background noise, as wire diameter increased. The SEI team therefore concluded that a direct stress measurement system for materials in the marine environment was not feasible at this time.

Subsequent work focused on LFVF measurements in external thin-film stress sensors configured similar to conventional strain gauge designs. Stress-dependent LFVF signals were observed in most of the metal and metal-alloy films tested but no LFVF was detected in any of the thin-film semiconductor material tested.

The LFVF measurement in the commercial sensor was more sensitive than the piezoresistive methods at low loading but exhibited random noise at higher loading, thus limiting the range of applicability of the LFVF technique. Although high sensitivity sensors were fabricated and tested, the sample-to-sample variability and the effect of ambient noise prevented adequate calibration required for commercialization of the technique.

SIGNIFICANCE: This effort showed that the LFVF noise response in thin films could be extremely sensitive to applied stress and could also have potential for application in ultra high-resolution stress detection systems. However, considerable research remains to isolate and control factors that contribute to variability of the LFVF effect. Meanwhile, the LFVF response will remain a phenomenon untamed by technology.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Development of a 3-D, Forward/Aft-Sweeping, High Resolution Buried Object Imaging System Phase 2

Sea Engineering, Inc. (SEI), Waimanalo, HI
Contract No. 44801 (FY98 Core) for $421,200

PERIOD OF PERFORMANCE: April 1, 1999 to September 30, 2000

OBJECTIVE: Design and demonstrate a portable sonar system capable of high-resolution discrimination of objects as small as 4-8cm buried 1-2m below the seafloor. Develop, test and demonstrate a sonar data-processing system to perform correlation processing, beam steering and target detection in real time. Develop and apply 3-D matrix processing and volume visualization algorithms for target display and classification.

BACKGROUND: With FY97 CEROS funding, SEI and Precision Signal, Boca Raton, Florida, designed and built a sonar system capable of forward/aft and port/starboard beam steering. They also developed software to form beams and control match-filter signal processing on stored data. The sonar operates over a frequency range of 5 to 23 kHz to produce high-target resolution and sufficient penetration in sand to image most buried targets of interest. The sonar consists of six transmitters and a 32-element receive array housed in a 300-lb tow vehicle 16-m long x 1.1-m wide. The sonar control computer and sonar transmitting and receiving electronics are housed in a pressure vessel attached to the tow vehicle. The five topside computers are the main system computer, two correlator/beamformer computers and a visualization computer. The five computers (seven Pentium processors) are networked through a standard 100Mb/s Ethernet. The sonar vehicle is designed to be towed within 5 m of the seabed by a survey boat.

RESULTS: SEI and Precision Signal developed and tested a sonar processing system comprising a sonar control computer and four additional computers in the topside processor. The sonar has a steerable transmission beam to minimize scattering noise and illuminate targets at various aspect angles. Images of cable and pipe sections, ordnance and cylinders buried 1 ft in sand were generated during testing at Makai Pier.

The sonar was tested successfully. The system detected and imaged targets and displayed the target field in real time. The tests demonstrated the importance of fore/aft beam steering for target detection in sand. Processing algorithms were optimized to enhance image quality and simplify data interpretation. The dimensions of linear objects were accurately imaged. The sonar proved effective at locating and mapping buried ordnance and pipe and cable sections.

SIGNIFICANCE: This two-phase project developed and proved a subbottom imaging technology for finding certain classes of buried objects and reporting target information in real time. This is the first sonar capable of forward/aft and port/starboard sweeping of transmission and reception beams. The sonar showed the importance of forward/aft beam steering for detecting objects buried in sand. The sonar is a useful adjunct to SEI for nearshore geophysical cable routing surveys in Hawaii and throughout the Pacific Basin

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

LIFE/FLOAT™ the One-Person Survival Craft
Phase 1

SEE/RESCUE Corp., Honolulu, HI
Contract No.44373 (FY98 Core) for $70,000

PERIOD OF PERFORMANCE: September 1, 1998 to August 31, 1999

OBJECTIVE: To develop and demonstrate an improved one-person life raft prototype for military, commercial, or civilian maritime and aviation applications. Specifically, Phase 1 will address proof of concept.

BACKGROUND: Need to update technology of one-person survival craft has long existed in all sectors of water safety. Immobility, lack of control, insufficient protection from exposure, and insufficient signal equipment are among the many disadvantages of antiquated survival life rafts. Expertise was used from Life Raft and Marine Safety Equipment, Inc., using the latest lightweight high-strength materials. Incorporating SEE/RESCUE® streamer, SEE/RESCUE Corporation constructed two generations of prototype of LIFE/FLOAT™ to address the problems of outdated survival life rafts. Sea trials on prototypes were conducted in Honolulu, Hawaii.

RESULTS: SEE/RESCUE Corporation developed an inflatable, rigid, surfboard-shaped rescue craft that can be paddled by the survivor. The craft is characterized by its mobility, thermal protection, and continuous passive emergency signaling. Before inflation by hand pump or compressed gas cartridge, LIFE/FLOAT™ packs into a compact pouch. In FY00, the proof of concept will be advanced by constructing a first-generation LIFE/FLOAT™.

SIGNIFICANCE: SEE/RESCUE Corporation has generated valuable intellectual property from this project. U.S. and foreign patents on the LIFE/FLOAT™ technology are pending. The U.S. Patent and Trademark Office has sent notification that the patents and associated claims will be granted. SEE/RESCUE Corporation provided working LIFE/FLOAT™ prototypes to the U.S. Navy Safety and Survivability Office for evaluation and comment.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Development of an Underwater Compositional Mapping (UCM) System

TerraSystems, Inc. (TSI), Honolulu, HI
Contract No. 44402 (FY98 Core) for $351,177

PERIOD OF PERFORMANCE: June 30, 1998 to June 29, 2001

OBJECTIVE: To build and test a prototype (towed) UCM system for rapidly surveying, at high spatial resolution, the material characteristics of the ocean floor at depths ranging from 30 to 100+m.

BACKGROUND: The rationale for this project was derived from TSI's previous CEROS-funded research of the diver-assist camera called underwater video camera for optical contrast and range enhancement using spectral stretching (UCSS). TSI's research concerning the irradiative transfer properties of water indicated that improved visibility and contrast enhancement from this spectral technique should improve the mapping ability of a towed camera system since (1) sunlight reaching and reflected from the bottom is attenuated both in intensity and spectral range by the overlying water and (2) the *in-path radiance* from atmospheric scattering, surface reflections (indirect sky and sun glint) and scattering by subsurface particulate matter (organic and inorganic) dominates the radiometric signal at the sensor.

RESULTS: A prototype UCM was built at TSI and tested both in the shallow (<6m) water dockside in Waimanalo Bay and in the shallow (<30m) ocean off the southwest coast, both sites on Oahu, Hawaii. As built, the system can be towed behind small ocean survey vessels at 1-5kt. Stabilization was achieved by an actuated-wing, vertical stabilizer wing tow-fish. Digital imagery is obtained in three narrow spectral bands concentrated near those wavelengths where water is clearest using sensitive charge coupled device (CCD) cameras, active aperture control, and computer storage. Location of the UCM (accurate to within 10m) is provided by a combination differential global positioning system (DGPS) location of the boat and location of the UCM relative to the boat determined by cable length and depth of the UCM. Recommendations for follow on include additional testing in more diverse environments, developing single 3-CCD camera (UCM-specific filters on each), more dependable method of focusing the camera, miniature low-cost GPS-independent underwater inertial navigation system to more accurately identify location and pointing the UCM while under tow.

SIGNIFICANCE: The UCM approach has potential application in underwater activities where optical range and contrast enhancement are important for mapping. Applications include environmental monitoring; inspection of underwater pipelines, communication lines, oil and gas well heads and surveys including unexplored ordnance and mines

FISCAL YEAR 1999 CORE PROJECTS

Hydrofist: A Nonexplosive Means for Generating Intense and Focused Underwater Shock Waves Phase 1

BBNT LLC dba BBN Technologies, Cambridge, MA
Contract No. 45694 (FY99 Core) for $999,819

PERIOD OF PERFORMANCE: August 1, 1999 to July 31, 2001

OBJECTIVE: To generate underwater shock waves in a safe and environmentally sound way.

BACKGROUND: The nonexplosive device for generating tailored underwater shock waves is called Hydrofist because one end of each pressure cylinder is forced outward by expanding water when it is triggered. By the nature of the energy-release mechanism, Hydrofist efficiently couples sound energy to water. Energy can also be coupled into earth with high efficiency because the input impedance of earth is not too different from water. Changing cylinder length and cylinder pressure will modify the time history of piston motion. The geometrical arrangement and relative trigger times control the radiation beam patterns.

RESULTS: BBN subcontracted for construction to Navatek, Ltd., Honolulu, Hawaii, and Bear Machinery, Kaneohe, Hawaii. A prototype Hydrofist was designed, built and tested in the water tank facility at BBN. Several deficiencies were found, the most serious of which was the top nut through which the radiating piston protrudes. The nut was not thick enough and failed at 12 ksi. Subsequently, a new design was made and successfully tested at 15 ksi. Also, a custom solenoid valve was required, which required several iterations. BBN designed and built a PC-based firing system. This system actuates the firing solenoid valves, measures the pressure in the low-pressure chambers, determines the firing latency of each unit, and compensates subsequent firing signals to correct for latency variations. Navatek tested the system twice at its Honolulu Pier 41 yard. BBN was awarded a CEROS-funded follow-on contract to continue Hydrofist research.

SIGNIFICANCE: The intended application for Hydrofist is a versatile means for shock testing ships, boats, and underwater equipment that has shock requirements. Any number of Hydrofist units can be arrayed to enable shocks of varying impulse and pressure. Changing the length of the working fluid chamber and its pressure also will change shock parameters. Both military and commercial applications exist for Hydrofist. Military applications include the remote disablement of antiship mines and incoming torpedoes. Many Hydrofist units would be needed for these applications, so the system would be very heavy. Only large warships could carry the array without some loss of payloads. However, smaller arrays can have commercial applications. Hydrofist is the subject of U.S. Patent No. 6173803.

Software Agents to Acquire and Visualize Environmental Information for Anti-Submarine Warfare (ASW) Surveillance
Phase 2

Guide.Net, Inc., Honolulu, HI
Contract No. 45513 (FY99 Core) for $360,000

PERIOD OF PERFORMANCE: June 30, 1999 to October 29, 2000

OBJECTIVE: To extend and improve interactive software system that automates portions of the meteorology and oceanography (METOC) information gathering for ASW mission support.

BACKGROUND: Guide.Net is an Internet software company specializing in interactive website development. This effort augmented the interactive retrieval software developed with CEROS FY98 support. Guide.Net's goal is to develop a system that retrieves the right data for the right person at the right time. The system consists of software agents and graphical user interfaces (GUIs). Data are retrieved over the World Wide Web and presented by the GUIs for visualization, forecasting, and presentations; e.g., briefing. The workflow manager controls the software agents as they retrieve and compute data points required to produce a forecast of winds and seas. Guide.Net executed the following technical development tasks in this FY99 effort:

- Add terms to and provide an Internet website for existing Navy markup formats
- Add software agents for satellite altimetry and scatterometry data
- Provide means to check retrieved data for temporal, seasonal, and geographic consistency and distribute workload over multiple machines
- Provide means to check agent and source data integrity
- Incorporate updated displays for wave height and related data
- Augment workflow module for dynamic operation

RESULTS: Guide.Net developed specialized visualization tools for PCs using standard Internet technology and for Navy tactical computers using the lightweight extensible information framework (LEIF). Guide.Net developed and implemented new software agents to retrieve and verify model wave data and satellite altimetry and scatterometry readings. Guide.Net also improved the rule-based workflow manager that activates and controls the data retrieval process. Guide.Net, Inc. received CEROS FY00 funding to follow on and complete their METOC workflow support effort.

SIGNIFICANCE: This advanced software and interactive graphic display increases METOC operator efficiency. The system incorporates data from different sources and verifies data integrity throughout the workflow process. The software is platform independent and adaptable for a variety of information acquisition and management applications, both military and commercial. A demonstration of the system, named SmartBuoy, is available on the Guide.Net website under METOC products.

SMART SCUBA™
Phase 2

Knapp Engineering, Inc. dba Structural Solutions, Aiea, HI
Contract No. 46008 (FY99 Core) for $312,000

PERIOD OF PERFORMANCE: November 1, 1999 to October 31, 2002

OBJECTIVE: To redesign a robust, low-cost, fiber-optic sensor system, consisting of an optical-fiber sensor embedded in the wall of a filament-wound composite tank, an optical connector, and hand-held optical instrumentation that reads light power attenuation as a function of tank internal pressure. With design of the composite tank and sensor system interrelated, a simple, low-cost microbend intensity sensor will be used.

BACKGROUND: U.S. pressurized cylinder manufacturers are developing composite Self-Contained Underwater Breathing Apparatus (SCUBA). Preliminary market research indicates that U.S. manufacturers alone produce more than 1 million composite pressure tanks each year. However, none has Department of Transportation (DOT) approval. Operational safety must be addressed first—specifically, ability to monitor structural integrity. Several firms indicate that they would be willing to evaluate SMART SCUBA™, and if it performs as claimed, would be interested in incorporating the technology. SMART SCUBA™ technology is expected to have an immediate and very broad market.

This report documents Phase 2 to design, fabricate, and test prototype smart pressure tanks for SCBA and SCUBA applications. The structural design of the composite E-glass/epoxy tank established in Phase 1 was used for Phase 2.

RESULTS: Development of an improved connector and three different fiber sensors in Phase 2 successfully demonstrated the technical feasibility of the overall design. The practicality of this design concept was demonstrated in the manufacturing methods that were developed.

SIGNIFICANCE: The overall success of the design, manufacturing, and testing of five prototype composite tanks suggest that SMART SCUBA™ is a commercially viable concept. However, the economics of producing and installing the fiber sensor will require further effort. In particular, mass production and installation issues of connector components will be needed before commercialization.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

The ROVer's Eye™ Terrain Database Visualization as an Aid to ROV Navigation Phase 2

Oceanic Imaging Consultants, Inc. (OIC), Honolulu, HI
Contract No. 45005 (FY99 Core) for $275,482

PERIOD OF PERFORMANCE: November 1, 1999 to December 31, 2002

OBJECTIVE: To create virtual reality software to allow a remotely operated vehicle (ROV) to be successfully operated in low- to zero-visibility conditions.

BACKGROUND: ROVs have many applications; e.g., military, medical, search and recovery. All applications have problems; e.g., poor light and water clarity. OIC wanted to create an on-the-fly virtual reality model derived from sonar sources. Specifically, it sought to provide a high-fidelity representation of the physical relationship between the ocean bottom representation derived from multibeam sonar and a texture image that is overlaid on the ocean-bottom structure. In FY98, Phase 1 consisted of two subprojects—(1) component specification/acquisition and user interface development, and (2) component integration and field testing. Commercial off-the-shelf (COTS) packages were selected for virtual reality modeling and on-land testing. In addition, COTS multibeam systems that met the forward-looking requirement were used.

As a result of the FY98 research, OIC had a prototype of ROVer's Eye™ that would communicate with GeoDAS to receive an initial model, and vehicle navigation. ROVer's Eye could load a .dxf file of a vehicle, attach a navigation feed (mouse, joy stick, or GeoDAS) and render both *wing man* and *bird's eye* views of the seafloor or given model, showing both the terrain and the texture overlay. OIC registered ROVer's Eye as a trademark; it is investigating patent possibilities

RESULTS: Phase 2 of ROVer's Eye™ consisted of two subprojects—(1) acquring and integratng the multibeam sonar sensor and its associated real-time processing, and (2) testing the integrated system at the site surveyed in Phase 1. OIC selected the Reson 8101 multibeam sonar to use to work on integration. The University of Hawaii (UH) Mechanical Engineering Department autonomous systems laboratory (ASL) was to have been made available for trials. However, by the time OIC completed preparations, UH needed the ASL so the trials were not completed. Meanwhile, OIC had demonstrated ROVer's Eye™ Johns Hopkins University Applied Physics Laboratory (JHU/APL). As a result, JHU/APL contracted with OIC to deliver two systems. As part of a forward-looking sonar feasibility conducted for JHU/APL's client, OIC used its multibeam and ROVer's Eye™ equipment and used equipment and mounting brackets developed for the aborted tests using the UH/ASL equipment for continued ROVer's Eye™ tests. Tests of real-time processing were conducted in the lab before at-sea work, using the actual sensors configured to deliver simulated data at realistic rates. OIC could not use a submerged platform for undersea tests. The ROVer's Eye™ sensor was depressed to a 20-ft depth, look direction was varied from 90 to 15 deg, which resulted in using all of the equipment.

SIGNIFICANCE: ROVer's Eye™ can serve as acoustic fog lights for driving the ROV. In addition, ROVer's Eye™ is a useful training tool for ROV or submersible pilots because the system permits predive mission and path planning and postdive reconstruction and model synthesis.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Cultured Fish as Biological Indicators of Pollution

Oceanic Institute, Waimanalo, HI
Contract No. 45852 (FY99 Core) for $216,766

PERIOD OF PERFORMANCE: September 30, 1999 to December 29, 2001

OBJECTIVE: To examine the feasibility of an innovative approach to assessing aquatic pollution of affected defense sites and monitors the effectiveness of remediation efforts.

BACKGROUND: Military presence in Hawaii makes it the second largest economic activity in the state. The Department of Defense (DOD) has long recognized environmental pollution caused by its various activities as a serious health and safety issue. In particular, there has been widespread media focus on pollution of Pearl Harbor waters. A 2-year Navy investigation of sediments and marine life indicated elevated levels of several chemical contaminants. In addition, concentrations of dieldrin found where rivers flow into the harbor suggests a regional watershed problem.

Using cultured fish as biological indicators to show direct effects of pollution on aquatic resources is a unique approach to coastal environmental assessment. These cultured fish would be unaffected by any unknown elements in the historical health.

RESULTS: Using two indigenous species, the Pacific threadfin (locally known as moi) and striped mullet, the cultured fish were identified with binary-coded tags and released into Pearl Harbor. Periodically over 1 year, the released fish were recovered and evaluated for presence and concentration of organochlorine pesticides through direct chemical analysis of whole body samples Five organochlorine pesticide compounds were found in fish tissues. In general, the weight of compounds found in the body increased with time and body size while concentration of compounds decreased, suggesting that compounds were sequestered in particular organs rather than within the fish as a whole. While cultured mullet were recaptured up to almost a year after release, no Pacific threadfin were recaptured in Pearl Harbor. Therefore, mullet would seem to be the most appropriate test species.

SIGNIFICANCE: The results support the feasibility of the concept as a tool for monitoring potential environmental impacts by DOD activities. Methods and technologies developed can provide the basis for remedial assessments at Pearl Harbor and similarly affected sites. In addition to the obvious requirements of DOD to address the critical issue of coastal pollution, this project presents future opportunities for using sentinels (i.e., Pacific threadfin) for human health in broader DOD chemical and biological defense planning.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

An Ocean Bottom Span Analyzer for Survey Planning and Installation of Submarine Cables

Oceantek, Inc., Waimanalo, HI
Contract No. 45770 (FY99 Core) for $188,000

PERIOD OF PERFORMANCE: September 15, 1999 to April 14, 2001

OBJECTIVE: To further develop and validate algorithms partially developed during an SBIR Phase I, and develop a stand-alone program capable of accurately analyzing the free spans and bend radii of submarine cables and pipelines installed on irregular bottoms.

BACKGROUND: As cables and pipes are laid over the ocean bottom, they bend over obstacles and create spans. The severity and length of these bends and spans, respectively, are a strong function of bottom roughness, weight and flexural rigidity of the cable/pipe, and tension applied. Long spans and small bend radii develop high stresses on the cables/pipes and ultimately shorten their life expectancy. Proper planning and route selection are essential components of a submarine cable/pipe system design. A user needs an engineering tool to compute, in near real time, a true and accurate representation of the cable/pipe shape on the bottom, including the free spans and points of contact on the bottom, as well as the bend radii to compute induced moments and stresses developed at the contact points.

Algorithms developed during SBIR Phase I allowed the user to compute an accurate representation of a bare cable/pipe shape as it lays on irregular bottom, including spans and contact points on the bottom, plus the bend radii and global forces developed at the contact points.

RESULTS: Algorithms described above were expanded to accommodate for the presence of multiple in-line bodies along the cable/pipe length. These algorithms not only can be used for both flexible and stiff cables/pipes, but include weight and tension to the cable/pipe. The flexural rigidity can model more accurately the moments and shear forces on the deflected cable/pipe. Tests used an 11/16-in. diameter submarine fiber-optic cable to validate all flexural rigidity values. The algorithms are optimized for speed, robustness, and accuracy. The software can analyze over 1 nm of laid cable/pipe in 4 sec when running on a Pentium III 550-MHz PC. The algorithms are incorporated into fully tested, self-contained dynamic link libraries (DDLs) that can be integrated into other existing software packages used by surveyors, planners, and installers. A stand-alone program; i.e., PCSPAN, was developed and copyrighted. PCSPAN© is PC based, operates in Windows 2000, and user friendly. Also, it can interact with existing software packages to allow the user to deal with large, 3-D sets of survey data.

SIGNIFICANCE: Further development is ongoing under an SBIR Phase II project. Enhancements will include features; e.g., modeling of extreme deflections, support analysis of free spans using 3-D terrain models, and near real-time analysis and 2- and 3-D renderings using a stand-alone PC, and Windows-based, interactive software.

**Electronic Charting Display and Information System (ECDIS-N)
With Special Emphasis on Submarine Navigation—Hi Plot**

Oceantronics, Inc., Honolulu, HI
Contract No. 45300 (FY99 Core) for $393,000[1]

PERIOD OF PERFORMANCE: June 21, 1999 to June 20, 2002

OBJECTIVE: To design a software electronics charting display and information, Hi Plot, software program that is compliant with U.S. Navy ECDIS-N requirements.

BACKGROUND: Hi Plot was designed to be the cornerstone of Oceantronics' SeaPlot Solution, which was to be used during maritime interdiction operation/visual board search and seizure (MIO/VBSS).

RESULTS: Space and Naval Warfare (SPAWAR) San Diego sponsored test and evaluation, including compliance, accuracy, and secured network (SIPRNET) capability. Hi Plot can

- Display gravity anomaly data from NOAA/Scripps
- Display water temperature and ocean depth using National Marine Electronics Association (NMEA) data format
- Display ship's track line in color representing water depth and temperature
- Provide course to steer to rigid hull inflatable boats (RHIBs) along with range and bearing between two RHIBs.

Further testing of Hi Plot, including the closed-circuit TV system and the SSR Engineering, Inc. processor will be done at the Pacific Missile Range Facility on Kauai.

SIGNIFICANCE: Hi Plot is established on 45 U.S. Navy ships, including 40 surface fleet ships, using Hi Plot alone or as a component of its derivative systems, SEAPLOT, SEALINK, and NavTrack. Oceantronics provides free downloads through its web site to keep users' versions of the systems current. Fleet feedback has acknowledged Oceantronics' contribution to added safety during MIO/VBSS operations.

[1] $95,000 (FY99), $98,000 (FY00), $200,000 (FY01)

Automation and Integration of Environmental Factors into ASW Tracking

ORINCON Hawaii, Kailua HI
Contract No. 45290 (FY99 Core) for $497,415

PERIOD OF PERFORMANCE: June 30, 1999 to September 20, 2000

OBJECTIVE: To implement an environmental evaluator to improve tracking performance by integrating up-to-date oceanographic information in all phases of target tracking.

BACKGROUND: ORINCON responded to a request by Combined Task Force-12 (CTF-12) headquarters, Pearl Harbor to improve the ASW commanders workstation. The request specified changes that would effectively exploit information from environmental models during track initialization and localization of so-called bearing only contacts. The workstation provides data fusion and environmental information for all undersea warfare operations in the Pacific. The workstation was developed under Navy/DARPA funding and installed at CTF-12 to support specific sea tests and experiments. With support through a previous CEROS contract, ORINCON permanently installed the workstation at CTF-12 in January 1996. With additional CEROS and Navy funding, ORINCON integrated an environmental evaluator in the system to improve target range resolution and discrimination.

RESULTS: ORINCON modified the workstation to automatically use environmental information to improve estimates of target location and track. Specific improvements were to

- Develop and install a new environmental evaluator to process oceanographic information and integrate results into target initialization estimates
- Increase mainframe system memory by 544 megabytes and overall system processing speed by 10 percent
- Build laboratory development version of the workstation and install the system at ORINCON Hawaii offices
- Develop and install report analysis window to allow operators to assess environmental factors involved in specific line of bearing estimates
- Develop and install software to distinguish applicable acoustic data for environmental processing
- Assemble and install a collection of application programming interfaces that generate probability of detection zones based on acoustical and environmental information
- Modify the kinematic evaluator processor to carry both left and right ambiguity track associations
- Add three new display windows to provide operators with insight regarding the conversion and integration of environmental factors into position measurements.
- Add a software module to allow workstation operator to define default acoustic values for track initialization
- Provide operational fixes to enhance operator interaction with the system
- Deliver and debug modifications and improvements to the ASW commanders workstation variant at CTF-12.

These changes enhanced tracking applications and improved localization of bearing-only contacts, enhanced connectivity between the environmental subsystem and the contact manager common module on the workstation, and increased capabilities and effectiveness of system operators.

SIGNIFICANCE: ORINCON and subcontractor Sonalysts Corp., Waterford, Connecticut, enhanced the power and effectiveness of the ASW commanders workstation. The improvements automatically integrate data and predictions from powerful environmental databases into processes for estimating target position from acoustic data.

At-Sea Evaluation of the Situation Assessment Processor

ORINCON Hawaii, Kailua, HI
No. 45812 (FY99 Core) for $775,864

PERIOD OF PERFORMANCE: September 28, 1999 to September 27, 2001

OBJECTIVE: To build and demonstrate signal processing capability for submarines to rapidly fuse, localize, and track own-ship detections of acoustic and nonacoustic target signals.

BACKGROUND: The situation awareness system (SAS) processor was developed under CEROS FY98 support to provide detection, all-source data fusion, classification, localization and tracking of surface and subsurface targets in littoral and deep-water environments. The SAS processor is based on the contact management common module—data fusion [$(CM)^2$-DF)], which performs multisensor data fusion, sensor performance prediction, and communications functions that are critical to effective antisubmarine warfare (ASW) surveillance in littoral and deep waters. A $(CM)^2$-DF system was installed at Combined Task Force-12 (CTF-12) headquarters at Pearl Harbor to provide multisensor fusion and localization capabilities and to optimize utilization of ASW assets in the Pacific Ocean. The system at CTF-12 successfully demonstrated its fusion and localization capabilities during Rim of the Pacific (RIMPAC) and other fleet exercises during this contract period. At-sea trials of the SAS processor were delayed because of deployment schedules of fleet operational assets.

RESULTS: In April 2001, system components, including an SAS processor, towed-array beamformer, and an improved version of the advanced real-time signal (ARTS) processor, were installed on *USS Charlotte*. One dataset from the advanced processor build (APB) 99 was processed through the SAS processor to determine localization performance under operating conditions. Satisfactory target localization was obtained throughout the exercise. At-sea system tests were scheduled to begin in October 2001 after contract period of performance ended. ORINCON subsequently adapted system components and capabilities into other systems such as the mission reconfigurable signal processing system with FY00 CEROS support.

SIGNIFICANCE: This project addressed a high priority request from the Commander, Submarine Force, U.S. Pacific Fleet (COMSUBPAC). ORINCON successfully transitioned data fusion and display technologies from the $(CM)^2$-DF system at CTF-12 to the SAS test bed and installed the system on *USS Charlotte*. ORINCON provided COMSUBPAC with a powerful tool for littoral ASW.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Mass Spectrometer Using Rotating Fields for Exploratory Research (Mass SURFER) Phase 1

Pacific Environmental Technologies (PaceTech) LLC, Honolulu, HI
Contract No. 45291 (FY99 Core) for $141,743

PERIOD OF PERFORMANCE: June 21, 1999 to August 20, 2002

OBJECTIVE: To develop a miniaturized mass spectrometer-based sampling system for i*n situ* measurement of dissolved gas and/or solutes present in marine waters, and for protein characterization that leads microbial identification

BACKGROUND: As analytical instruments, mass spectrometers have the capability of extremely high sensitivity, isotopic resolution, and wide dynamic range. Field-portable units incorporating mass spectrometers could therefore revolutionize the ocean and earth sciences. However, useful, low-power and compact instruments capable of long-term field applications, especially autonomous units capable of operating in the deep ocean, have been slow to arrive. The delay results from problems of sample introduction, vacuum maintenance, and power consumption.

RESULTS: In conjunction with Jet Propulsion Laboratory (JPL), PaceTech is building and testing miniaturized mass spectrometer-based field sampling systems. Incorporating the rotating field mass spectrometer (RFMS), Mass SURFER is housed within a 6.5-in., 5.5-ft long, OD pressure vessel capable of 20000+m deployments. The gas-only sampler incorporates a hydrophobic membrane that has been successfully used in laboratory to 200 bars hydrostatic pressure and in the field on Loihi Seamount off Hawaii Island to 1,200-m water depth. Direct liquid sampler uses an on-line capillary nano-electrictrospray interface (ESI) capable of high-sensitivity mass spectrometry at nano-liter/min flow rates. This type of interface presents a challenge of clogging by fine suspended particles and salts build up. Preliminary direct seawater injections have not produced significant negative effects. Also being incorporated is an on-line capillary electrophoresis column to aid in sample spectral resolution.

SIGNIFICANCE: Beyond the Mass SURFER, the planned enhancements to field mass spectrometers will make the next-generation instruments smaller, lighter, even lower power, and of greater sensitivity. Besides providing basic research and development, PaceTech will in the future provide user training, instrument support, and analytical services.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Fabrication and Demonstration of a Patentable Combination Propeller-Pump Jet Integrated Propulsion Pod with Boundary Layer Suction

Pacific Marine & Supply Co., Ltd., Honolulu, HI
Contract No. 45496 (FY99 Core) for $1,019,000

PERIOD OF PERFORMANCE: June 30, 1999 to December 29, 2001

OBJECTIVE: At-seal trials to demonstrate boundary layer ingestion (BLI) with a submerged antisymmetric pod with a relatively high Reynolds number.

BACKGROUND: BLI is a type of boundary layer control in the form of an integrated propulsion system for an aerodynamic or hydrodynamic body. The concept is to ingest or suction off part of the boundary layer that has developed because of viscous effects and propel the fluid out the end of the body to fill in the wake deficit. By suctioning fluid that has already been accelerated to near the body speed, less power is required to propel the body compared to an external propulsion system that accelerates fluid at rest. F.R. Goldschmied has authored many papers on the subject and claims to have demonstrated power reductions as much as 65 percent with an axis-symmetric body in a wind tunnel.

RESULTS: A 16.8-ft, 44-in. diameter, composite (fiberglass and foam) pod and strut assembly was fabricated by Mystic Innovations Group/New England Boatworks, Portsmouth, Rhode Island, for this test. Testing of the BLI pod occurred at Kewalo Basin, Oahu, Hawaii. The experiments consisted of four separate subtests to measure the static pressure distribution, boundary layer velocity profile, laminar to turbulent transition zone, and wake produced by a BLI propulsion system. Data acquired indicate that USAERO is a good computational fluid dynamics (CFD) tool for predicting pressure distribution, boundary layer profiles, and transition. This implies that predictions for friction drag are good, and an analysis of a boundary layer ingestion system, which relies on an accurate estimate of friction, can be performed with some confidence.

An area of uncertainty was discovered during the post test evaluation of the test data where the rotor was found to be operating far outside of its design envelope. This finding questioned the rotor efficiencies. A range of efficiencies were evaluated, which showed that the fundamental conclusion was not altered.

SIGNIFICANCE: The CFD tool USAERO produced results that agreed with test data and can be used to design a large-scale BLI ingestion system.

Frequency Agile Sequential Transmission Synthetic Aperture Sonar (FastSAS)
Risk Reduction Technology Demonstration

Raytheon Co. dba Raytheon Systems Co., Poulsbo, WA
Contract No. 45773 (FY99 Core) for $119,976

PERIOD OF PERFORMANCE: July 15, 1999 to TERMINATED February 29, 2000[2]

OBJECTIVE: To develop and demonstrate a FastSAS for platforms operating at speeds in excess of 10 kt. Specifically, to upgrade hardware and processing systems to demonstrate improved azimuthal resolution for platforms moving in excess of 10 kt. To use the test bed to gather data to validate improved processing capabilities of the system.

BACKGROUND: This contract involved upgrading the sonar test bed developed under CEROS Contract No. 41401 and developing signal processing routines to overcome speed constraints of conventional SAS systems as demonstrated under CEROS Contract No. 43320.

Raytheon received more than $5 million from CEROS through various contracts since FY94 to develop a SAS in partnership with researchers at the Hawaii Mapping Research Group (HMRG) of the University of Hawaii. Progress through calendar 1999 was incremental though the system's resolution still remained less than ideal for reliable applications to mine hunting. However, the system and processing scheme showed promise as a tool for subbottom exploration for HMRG.

In 1999, Raytheon reorganized and closed the facility in Mukilteo, Washington, where Raytheon's SAS effort was centered; the contract's original principal investigators were assigned to different projects elsewhere. After reviewing program plans and progress in February 2000, DARPA recommended that CEROS terminate the contract.

RESULTS: After a late start while a new project management team was assembled, the Raytheon effort concentrated on defining requirements for upgrading the SAS test bed to meet frequency and dynamic range requirements. Only preliminary work was completed for planning, processing, and test-bed upgrading tasks and no progress was made on system upgrades and testing.

SIGNIFICANCE: The SAS system and the associated field support activities developed under different contracts to Raytheon, Naval and Maritime Systems since FY94 remain in the care of HMRG. HMRG uses the hardware and processing routines for advanced ocean research and exploration.

[2] Original contract amount was $865,631

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Web-Based Processing for State-of-the-Art Large Aperture Multidimensional (SLAM) Array

Science Applications International Corp.(SAIC), McLean, VA
Contract #45772 (FY99 Core) for $500,000

PERIOD OF PERFORMANCE: July 1, 1999 to September 30, 2001

OBJECTIVE: To focus on developing a Web-based broadband acoustic propagation modeling and signal processing software capability that would reside on and utilize the parallel computing and high-performance storage assets at the Maui (Hawaii) High Performance Computing Center (MHPCC).

BACKGROUND: The ultimate objective of this project was to demonstrate a real-time broadband processing capability using the DARPA Santa Barbara Channel Experiment (SBCX) data as an example. SLAM array was the instrument set-up used to gather the data for SBCX. For the purpose of this project, real time is defined as having the processing keep up with the real input data rate for a 100-Hz bandwidth and a 30-element vertical line array.

RESULTS: The decision to wrap sophisticated processing programs into an easy-to-use, easy-to-maintain, and globally accessible form, allows the investigators to provide a good framework for compute-intensive problem-solving scenarios in both real time or nonreal time. This architecture also allows preparation for future enhancements, especially when new algorithms need to be implemented or different research goals are needed.

The development did not proceed flawlessly, but it appears that all of the unresolved difficulties have remedies, and they will be addressed in follow-on programs. For example, a dedicated computing platform would alleviate the conflicts associated with other jobs, as well as helping to solve the classified data-processing needs. Unfortunately, the latter implies using two separate platforms to efficiently accommodate both classified and unclassified modes of processing. The platform-dependent issues associated with multiple program multiple date (MPMD) message-passing implementing (MPI) programs can be solved with sophisticated schedulers and parallel debuggers; e.g., those at MHPCC. A public domain clone of MatLab exists (Octave), as well as Java, as alternatives to the proprietary software currently used for the graphic displays. Finally, a more sophisticated (Metron) tracker could replace the one now used.

SIGNIFICANCE: The follow-on CEROS-supported project will include improving the capabilities of the algorithms, access to data at the Pacific Missile Range Facility (PMRF), Kauai, Hawaii, and the ability to locate and track ships and humpback whales from the PMRF acoustic range in the vicinity of Kauai.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Development of an Enhanced Resolution Filter for Improving SONAR Imagery

Sea Engineering, Inc. (SEI), Waimanalo, HI
Contract No. 45514 (FY99 Core) for $148,287

PERIOD OF PERFORMANCE: June 30, 1999 to July 29, 2000

OBJECTIVE: To develop and demonstrate time-domain filter techniques to enhance sonar system resolution for a variety of sonar configurations.

BACKGROUND: Improved techniques for range resolution and target discrimination benefit sonar operations in general. Many military and commercial marine projects require location and discrimination of buried, proud (i.e., on the bottom) or floating objects; e.g., cables, pipelines, ordnance, hazardous waste, or miscellaneous debris. The contemporary frequency modulated single-sensor sonar imaging systems typically use conventional matched-filter (or replica correlation) processing for range resolution. The width of the main lobe of the range ambiguity function determines the range resolution of these systems. In such frequency domain processors, range resolution depends on the transmitted signal bandwidth; increasing the pulse bandwidth enhances range estimation. The enhanced resolution filter (ERF) is a time-domain processing technique that improves range resolution by reducing the main lobe of the ambiguity function and suppressing the sidelobes for a given bandwidth. MultiSpec Corp, Huntington Beach, California, developed and patented the ERF technique.

RESULTS: SEI provided a variety of sonar case studies for testing the ERF processing technique. This project was the first application of ERF to sonar data. The ERF technique was tested for a variety of conditions, including different physical locations, geological settings and sonar characteristics. For most cases, the ERF processing increased range resolution of the processed sonar signal. The investigators demonstrated further resolution enhancement with so-called lateral focusing through sidelobe suppression. Lateral focusing seems particularly effective for characterizing buried targets.

SIGNIFICANCE: This project is the first known effort to adapt ERF to sonar data processing. Results demonstrated that ERF techniques can improve sonar system resolution without the need for increased signal bandwidth or computational capacity. Added value is the reasonable cost of the improvements. Additional processing techniques; e.g., sidelobe suppression and lateral focusing, could enhance resolution.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Enhanced Sea & Land Rescue Visibility Systems

TerraSystems, Inc., Honolulu, HI
Contract No. 45292 (FY99 Core) for $253,839

PERIOD OF PERFORMANCE: June 21, 1999 to December 20, 2001

OBJECTIVE: To investigate ways to improve the search and rescue process by testing the increased visibility of plastic rescue streamers made with fluorescent materials.

BACKGROUND: The key element investigated was whether the spectral properties of the fluorescent materials and the spectral characteristics of a modified charge coupled device (CCD) camera (called enhanced video system [EVS] camera) could be matched for greater search effectiveness and increase the probability of detection.

TerraSystems' approach was to find and test fluorescent materials with the right physical properties for ocean- and land-deployable banners, develop a camera with enhanced spectral capabilities to capitalize on the fluorescent and spectral properties of these materials, and test the efficacy of the materials and banners in terms of improving the search and rescue process.

RESULTS: This project showed that

- Common fluorescent pigments are available and can be used in the low-density plastic materials (<0.95 gm/cc) used in search and rescue banners and systems
- Spectral contrast and visibility of rescue streamers can be increased by using these materials
- At least one EVS camera can be modified to provide enhanced detection of these fluorescent banners
- Certain fluorescent materials exist that exploit near infrared (NIR) fluorescence to provide low visibility to the eye but high visibility to the EVS camera.

SIGNIFICANCE: The degree of interest in this *automatic target recognition/automatic alarm* method leads the investigators to recommend this approach as the next step toward commercialization of this EVS technology. This project has helped TerraSystems further its business goals, attract other business, and provide synergism with other research and development small businesses in Hawaii.

FISCAL YEAR 2000 CORE PROJECTS

Hydrofist: A Nonexplosive Means for Generating Intense and Focused Underwater Shock Waves Phase 2

BBNT, LLC dba BBN Technologies, Cambridge, MA
Contract No. 47343 (FY00 Core) for $800,000

PERIOD OF PERFORMANCE: October 1, 2000 to December 31, 2002

OBJECTIVE: To generate underwater shock waves in a safe and environmentally sound way.

BACKGROUND: The nonexplosive device for generating tailored underwater shock waves is called Hydrofist because one end of each pressure cylinder is forced outward by expanding water when it is triggered. By the nature of the energy-release mechanism, Hydrofist efficiently couples sound energy to water. Energy can also be coupled into earth with high efficiency because the input impedance of earth is not too different from water. Changing cylinder length and cylinder pressure will modify the time history of piston motion. The geometrical arrangement and relative trigger times control the radiation-beam patterns.

RESULTS: Resulting from a CEROS-awarded contract in FY99, BBN began developing Hydrofist. The following development obstacles were met and overcome—metal failures and hydraulic seals not meeting psi differential. A supplier was never found to solve the third problem, suitable electrical solenoid valves that would operate reliably at 32,000 psi. A work around was fashioned but it was so complicated that it did not work with precise timing. BBN believes that Hydrofist will achieve its predicted performance with proper solenoid valves, a better piston seal, and large LP hydraulic lines and fittings.

SIGNIFICANCE: Hydrofist is intended to provide a versatile means of shock-testing ships, boats, and underwater equipment. Any number of Hydrofist units can be arrayed to enable shocks of varying impulse and pressure. Changing the length of the working fluid chamber and its pressure also will change shock parameters. Both military and commercial applications exist for Hydrofist. Military applications include the remote disablement of antiship mines and incoming torpedoes. Many Hydrofist units would be needed for these applications, so the system would be very heavy. Only large warships could carry the array without so loss of payloads. However, smaller arrays can have commercial applications. Hydrofist is the subject of U.S. Patent No. 6173803.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Deep Seawater Use in Photobioreactor; More Efficient Microalgal Production and Broader Deep Seawater Applications

Black Pearls, Inc., Holualoa, HI
Contract No. 46762 (FY00 Core) for $173,201

PERIOD OF PERFORMANCE: June 30, 2000 to September 29, 2001

OBJECTIVE: To investigate using deep seawater as a growth medium for sterile microalgae culture in continuous production photobioreactors.

BACKGROUND: Continuous production systems, although requiring greater capital investment, alleviate much of the manpower needs of aquaculture operations.

RESULTS: Despite repeated attempts at setting up the system because of bacterial contamination, on a small scale, utilizing deep seawater in continuous culture systems proved to be very economical. On a large scale, it was extremely economical. If sterile algae were not required by a culture system, this system would be the most cost effective because of the significant labor savings. The feeding trial results with microalgae produced in the sterile continuously operated systems were very significant. This indicates that the food cultured in the systems with deep seawater was of superior quality to Black Pearls' typical batch cultured food.

SIGNIFICANCE: Deep seawater was a superior culture media in continuous culture systems providing an extremely cost-effective algal production system. The investigation was successful and contributed new methodology for algal culture utilizing deep seawater. The only problems were reliably maintaining sterility in large-scale systems.

As part of the outreach and educational program, three demonstration modules were designed and built. Demonstrations of each module separately were presented to classes from the University of Hawaii, and West Hawaii Explorations Academy, and a representative of Academy Sea Grant Extension Service, One module demonstration included lesson plans. Feedback was positive with a request for repeat presentations. The modules were transferred to Sea Grant Extension Service for future use in instruction of microalgae culture.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Surface-Enhanced Raman Spectroscopy (SERS) Immunoassay Detection System: "Dog Nose" Sensor for TNT Detection and Detection of an Aquaculture Virus

Detection Limit Technology (DLT), Inc., Waimanalo, HI
Contract No. 47339 (FY00 Core) for $439,937

PERIOD OF PERFORMANCE: October 1, 2000 to May 31, 2002

OBJECTIVE: To design and develop a field-deployable system that uses surface enhanced Raman immunoassay (SERIA) technique and demonstrate the system for detection of trinitrotoluene (TNT) in water and soil and pathogenic viruses in fish and crustaceans.

BACKGROUND: Unexploded ordnance (UXO) poses a variety of problems on land and under water. Explosive related chemicals (ERCs); e.g., 2, 4, 6-trinitrotoluene (TNT) and 2,4-2-6 DNT, are dangerous contaminants on military reservations and on and around present and former target ranges. In Hawaii, serious problems exist on Kaho'olawe Island and in the Makua Valley on the island of O'ahu.

In 1997, DARPA initiated a "dog nose" program to replace the UXO detection systems based on infrared and electromagnetic induction with a system to detect the explosive material or its byproducts directly. Research generated from this program has shown the feasibility of vapor-phase detection of TNT (or more probably DNT) in locations close to the buried UXO. TNT has been identified in soil and groundwater after leaching from disposal sites. Only high-pressure liquid chromatographic methods are used for detection of TNT and ERCs in water samples, and no online or near real-time method exist for measuring the noxious compounds *in situ*.

The SERIA technique combines immunological methods with a portable Raman spectrometer. DLT has developed and perfected the SERIA techniques and associated instrumentation under previous CEROS support; i.e., FY98 Contract No. 44528.

RESULTS: DLT developed a TNT assay utilizing a colloidal silver solution treated with commercially available antibody for TNT and a TNT/dye conjugate. An improved detector system and analytic software were developed and incorporated into a Raman TNT *sniffer* system. The system was able to detect and identify TNT in seawater at levels of 1 ppm. In field use around Kaho'olawe, this sensitivity translated into detection distances of 5 m from the explosive.

SIGNIFICANCE: Processing time for the DLT device was near real time, a major breakthrough. The success of the work suggested improved methods of detection that when calculated, should improve the detection limit to 10 ppb, extending the detection range to up to 30-50 m, and be suitable for extended use as a device deployed and used by underwater divers during detect and locate maneuvers. The disappointing part of the effort was that the instrument was not sensitive underwater as TNT *sniffers* are on land.

Analysis of Synthetic Aperture Sonar (SAS) Data for Geological Surveys

Dynamics Technology, Inc. (DTI), Torrance, CA
Contract No. 47258 (FY00 Core) for $98,239

PERIOD OF PERFORMANCE: September 1, 2000 to April 30, 2002

OBJECTIVE: To analyze existing geological data sets collected by the SAS system and assess the performance of the system as a geological and geophysical survey tool.

BACKGROUND: Under earlier contracts, CEROS supported Raytheon Systems Company (with a subcontract to the University of Hawaii [UH]) to develop and test a high-resolution, bottom-penetrating, multimode SAS. The primary purpose was to provide a tool that can search for buried munitions and unexploded ordnance (UXO). The testing resulted in a large volume of sonar data, which was provided to the Hawaii Mapping Research Group (HMRG) at UH School of Ocean and Earth Science and Technology (SOEST). This report describes DTI's SAS processing methods, data selection, and processing results.

RESULTS: The SAS system performed well when used for its designed purpose. Characteristics exhibited were

- Good data quality
- Ease of processing
- Subbottom imagery capability

The system was found lacking in several areas that are important for geological and geophysical survey work. The key shortcomings are

- Limited bottom penetration
- Limited practical survey capabilities in real-time processing and display, navigation, and handling.

DTI identified solutions to the above problems.

SIGNIFICANCE: One of the goals of this work was to gain understanding of the types of background clutter that might be encountered during ordnance surveys with this system. DTI believes that the SAS image results generated under this program are a foundation for understanding the environment in which systems of this type must operate if they are deployed in the future. If the suggested solutions are addressed, DTI believes that the SAS system would result in a survey instrument that would meet the requirements of the academic geology and geophysical communities, and would also aid naval research efforts in the continuing search to safely locate and identify buried UXO.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Workflow Paradigm for Antisubmarine Warfare (ASW) by Reliable Meteorology and Oceanography (METOC) Data and Tasks Phase 3

Guide.Net, Inc., Honolulu, HI
Contract No. 46676 (FY00 Core) for $397,050

PERIOD OF PERFORMANCE: June 15, 2000 to December 14, 2001

OBJECTIVE: To extend and improve an interactive software system that automates portions of the METOC information gathering for ASW mission support.

BACKGROUND: Guide.Net. is an Internet software company specializing in interactive website development. This represents the third year of this investigation. In year 1, Guide.Net developed software routines (webcrawlers) to retrieve METOC data over the Internet. Also developed was display interface for collected data. In year 2, Guide.Net developed an interactive software system that automates portions of the METOC information gathering that must take place before and during an ASW mission. The system consists of a suite of knowledge-based software agents with a graphical user interface (GUI). The software provides for automated and rapid METOC data retrieval from resources available over the Internet as well as SIPRNET secured network.

RESULTS: In year 3, Guide.Net achieved several additional research and implementation objectives. The extensible information system (XIS, formerly lightweight extensible information framework [LEIF])-based visualization tool has been enhanced with complete reporting features and a web-based version was developed for easy deployment. New data retrieval agents were added to have two of each type of data for redundancy with workflow manager dynamically controlling the cross checking of display data sets. SIPRNET data sources were not suitable for Guide.Net's GUI and data retrieval agents so a new agent approach was developed to automate the most time-consuming part of the ASW planning workflow.

SIGNIFICANCE: The system incorporates recent research advances in intelligent agent software, and interactive platform-independent graphic tools. While the primary focus was to support naval littoral surveillance requirements, many of the software modules can be easily adapted to a broad range of information acquisition and management needs. A demonstration of the system, named SmartBuoy, is available on the Guide.Net website under METOC products.

Modeling of Cable Fatigue

Knapp Engineering, Inc. dba Structural Solutions, Aiea, HI
Contract No. 47073 (FY00 Core) for $345,737

PERIOD OF PERFORMANCE: September 30, 2000 to September 29, 2002

OBJECTIVE: To develop a cable fretting fatigue model.

BACKGROUND: During an extensive literature survey, fatigue test data were identified; however, the data are largely incomplete and do not fully describe all geometrical and material properties of the cables that were tested. Further experiments needed to be conducted on well-defined cable specimens if reliable confirmation of the fatigue model was to be achieved. Data for six different cables were identified; however, some missing information had to be estimated. Estimates included the low and high values to bracket model predictions.

RESULTS: The equivalent notch model was used to predict cycles-to-failure for cyclical tension, simple (one-way) bending-over-sheave, and reversed bending. Model results compared favorably with experimental data. The experimental results are for cables that did not experience wire fretting failures. In each case, the relative motions caused by slip were either too small or too large to be classified as fretting. Thus, the conclusion drawn is that the equivalent notch model performs reasonably well in the absence of wire fretting. The result was that Structural Solutions developed the CableFATIG™ axial and bending fatigue models (equivalent notch and fretting). Cable strength members (regular helical layers) have been incorporated into the existing finite-element analysis software for CableCAD™. Structural Solutions developed CableCAD™ in an earlier CEROS-supported project.

SIGNIFICANCE: During the CEROS-supported FY01 program, *Experimental Investigation of Cable Fatigue*, cable tests are planned to reveal fretting damage. These data will be used to verify and improve the CableFATIG™ fretting fatigue model. Also, these tests will provide as-built cable construction details critical to developing and verifying the CableFATIG™ software.

Remote Monitoring and Expert Control of Submarine Cable and Array Installations

Makai Ocean Engineering, Inc., Kailua, HI
Contract No. 46765 (FY00 Core) for $345,737

PERIOD OF PERFORMANCE: June 23, 2000 to June 22, 2001

OBJECTIVE: To provide a remote monitoring and control system whereby a shore-based cable installation expert can provide expert installation guidance and backup for one or more cable ships at sea. To enable shore-based managers to have better information available for planning and support purposes.

BACKGROUND: Makai provides state-of-the-art control and monitoring software for both the cable industry and DOD. Makai has been sole-sourced for many commercial and military projects because of the unique quality and accuracy of its software and services. This project—performing highly technical and complex missions at sea without the need for on-site highly technical and complex personnel—was a natural extension of Makai's previously developed technology.

RESULTS: The Makai remote software was developed to allow users of MakaiLay to reliably and easily send lay data ashore, which can be used for monitoring, quality control, or to control the cable lay. MakaiLay software includes an option to link the shipboard control system with an onshore location such that oversight and assistance can be provided anytime. With appropriate software, the customer can train and staff its own onshore station. In addition, software can be provided that links at regular intervals with the control software at sea and provides a quick summary and display of progress. However, this option will not allow historical queries and will be limited in offering technical assistance from the onshore site. Makai can also offer onshore site service that will be an extension of services already provided onboard.

SIGNIFICANCE: This development is useable by both DOD and commercial cable installers. Makai has filed a software copyright application. The feasibility of a patent application is being reviewed.

Improving Flow from Deep Water Pipelines

Makai Ocean Engineering, Inc., Kailua, HI
Contract No. 47072 (FY00 Core) for $388,950

PERIOD OF PERFORMANCE: July 1, 2000 to June 30, 2002

OBJECTIVE: To create a 30-percent cost savings for cold seawater furnished by deep intake suction pipelines.

BACKGROUND: The means of achieving the 30-percent cost savings is to increase the pipeline's design limits for flow and pressure by having a better understanding of its structural strength, and by increasing its strength with external pipe stiffeners. As a high-definition polyethylene (HDPE) withstands high suction to provide large flows, it will subtly deform from circular to oval shape. The pipe simply buckles because of high external pressure. The intent of this study is to be able to design a pipeline by taking relaxation into account.

RESULTS: Makai hypothesized that by modeling HDPE's creep and recovery response to the cyclic cooling load, the HDPE suction pipe could be aggressively pumped to meet large loads and then allowed to recover its circular shape during smaller loads. To investigate the hypothesis, Makai developed and operated testing devices to gather data, which demonstrated that the assumptions were correct. Pipes were tested with and without stiffeners. The most cost-effective stiffener is cast ductile iron that has been hot-dipped galvanized, with bolt-on zinc anodes. The benefits of ring stiffeners were minimizing initial ovality, reinforcing a loaded pipe, and controlling pipe ovality as installed on the seafloor.

Overall test results were not as successful as anticipated. The most difficult challenge was in implementing an adequate mathematical model that predicts HDPE behavior. All models investigated had serious flaws, so Makai developed its own models and found they have limited applicability between different cyclic testing regimes or initial conditions.

SIGNIFICANCE: Makai has continued to try to develop an adequate HDPE model and has made significant progress. In the absence of an accurate model, Makai has performed extensive testing under a wide variety of loading conditions and temperatures to develop empirical rules for designing suction pipelines subjected to cyclic loading. Those rules are being used now worldwide in designing suction pipelines.

Small Water Plane Area Twin Hull (SWATH) Ship Software and Verification

Ocean Engineering Consultants, Inc. (OEC), Honolulu, HI
Contract No. 46684 (FY00 Core) for $164,954

PERIOD OF PERFORMANCE: July 15, 2000 to June 14, 2001

OBJECTIVE: To extend and verify the hydrodynamic analysis capabilities at OEC for SWATH ship design.

BACKGROUND: SWATH is a relatively new ship type that can greatly reduce or eliminate passenger seasickness while increasing crew effectiveness and safety. A well-designed SWATH ship rides through a seaway without the large motions and accelerations of conventional vessels. A primary cause of seasickness is the periodic vertical accelerations of traditional ships. By canceling out wave forces that cause large motions and accelerations, a SWATH ship can offer a level of passenger comfort unattainable on a monohull or catamaran of similar size. Precursors of the modern SWATH go back to the late 19th Century. Subsequent iterations of SWATH continued through a passenger vessel in 1989 followed by U.S. Navy hulls developed, built, and revealed between 1991 and 1993. In FYs 94, 95, and 96, CEROS funded OEC investigations that focused on SWATH Motion/Structural Software Development, SWATH Motion/Structural Software Development and Verification, and Flow Simulation and Visualization for SWATH Ships, respectively.

RESULTS: In this portion of the overall project, extension of software capability includes the following refinements to OEC's suite of software:

- An integrating shell to speed the design process to optimize resistance
- Expansion of the range of hull geometries that can be analyzed by the OEC suite
- Comparison of resistance values with very large-scale model tests
- Comparison of resistance and ship motions for the same hullform in prototype sea trials

The calm water resistance and propulsion tests of sea trials showed excellent agreement with the calculated and model basin predictions. The ship-motion tests during sea trials showed at times reasonable agreement with the calculated predictions, though action of the ride-control system made better comparisons impossible.

SIGNIFICANCE: The modifications to the analytic software yielded good-to-excellent predictions of conditions measured in sea trials. Effects of a ride-control system made predictions of ship motions more problematic, but good agreement were indicated between predictions and sea-trial data. Further refinements of the software were recommended to improve the predictive ability. OEC has used CEROS support to improve its design and analysis capability and has successfully applied these capabilities in commercial contracts for SWATH vessels.

Mission Reconfigurable Signal Processing (MRSP) System

ORINCON Hawaii, Kailua, HI
Contract No. 46675 (FY00 Core) for $749,504

PERIOD OF PERFORMANCE: June 15, 2000 to October 14, 2001

OBJECTIVE: To provide the final design specification for the MRSP system.

BACKGROUND: The Naval Air Warfare Systems Command (NAVAIR) is seeking improved signal-processing techniques and equipment to upgrade the hardware in the maritime patrol aircraft (MPA) fleet for advanced undersea warfare (AUSW). The AUSW hardware suite is a network-centric warfare demonstration application designed to connect P-3C aircraft to other operational forces to allow the aircraft to function as part of a coordinated air-surface-undersea operation.

In FY97 with CEROS support, ORINCON upgraded the antisubmarine warfare (ASW) commander's workstation and reconfigured the advanced real-time sensor (ARTS), both of which significantly enhanced ASW capability. In FY98, again with CEROS support, ORINCON continued the effort, which resulted in the Navy selecting several signal-processing algorithms as part of a service-wide upgrade of sonar processors.

RESULTS: The MRSP final design specification includes hardware requirements, algorithm descriptions and computational throughput loading estimates, and interface descriptions. The MRSP system will reside within the analyzer subunit (ASU) section of Lockheed Martin's AN/USQ-78B system. The hardware requirements will consist of a single 6U VME-format DSP multiprocessor board from Mercury Computer Systems, Inc., which will perform the real-time processing of sonobuoy time-series data and environmental information. The MRSP will require the time-series data from the digital reformat card via VME64 data transfers. The data will then be processed within the MRSP system, using selected signal-processing algorithms. Outputs from MRSP, consisting of processed spectral data and alerts, will be available in local MRSP memory for use by the SPARC processor using Mercury's shared-memory buffer routines. Algorithms to be used in real-time processing will be selected, based on mission requirements from routines resident in the software toolbox, integrated by the development workstation, and then downloaded into the MRSP.

SIGNIFICANCE: The work satisfied the NAVAIR request to develop and integrate an advanced signal-processing system for MPA. The program will define, document, and verify an integration and installation design for modifications of baseline P-3C aircraft to obtain a P-3C Update III block modification upgrade (BMUP) configuration.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Mass Spectrometer Using Rotating Fields for Exploratory Research (Mass SURFER) Phase 2

Pacific Environmental Technologies (PaceTech) LLC, Honolulu, HI
Contract No. 46821 (FY00 Core) for $171,864

PERIOD OF PERFORMANCE: June 30, 2000 to December 29, 2002

OBJECTIVE: To develop a miniaturized mass spectrometer-based sampling system for i*n situ* measurement of dissolved gas and/or solutes present in marine waters, and for protein characterization that leads microbial identification

BACKGROUND: There have been several attempts at making small mass spectrometers as field instruments. Mass spectrometer using rotating fields for exploratory research (Mass SURFER) has the distinction of ranging in mass detection from 1 to >100,000 atomic mass units (amu) while consuming <10 watts power. Detection limits are presently below part per billion (ppb) levels, and the investigators intend to extend this limit to part per trillion (ppt) levels. Samples can be injected for both dissolved gases and solutes (cations and anions). This investigation is a follow on to CEROS-supported FY99 effort.

RESULTS: The investigators have completed a working prototype of a low-power miniature mass spectrometer-based field instrument that can perform under ambient pressures ranging from 1 to 200 atmospheres (bars), or greater than 2,000-m water depth, and are presently working on a second, enhanced version. The Mass SURFER vacuum levels need only be at the millitorr level for a quality measurement, and the complete, active system draws only 8 watts. Samples can be directly injected into the rotating field mass spectrometer (RFMS) mass resolution of 1 part in 1,000 is comparable with the best of other small mass spectrometers. The extremely large analytical mass range of the RFMS (from 1 to >100,000 amu), coupled with soft ionization techniques make the Mass SURFER capable of analyzing light gases such as H_2 and He as well as large dissolved organic compounds; e.g., peptides, proteins, and DNA fragments. Its extremely high sensitivity and low-power requirements will allow automated, quasicontinuous, *in situ* monitoring of the chemical composition of natural waters, hydrocarbon and other chemical pollutants, and microbial populations in streams, rivers, wells, coastal waterways, harbors, and deep ocean.

SIGNIFICANCE: Modified versions of this instrument will have a wide variety of environmental applications. These include: water quality monitoring of remote systems; e.g., space stations, shuttle, ships, and military base/municipal supplies, coastal and groundwater point- and diffuse-source pollution monitoring, offshore oil exploration and production monitoring, exploration and monitoring of seafloor methane seeps and hydrothermal vents, and natural hazards and global climate research. PaceTech believes that modified versions of this instrument will have a wide variety of environmental applications, including water quality monitoring of remote systems, coastal and groundwater point- and diffuse-source pollution monitoring, offshore oil exploration and production monitoring, exploring and monitoring of seafloor research. Several materials used in this project have been copyrighted. A U.S. patent is pending.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Large-Scale Producibility Demonstration of CEROS-Developed Three-Dimensional (3-D) Lifting Bodies for Use in the U.S. Navy's Littoral Support Craft (LSC) Program

Pacific Marine & Supply Co., Ltd., Honolulu, HI
Contract No. 47257 (FY00 Core) for $980,000

PERIOD OF PERFORMANCE: August 1, 2000 to December 31, 2002

OBJECTIVE: To demonstrate the affordable production of complex 3-D lifting bodies for use in the Navy's LSC program using advanced composite manufacturing and assembly technologies. To design and fabricate four lifting-body pods and evaluate manufacturing and assembly systems.

BACKGROUND: The objective is being accomplished through designing and fabricating an underwater lifting body for the Navy's SES-200B, which will serve as a mission concept demonstrator for the proposed littoral support craft (LSC). With an underwater configuration similar to the LSC, the converted SES-200B will provide significant risk mitigation for the LSC program. SEs-200B conversion to a hybrid small-water plane area craft (HYSWAC) is proceeding under an Office of Naval Research cooperative agreement.

Under funding from CEROS Contract Nos. 43949 (FY98) and 45496 (FY99), Pacific Marine conducted research and engineering, designed and developed a high-performance podded propulsor unit that is applicable to high-speed craft. Pacific Marine also finalized construction design drawings, specifications, and a test plan for an integrated podded propulsor (IPP), constructed the IPP, installed the IPP on *MV Westfoil*, and conducted sea trials.

RESULTS: In the course of this effort, design analysis revealed that the four-pod configuration originally envisioned for this demonstration produced unacceptable stress in the interface between the struts and vessel structure. Accordingly, the focus of the effort was redirected. Two candidate single lifting-body designs were evaluated and a 160-ton configuration (the "H" body design) was selected for the SES-200B lifting-body system. Aluminum and composite components were fabricated and the lifting body was assembled.

SIGNIFICANCE: The most significant finding of this effort was the design analysis, which indicated that four-pod concept was not a viable concept for the SES-200B demonstrator. Also, Pacific Marine developed technique and technology for fabricating large lifting bodies. The analysis of cost and schedule performance for this effort was based on techniques and lessons learned from construction of *Midfoil* lifting body under CEROS FY99 Contract No. 45496.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Hydrofist: A Nonexplosive Means for Generating Intense and Focused Underwater Shock Waves
Phase 2

BBNT, LLC dba BBN Technologies, Cambridge, MA
Contract No. 47343 (FY00 Core) for $800,000

PERIOD OF PERFORMANCE: October 1, 2000 to December 31, 2002

OBJECTIVE: To generate underwater shock waves in a safe and environmentally sound way.

BACKGROUND: The nonexplosive device for generating tailored underwater shock waves is called Hydrofist because one end of each pressure cylinder is forced outward by expanding water when it is triggered. By the nature of the energy-release mechanism, Hydrofist efficiently couples sound energy to water. Energy can also be coupled into earth with high efficiency because the input impedance of earth is not too different from water. Changing cylinder length and cylinder pressure will modify the time history of piston motion. The geometrical arrangement and relative trigger times control the radiation-beam patterns.

RESULTS: Resulting from a CEROS-awarded contract in FY99, BBN began developing Hydrofist. The following development obstacles were met and overcome—metal failures and hydraulic seals not meeting psi differential. A supplier was never found to solve the third problem, suitable electrical solenoid valves that would operate reliably at 32,000 psi. A work around was fashioned but it was so complicated that it did not work with precise timing. BBN believes that Hydrofist will achieve its predicted performance with proper solenoid valves, a better piston seal, and large LP hydraulic lines and fittings.

SIGNIFICANCE: Hydrofist is intended to provide a versatile means of shock testing ships, boats, and underwater equipment. Any number of Hydrofist units can be arrayed to enable shocks of varying impulse and pressure. Changing the length of the working fluid chamber and its pressure also will change shock parameters. Both military and commercial applications exist for Hydrofist. Military applications include the remote disablement of antiship mines and incoming torpedoes. Many Hydrofist units would be needed for these applications, so the system would be very heavy. Only large warships could carry the array without so loss of payloads. However, smaller arrays can have commercial applications. Hydrofist is the subject of U.S. Patent No. 6173803.

Water Properties Sensor Project

Richard E. Cox dba Cox Environmental Systems, Columbia, MD
Contract No. 46763 (FY00 Core) for $215,004

PERIOD OF PERFORMANCE: June 15, 2000 to June 14, 2001

OBJECTIVE: To design and demonstrate an *in-situ* prototype instrument to measure inherent optical properties (IOPs) and apparent optical properties (AOPs) of ocean water.

BACKGROUND: This effort combines elements from two proposals submitted by Cox Environmental Systems under BAA-CEROs-2K-01. The intent of this effort is to provide a proof-of-concept demonstration of a single instrument capable of measuring both IOP and AOP in seawater. The bulk or large-scale, optical properties of water are divided into the following mutually exclusive classes:

- IOPs depend only on the medium and therefore are independent of the ambient light field within the medium. Two fundamental IOPs are absorption coefficient and volume scattering function. Others include the index of refraction, beam attenuation coefficient, and single-scattering albedo.
- AOPs are properties that depend both on the ambient light field and that display enough regular features and stability to be useful descriptors of the water body. Commonly used AOPs are the irradiance reflectance, average cosines, and various diffuse attenuation coefficients.

RESULTS: The prototype water properties sensor merges into one instrument capabilities currently requiring several separate instruments. The sensor is relatively small and light weight. The instrument has no protrusions or exposed sensor systems, no moving parts, and does not require a cage. Beyond the physical advantages, it is a precision measuring instrument. The water properties sensor's signal collection capability was demonstrated during laboratory, dock, and *in-situ* ocean testing. Post processing and analysis of the acquired signals showed the sensor's capability to provide a consistent and comprehensive assessment of the ocean's AOP and IOP properties. The prototype sensor met the project goals. Furthermore, it exceeded the project's basic goals by providing signals having full visible-band spectral capabilities. The prototype system is larger than desired and requires shipboard signal processors. Utilization requires significant post processing.

SIGNIFICANCE: Post processing and analysis of the acquired signals showed the sensor's capability to provide a consistent and comprehensive assessment of the ocean's AOP and IOP properties. The prototype sensor met the project goals. Furthermore, it exceeded the project's basic goals by providing signals having full visible-band spectral capabilities. Future developments should integrate the sensors, and provide internal signal processing and real-time utilization.

SIGNIFICANCE: Post processing and analysis of the acquired signals showed the sensor's capability to provide a consistent and comprehensive assessment of the ocean's AOP and IOP properties. The prototype sensor met the project goals. Furthermore, it exceeded the project's basic goals by providing signals having full visible-band spectral capabilities. Future developments should integrate the sensors, and provide internal signal processing and real-time utilization.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Web-Based Propagation and Noise Effects On Signal Processing
Phase 2

Science Applications International Corp. (SAIC), McLean, VA
Contract No. 47316 (FY00 Core) for $670,000

PERIOD OF PERFORMANCE: September 1, 2000 to October 31, 2002

OBJECTIVE: To focus on developing a web-based broadband acoustic propagation modeling and signal processing software capability that would reside on and utilize the parallel computing and high-performance storage assets at the Maui (Hawaii) High Performance Computing Center (MHPCC).

BACKGROUND: The ultimate objective of this project was to demonstrate a real-time broadband processing capability using the Santa Barbara Channel Experiment (SBCX) data as an example. For the purpose of this project, real time is defined as having the processing keep up with the real input data rate for a 100-Hz bandwidth and a 30-element vertical line array.

CEROS supported initial analysis of SBCX under FY99 Contract No. 45772. Results from the FY99 effort include the decision to wrap sophisticated processing programs into an easy-to-use, easy-to-maintain, and globally accessible form, which allows the investigators to provide a good framework for compute-intensive problem-solving scenarios in both real or nonreal time. This architecture also allows preparation for future enhancements, especially when new algorithms need to be implemented or different research goals are needed.

RESULTS: As a follow-on to the CEROS-supported FY99 project, extensions were made to the parabolic equation (PE)-based propagation engine in the form of modeling internal waves as well as moving ships. Additionally, new functionality was added that uses the Web interface to monitor the acoustic signals received from the Pacific Missile Range Facility (PMRF), Kauai, Hawaii, hydrophones in real time. A software agent was built that monitored the signal levels from some of the PMRF Barking Sands Tactical Underwater Range (BARSTUR) hydrophones. To support this new function, a set of graphical user interfaces (GUIs) were added to the suite of menus that allows an operator to archive the files that have been recorded at PMRF, as well as allow the operator to listen to any of the hydrophones by clicking on a map of the phone locations. Some of these signals were then used to localize whales during spring 2001. Improvements were made in the remote system administration capabilities, in that a new web page was developed that allows a system administrator to initialize platform-specific parameters via a web browser. Finally, to investigate alternatives to general-purpose supercomputing platforms, a small Linux cluster was built at MHPCC that mirrors the one SAIC has been using for 2 years.

SIGNIFICANCE: The web is a good forum for accessing powerful remote computing facilities. It has provided the basis for building flexible and user-friendly interfaces to complex data processing. This paradigm also fits well within the applications that are adopting this strategy for distributed computing. This programming model can be used to study real-time processes from remote locations, as well as provide the basis for automated data mining application; e.g., illustrated by the acoustic monitoring system. From an algorithmic standpoint, adding two new simulation capabilities and the acoustic monitoring function show that interesting science can be accomplished using these software tools, and more innovative applications can be added.

Compact-Inflatable-Mobile Survival Platform for Military/Special Forces and Commercial Applications
Phase 2

SEE/RESCUE Corp., Honolulu, HI
Contract No. 47505 (FY00 Core) for $120,000

PERIOD OF PERFORMANCE: November 20, 2000 to April 19, 2002

BACKGROUND: SEE/RESCUE initiated this project to update technology of one-person survival craft. Immobility, lack of control, insufficient protection from exposure, and insufficient signal equipment are among the many disadvantages of antiquated survival life rafts. Expertise was used from Life Raft and Marine Safety Equipment, Inc., using the latest lightweight high-strength materials. Incorporating SEE/RESCUE® streamer, SEE/RESCUE Corporation constructed two generations of prototype of LIFE/FLOAT™ to address the problems of outdated survival life rafts. Sea trials on prototypes were conducted in Honolulu, Hawaii. SEE/RESCUE Corporation developed an inflatable, rigid, surfboard-shaped rescue craft that can be paddled by the survivor. The craft is characterized by its mobility, thermal protection, and continuous passive emergency signaling. Before inflation by hand pump or compressed gas cartridge, LIFE/FLOAT™ packs into a compact pouch.

RESULTS: Phase 2 of this concept built on the initial proof-of-concept advancements made in FY98 by constructing a first-generation LIFE/FLOAT™. The name MILITARY LIFE/FLOAT™ resulted from Phase 2. Patented and military-approved LIFE/FLOAT™ technology, including infrared (IR) reflectors, can be built into the device for emergency signaling. Also, protective thermal covering can be incorporated to prevent the human occupant from hypothermia and excessive ultra-violet radiation exposure.

SIGNIFICANCE: SEE/RESCUE Corporation has generated valuable intellectual property from this project. A U.S. patent was granted and worldwide patent coverage is pending and will be pursued through the life of the program. Following completion of final prototypes, the MILITARY LIFE/FLOAT™ technology will be presented to both the Navy SEALs in San Diego and the Special Forces Command headquarters in Tampa, Florida, for evaluation. Both organizations have already expressed interest in the technology for covert military water-based actions. Units will be made available to commercial and recreational boaters and aviators as standard one-person life rafts. In addition, further commercial spin offs include marketing modified versions to the recreational community as surf and paddleboards.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Development of a Sensor for Pesticide Monitoring Based on a Porous Silicon (PS) Optical Biosensor Phase 1

ThermoTrex dba Trex Enterprises, Kihei, HI
Contract No. 46764 (FY00 Core) for $537,000

PERIOD OF PERFORMANCE: June 30, 2000 to February 28, 2002

OBJECTIVE: To develop, fabricate, and test a sensor based on PS optical technology to monitor and detect organophosphate molecules in water. For this (initial) effort, Trex was to etch silicon wafers and develop a sensing surface specific to optical technology species. Finally, Trex was to test the sensor function under laboratory conditions.

BACKGROUND: PS is a high surface-area network of silicon nanocrystallites. It is produced by an anodic electrochemical etch of bulk crystalline silicon. PS also has been used as the large surface area matrix for immobilizing a variety of biomolecules including enzymes, DNA fragments, and antibodies. It has been shown that the electronic or optical properties of PS can also be used a the transducer of biomolecular interactions, thus qualifying its utility in biosensor applications. The prerequisite for using PS as an optical interferometric biosensor is to adjust the size as well as the geometrical shape of the pores by choosing the appropriate etching parameters. The purpose of this effort was to develop and characterize the chip.

RESULTS: Trex fabricated and characterized PS substrates using highly doped *p*-type silicon wafers. Transparent PS thin films with large surface areas were prepared to give, depending on the fabrication condition used a wide range of pore sizes. The pore size and the structure of the PS layer was characterized using atomic force microscopy (AFM). Reflectance interference spectroscopy was used to determine the optical properties. Fourier transform infrared (FTIR) spectroscopy was used to determine the surface species of the freshly etched substrates.

SIGNIFICANCE: This effort showed that functionally appropriate PS chips could be developed and produced. This was the first step in developing an instrument to detect a variety of complex and potentially harmful molecules in nature.

FISCAL YEAR 2001 CORE PROJECTS

A Proposal to Implement and Demonstrate Antisubmarine Warfare (ASW) Targeting and Weapon Control Using Nonorganic Sensors: Netted Combat Control System (CCS) Phase 1

BBNT LLC dba BBN Technologies, Mililani, HI
Contract No. 48213 (FY01 Core) for $1,112,450

PERIOD OF PERFORMANCE: June 25, 2001 to September 24, 2002

OBJECTIVE: To extend the net-centric search, acquisition and targeting (NetSAT) system to provide a robust, demonstrable system that will find utility in Navy training and tactical development in net-centric warfare.

BACKGROUND: NetSAT is a net-centric search, acquisition, and targeting system (a DARPA-sponsored underwater weapon performance enhancement program). Moreover, NetSAT is a precursor to Netted CCS that began as a program with a primary focus on improving performance of lightweight torpedoes in the presence of acoustic countermeasures (ACMs). The first phase also included the development of a fiber-optic control link to the Mk46 lightweight torpedo. In a latter stage, COMSUBPAC's interested prompted adapting the NetSAT concept to include a submarine-launched M48/ADCAP heavyweight torpedo.

RESULTS: Phase 1 has proceeded in the following areas:

- Consolidation/automation of the NetSAT processor hardware and functionality to make possible installation on and operation from a P3 aircraft
- Specification and identification of an radio frequency (RF) communication system to make it possible to transmit scene awareness data from a P3 aircraft to a submarine during a summer 2002 Netted CCS tactical demonstration
- Preparation for an execution of a November 2001 engineering sea test as part of a COMSUBPAC TACDEVEX at PMRF.

SIGNIFICANCE: Netted CSS continues with work on the NetSAT heavyweight weapon concept. Phase 1 work will lead directly into Phase 2, which will include an at-sea tactical demonstration of Netted CSS technology, featuring communication between a prosecuting submarine and a Netted CSS-equipped P3 aircraft.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Development of a Sensitive, Sessile Monitor for Nonpoint Source Heavy Metal Pollution for Tropical and Subtropical Indo-Pacific Waters

Black Pearls, Inc., Hualaloa, HI
Contract No. 48210 (FY01 Core) for 138,097

PERIOD OF PERFORMANCE: June 30, 2001 to June 29, 2002

OBJECTIVE: To assess the feasibility of using pearl oysters as a bioindicator of heavy-metal pollution in near-shore areas of Hawaii and other tropical regions.

BACKGROUND: Heavy-metal pollution is a concern worldwide, especially in harbors and shoreline military facilities. Although biomonitoring programs exist in North America and Europe, no such program exists in the tropics. Pearl oysters have several characteristics that make them ideal for biomonitoring. Hatchery-reared pearl oysters can be deployed for any length of time. Analysis requires an atomic absorption spectrograph.

RESULTS: Controlled-exposure trials were carried out in the laboratory and ocean. Two techniques were attempted to see where in the tissues, organelles, and shell layers these metal molecules were accumulating. One approach used an electron microprobe to determine the amount of metals accumulated in the shell. However, this instrument does not appear to be a good tool for this purpose. The other method used an energy-filtering, transmission electron microscope to locate where in the cells and tissues the metals were accumulating. Copper and zinc were the prevalent metals found in several test areas.

The results showed that the black-lipped pearl oyster is suitable for biomonitoring. A successful protocol for laboratory experiments has been developed to determine levels of bioaccumulation over time and at different concentrations. Also, successful methods have been determined for field trials to monitor environmental pollution levels.

SIGNIFICANCE: Additional trials should be done to investigate the likelihood that oysters can also concentrate metals other than zinc and copper. The potential exists for establishing a commercial method for biomonitoring along Hawaii's various coastlines. The method could be used to monitor short-term effects during construction projects. Black Pearls is part owner of a pearl farm and hatchery in the Marshall Islands. Because atomic bomb testing was conducted there, there is great concern about the long-term effects. There is potential for using pearl oysters to monitor levels of radioactive strontium and cobalt.

Snap-To Amphibious Footwear System

Frank W. Garske dba Nextwave Engineering, Kailua-Kona, HI
Contract No. 48002 (FY01 Core) for $75,700

PERIOD OF PERFORMANCE: June 15, 2001 to December 14, 2002

OBJECTIVE: To create dual-purpose amphibious footwear suitable for both civilian and military applications.

BACKGROUND: The original concept was for the footwear to be both a boot and a fin wearable on land or in water.

RESULTS: Three military-focused prototypes were built and tested. Each generation improved on disadvantages of its predecessor but none was completely successful. Opinions were gathered from NAVSPECWAR personnel and the consensus was that there were many inadequacies. One civilian-focused prototype was built and was found to be adequate for the average dive or snorkel boat.

SIGNIFICANCE: Although the Snap-To amphibious footwear system is probably suitable for civilian application, it is not adequate for military use. During final stages of development, a previous patent was discovered that would require key components of Snap-To to be redesigned. A redesign could improve the overall functionality.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Temporally Enhanced Adaptive Multispectral (TEAMS) System for Detection of Underwater Objects

Innovative Technical Solutions, Inc. dba NovaSol, Honolulu, HI
Contract No. 48580 (FY01 Core) for $34,953

PERIOD OF PERFORMANCE: September 24, 2001 to April 23, 2002

OBJECTIVE: To compare NovaSol TEAMS approach for littoral underwater object detection with current and developmental military sensors.

BACKGROUND: For deep-water threats, acoustic sensors and magnetic anomaly detectors (MAD) have been very successful. However, the Navy's changing mission demands detection of submerged objects in shallow littoral areas. In response, the Navy has developed several multispectral imaging (MSI), hyperspectral imaging (HSI), and lidar sensors. Ideally, one would use an adaptive MSI system that provides enhanced surface-effect mitigation. The TEAMS system accomplishes this. CEROS funded this feasibility demonstration/risk-reduction effort. The principal reason was to document the potential benefits of the TEAMS concept and compare TEAMS with other sensing schemes.

RESULTS: The Navy and Marine Corps are developing several systems to address detection of threat objects in the littoral region. Two passive systems are under current sponsorship—coastal battlefield reconnaissance and analysis (COBRA) system and littoral airborne hyperspectral (LASH) system. The following table summarizes the benefits of TEAMS compared to COBRA (MSI sensors), and LASH (HSI sensors).

Parameter	**MSI (COBRA)**	**HSI (LASH)**	**TEAMS**
Spectral band optimization	Poor	Excellent	Very good
Extended integration time for increased signal	Good	Poor	Good
Temporal processing gain	None	None	Good
Processing requirements	Moderate	High	Moderate
Spatial resolution	Good	Poor	Good
Coverage rate	Good	Poor	Excellent
Fieldability and cost	Good	Poor	Excellent

SIGNIFICANCE: NovaSol proposes a subscale TEAMS sensor demonstration program to design, assemble, and flight test a cost-effective sensor capable of proving the key performance benefits of the TEAMS concept. The scope includes designing and fabricating a subscale version of a TEAMS sensor using a commercially available charge coupled device (CCD) camera configured for segmented multispectral time-delay integration (TDI) operation; limited algorithm development on a laboratory test station; leveraging of planned flight testing of a stabilization system for a NASA program to collect data with the TEAMS sensor; and data analysis. The overall goal is to demonstrate the key TDI gain feature of the TEAMS concept, as well as explore the benefits of surface effect mitigation.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Experimental Investigation of Cable Fatigue

Knapp Engineering, Inc. dba Structural Solutions, Aiea, HI
Contract No. 48488 (FY01 Core) for $192,000

PERIOD OF PERFORMANCE: September 1, 2001 to August 31, 2002

OBJECTIVE: To develop a cable fretting fatigue model.

BACKGROUND: In the CEROS-supported FY00 effort, *Modeling of Cable Fatigue*, Structural Solutions developed. the CableFATIG™ axial and bending fatigue models (equivalent notch and fretting). Cable strength members (regular helical layers) have been incorporated into the existing finite-element analysis software for CableCAD™. Structural Solutions developed CableCAD™ in an earlier CEROS-supported project.

RESULTS: This report documents the experimental validation of the cable fatigue models The models include cyclical tension, single-curvature cyclical bending, and reversed bending. An analysis model based on a stress concentration factor and another model based on fretting were programmed in the CableFATIG™ software. The equivalent notch model introduced by Knapp and Chiu has been used for all cable test specimens. In addition to the test data obtained from the FY00 effort, tests of a 1x19 galvanized extra-improved plow steel strand were successfully performed at Structural Solutions. As a result, modifications and additions were made to CableFATIG™, which improved performance. The program was used again to model the aerostat and stay cables.

SIGNIFICANCE: CableFATIG™ has been evaluated for three load types and three different cable constructions and provides a reasonable prediction of cable fatigue for all the cables studied. The investigators found no evidence that this has been accomplished by anyone else.

Three-Dimensional Cloud Height Indicator for Marine Application (3D-CHIMA)

Oceanit Laboratories, Inc., Honolulu, HI
Contract No. 48216 (FY01 Core) for $400,000

PERIOD OF PERFORMANCE: June 30, 2001 to June 29, 2002

OBJECTIVE: To finalize the design of the 3D-CHIMA, purchase components, assemble and test the prototype, and develop necessary software.

BACKGROUND: The primary reason the Navy requires cloud height measurements and cloud amounts is to support Navy aviation; consequently, all major ships have this need, especially aircraft carriers and helicopter ships. Flight safety, namely protection of Navy personnel and assets, is the issue. Currently cloud ceiling and coverage are estimated on Navy ships primarily by manual observation, which has serious shortcomings. To help alleviate this problem, Oceanit developed a three-dimensional cloud ceiling height and cloud coverage measurement system called 3D-CHIMA.

RESULTS: Design parameters were established for application of 3D-CHIMA to naval ships. Design options were explored for both a scanning mirror system and a gimbaled yoke system. Advantages and disadvantages for each were identified. The gimbaled yoke design was the most desirable because of the high signal-to-noise ratio of the configuration, adaptability, and performance of the system. The Vaisala CT25K LIDAR ceilometer was chosen for the system because of its range and performance. The system was successfully constructed and software was written to control system functions and process data. Land testing was performed to test the system as a whole and evaluate system functions.

SIGNIFICANCE: Testing aboard a naval vessel is a critical step in the migration of this technology to a fully approved and commissioned system. After a suitable vessel is approved by the Navy, a prototype device will be installed. After a minimum of 3 months to trouble shoot early problems and judge the efficacy of the device, actual onboard testing will take approximately 3 weeks. CEROS funded a follow-on effort in FY02 (Contract No. 49332) for system testing.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Theater-Wide Situational Awareness for Decision Wall

ORINCON Hawaii, Kailua, HI
Contract No. 48163 (FY01 Core) for $150,000

PERIOD OF PERFORMANCE: June 30, 2001 to December 29, 2001

OBJECTIVE: To provide a capability that publishes and delivers live, near real-time and operator-interactive theater undersea warfare (TUSW) tactical information to the Pacific Command that will significantly improve global situational awareness of theater-wide operations.

BACKGROUND: As the first step to integrate undersea situational awareness information to CINCPAC CINC-21 Decision Wall concept (later known as the *delivering the right information to the right person at the right time* initiative), ORINCON installed and configured Web Centric Antisubmarine Warfare Network (WeCAN) collaboration tool in the CINC-21 secured network (SIPRNET) facility. This report summarizes and details the synthesis and results of the server configuration and installation process. Currently, the only available backup site for the main WeCAN server is installed within the Commander Antisubmarine Warfare (ASW) Forces Pacific (CTF-12) command center, which does not include any geographical separations. Adding another backup server geographically separated from the CTF-12 command center provides a more robust system redundancy. Under CEROS funding, the ASW commander (ASWC) workstation was installed at CTF-12 and ORINCON has provided a continuous stream of improvements that support day-to-day fleet operators.

RESULTS: The WeCAN server is a commercial off-the-shelf (COTS) Dell rack-mounted web server running a widely available and secure Apache web server and Perl. The configuration is set up to be self running and requires only minimum operator maintenance. The main operator interaction with WeCAN uses a standard IT-421-compatible web browser window. There are no additional software needs to be installed on client machines. All scripting engines are server side and transparent to clients. All product objects were successfully completed and installed at CINC-21, pending SPAWAR issuing interim authority to operate to connect to the SIPRNET.

SIGNIFICANCE: Continued support is needed to deliver undersea information to CINCPAC at a very high level by integrating intelligent agents to process and extract critical information. The extraction should happen automatically without operator intervention. WeCAN software already has built-in capabilities to include external agents executing additional information processing. Immediate and additional follow-on funding to include external processing capable of extracting fleet-level knowledge will assist senior-level decision makers as well as warfighters to gain better awareness and form a clearer common operational picture to increase national security and well being of U.S. citizens.

Passive Assured Access (PAA) System

ORINCON Hawaii, Kailua, HI
Contract No. 48390 (FY01 Core) for $749,203

PERIOD OF PERFORMANCE: July 26, 2001 to October 25, 2002

OBJECTIVE: To develop a system design specification for the PAA system.

BACKGROUND: CEROS funded ORINCON to design and develop the towed-array beamformer, towed-array and hull array auto detector systems, which are part of the PAA system. The PAA system to be installed onboard a COMSUBPAC-designed Pearl Harbor-based submarine is a real-time prototype passive acoustic signal and information processing system that will allow its host platform open and safe access to all international shallow-water environments. The system will be used to detect and manage heavy surface-ship traffic in the littoral regions and will improve the submarine's ability to detect potentially hostile, quiet diesel-electric submarines.

RESULTS: The PAA system consists of the beamformer virtual machine environment (VME) chassis, signal-processing VME chassis, and data fusion workstation. The PAA system final design specification addresses issues related to the system's hardware and software, including processor assignment, hardware configuration, interface types, and algorithm descriptions.

SIGNIFICANCE: Work performed under this program can be directly transitioned to the Navy's acoustic rapid commercial off-the-shelf (COTS) insertion (A-RCI) program.

Flapping Foil Technology for Motion Stabilization of Novel High-Speed Vehicles

Pacific Marine & Supply Co., Ltd., Honolulu, HI
Contract No. 48211 (FY01 Core) for $250,000

PERIOD OF PERFORMANCE: June 30, 2001 to June 29, 2002

OBJECTIVE: To provide a sturdy design tool that will be used in optimizing the flapping foil system.

BACKGROUND: There is currently a great commercial and military demand for high-speed stable ship platforms that can operate safely in larger sea states. Small water plane area twin hull (SWATH) is a relatively new ship type that can greatly reduce or eliminate passenger seasickness while increasing crew effectiveness and safety. A well-designed SWATH ship rides through a seaway without the large motions and accelerations of conventional vessels. High-speed ships, SWATH vessels, and other advanced vessels currently use flaps, fins, and other forms of stabilizers to improve sea keeping and stability.

RESULTS: In the course of the project, systematic experiments and computations were carried out to map the performance characteristics of a flapping foil. In addition, a framework for evaluating the motion and approximate lifting forces for flapping foil mechanisms is incorporated with the large amplitude motion program (LAMP) system. Multiple flapping foils can be added to a vessel with or without proportional, integral, and derivative (PID)-type motion controllers. There are currently three types of models to approximate the lift acting on a flapping foil—(1) LAMP default foil, (2) Xfoil computational prediction, and (3) a limited experimentally determined model. Experiments were conducted involving flapping foil using FLEX3D, incorporating Xfoil and experimentally derived flapping foil models into LAMP, and hybrid small water plane area craft (HYSWAC) motion in regular and irregular waves with and without PID-type foil controller.

SIGNIFICANCE: The results of this technology could revolutionize vehicle propulsions efficiencies, vehicle motion control, and increase vessel-maneuvering capabilities. CEROS funded a follow-on effort led by Science Applications International Corp. (SAIC) in FY03 (Contract No. 50583) for a feasibility demonstration.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Web-Based Simulation, Modeling, and Signal Processing

Science Applications International Corp. (SAIC), McLean, VA
Contract No. 48575 (FY01 Core) for $399,868

PERIOD OF PERFORMANCE: September 1, 2001 to December 31, 2002

OBJECTIVE: To enhance the capabilities incorporated within the parabolic equation (PE)-based acoustic propagation engine, as well as within the matched field processing (MFP), beam forming stream of programs.

BACKGROUND: The software system that has been built over the past 3 years represents the start of a fully distributed processing capability that could be used by the Navy or any other entity that wants to perform large-scale computing from remote sites. SAIC has shown that by using web-based tools to access supercomputing resources in a secure fashion, large problems can be solved, and the results can be viewed from anywhere in the world via the Internet.

The objective of the FY00 work was to focus on developing a web-based broadband acoustic propagation modeling and signal processing software capability that would reside on and utilize the parallel computing and high-performance storage assets at the Maui (Hawaii) High Performance Computing Center (MHPCC).

RESULTS: To better support the remote distributed-processing paradigm, all programs were migrated from the IBM general-purpose supercomputer to the dedicated CEROS Linux cluster in Maui. Fortran 90 and MatLab licenses were purchased to support software needs. Software additions include two new signal-processing algorithms and three new interfaces into a Navy standard database to support the acoustic modeling effort. Several commercial off-the-shelf (COTS) and public domain packages were included. SAIC's multiple program multiple data (MPMD) style of programming is now working under the MPICH-2 environment. This nontraditional message-passing implementation (MPI) system has not yet been linked to the PBS queuing system.

SIGNIFICANCE: The web is a good forum for accessing powerful remote computing facilities. This programming model can be used to study real-time processes from remote locations, as well as provide the basis for automated data-mining applications. Because of the drop in computer hardware costs, adoption of dedicated PC clusters has become a realistic alternative to traditional supercomputing platforms. Adding two new data processing capabilities and linking into a standard Navy database show that challenging science and technology problems can be addressed using these software tools, and can provide the foundation for more innovative applications.

Implementation of an Ocean Acoustic Laboratory (OAL) at Pacific Missile Range Facility (PMRF)

Scientific Solutions, Inc. (SSI), Kalaheo, HI
Contract No. 48389 (FY00) for $150,392

PERIOD OF PERFORMANCE: July 11, 2001 to July 20, 2002

OBJECTIVE: To develop an ocean circulation computer model.

BACKGROUND: The Office of Naval Research (ONR) is investigating developing an OAL at the PMRF on Kauai, Hawaii. One of the basic components is a high-resolution ocean circulation model that would cover the PMRF acoustic ranges and surrounding waters of Kauai and Niihau. The model would be used to provide nowcasts of water temperatures and salinities as well as forecasts of acoustic conditions in the region. The forecasting capability of the ocean model is important because it provides the ability to predict when conditions could be conducive for various activities, both military and civilian. CEROS funded three tasks related to the ocean model. The ocean circulation computer model was developed using a version of the Princeton ocean model.

RESULTS: The Princeton ocean model was tuned for the six major tidal constituents observed at two stations on Kauai. Monthly climatologies were developed for each grid cell of the model. Limited model-data comparisons confirm the predictive capability of the model, but test simulations show that SSI needs distributed atmospheric mesoscale prediction system (DAMPS) and modular ocean data assimilation system (MODAS) inputs from the Naval Pacific Meteorology and Oceanographic Center (NPMOC) for accurate predictions. The model code has been adapted to accept DAMPS and MODAS fields, coupling with these NPMOC data was tested, and the impact of the various forcings was determined. Linking and funding difficulties between NMPOC and the Maui High Performance Computer Center (MHPCC) have prevented accomplishing the final task.

SIGNIFICANCE: Both the NPMOC and SUBPAC submarine technical directors are interested in using the information from the ocean models. Specifically, they want to use the nowcasts and forecasts in antisubmarine warfare (ASW) products to the fleet. Test demonstrations are being prepared. CEROS funded a follow-on effort in FY03 (Contract No. 50584) for application and demonstration of the model in support of ONR underwater communications tests at PMRF.

vSAR: Video Search and Rescue

STI Services, Inc. (TerraSystems, Inc.), Honolulu, HI
Contract No. 48214 (FY01 Core) for $337,123

PERIOD OF PERFORMANCE: June 30, 2001 to June 29, 2002[1]

OBJECTIVE: To develop a real-time multispectral processing system as a possible adjunct to Navy and Coast Guard search and rescue operations.

BACKGROUND: The vSAR system is based on previous CEROS-funded research and rescue technologies, multispectral imaging, and automatic target recognition. It is a stand-alone system designed to aid at-sea military SAR operations and could be adaptable to unpiloted air vehicles (UAVs). With previous CEROS funds, STI and SEE/RESCUE Corporation showed that a two-part enhanced visibility system (EVS) can increase the visibility of the target survivor (TS) and improve the search party to see the TS. CEROS awarded the vSAR contract to TerraSystems in June 2001.

RESULTS: The contract was assigned to STI when STI purchased TerraSystems in October 2001. Under the contract, STI and its subcontractors successfully developed the vSAR hardware and software as planned; they also tested the system in the laboratory and fitted the prototype vSAR into an aircraft for flight tests. Unanticipated system redesign, required to obtain Federal Aviation Administration (FAA) approval for the prototype system to fly, took longer and cost more than planned. Furthermore, the prototype-capable aircraft and pilot were unavailable for test flights as anticipated. In the end, there was neither enough time nor money, so the test flight task in the contract was not fulfilled. The discussion with STI focused on adjusting the final payment to an amount commensurate with the results of the effort, particularly task 6 to test prototype vSAR in aircraft. STI failed to notify CEROS about difficulties in receiving FAA approval and further failed to request a modification of the contract before it expired.

SIGNIFICANCE: STI and its vSAR partners are vigorously pursuing follow-on funding from potential sponsors both within and outside of DOD.

[1] Original contract was for $352,123

Reconnaissance of Mines and Obstacles in Surf Zone (SZ)

STI Services, Inc. (TerraSystems, Inc.), Honolulu, HI
Contract No. 48574 (FY01 Core) for $34,999

PERIOD OF PERFORMANCE: October 1, 2001 to March 31, 2002

OBJECTIVE: To determine whether the multiframe, multispectral temporal approach should be recommended for further development or consideration for future Navy littoral surveillance systems.

BACKGROUND: Existing reconnaissance technologies provide options for all littoral areas except the difficult SZ where, in current implementation, each fails to adequately address the dynamic and temporal SZ aspects. The Office of Naval Research (ONR) singled out the SZ as a priority. No sensor has been demonstrated to deal with breaking waves, foam, water turbulence, sediment plumes, sun glitter, and substrate reflections. Also, the high radiance contrast between water and adjacent beach exceeds current sensor range.

STI initiated a major surf zone mine-counter-measures (MCM) activity under the littoral airborne system:hyperspectral (LASH) program that incorporates many concepts essential to solving the SZ program. The LASH MCM effort involves fabricating a sophisticated six-camera multispectral imaging (MSI) system to be flown from a helicopter. Because it has more potential in dealing with the complex, dynamic optical SZ environment, STI's approach is to use an MS framing camera. With current CEROS support and using LASH MCM technology, STI will develop a six-camera test bed to test data collection and algorithm development scenarios.

RESULTS: STI expects tests in spring 2003 to validate the idea that an MSI framing camera is the better approach for the SZ mine and obstacle reconnaissance. Because SZ phenomena vary, on a relatively short time scale, a sensor that can dwell long enough and with sufficient frame rate is required. With this sensor, the system can

- Discriminate between clutter and targets by motion and lifetime
- Increase the probability of encountering a clear optical path in the vicinity of the targets
- Integrate frames to achieve increased exposure time for dimmer targets

SIGNIFICANCE: This study deals specifically with daytime detection in the SZ. However, the hardware and algorithms currently being developed at STI can also be the foundation for future expansion to other zones and nighttime use.

FINAL TECHNICAL REPORT
DARPA COOPERATIVE AGREEMENT #MDA972-97-2-000-1

Porous Silicon (PS) Biosensor
Phase 2

ThermoTrex dba Trex Enterprises, Kihei, HI
Contract No. 48215 (FY01 Core) for $499,826

PERIOD OF PERFORMANCE: June 25, 2001 to August 24, 2002

OBJECTIVE: To develop, fabricate, and test a sensor based on PS optical technology to monitor and detect organophosphate molecules in water.

BACKGROUND: PS is a high surface-area network of silicon nanocrystallites. It is produced by an anodic electrochemical etch of bulk crystalline silicon. PS has been used as a large surface-area matrix for immobilizing a variety of biomolecules including enzymes, DNA fragments, and antibodies. It has been shown that the electronic or optical properties of PS can also be used a the transducer of biomolecular interactions, thus qualifying its utility in biosensor applications. The prerequisite for using PS as an optical interferometric biosensor is to adjust the size, as well as the geometrical shape, of the pores by choosing the appropriate etching parameters. This portion of the two-phase project reports on Phase 2. Phase 1 is reported in research funded by CEROS in FY00.

RESULTS: Although the ultimate aim of the overall development effort remains the same as in Phase 1, Trex scaled back the effort to a more reasonable level. The focus of this effort is on demonstrating the PS system functionality as a medical diagnostic tool. To demonstrate the feasibility, Trex showed that the PS sensor could detect and monitor “biological interactions” in blood cells.

SIGNIFICANCE: Trex’s research has proven that picomolar concentrations of protein for the immunosensor can be detected. The scope of the work has been expanded to increase the length of the interferometer to increase sensitivity.