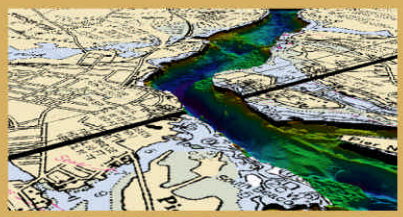

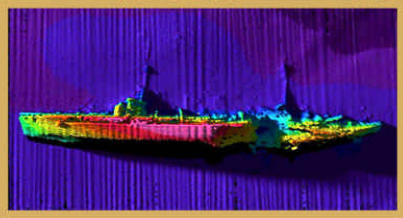
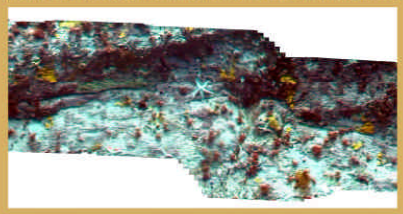
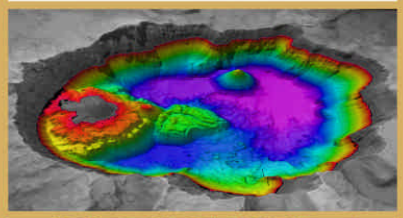
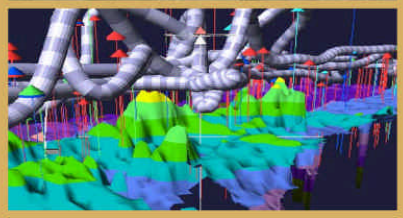
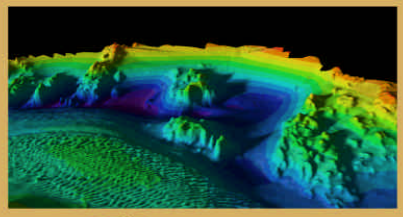

Performance and Progress Report: UNH/NOAA Joint Hydrographic Center

NOAA Ref No.: NA970G0241

NOAA Ref No: NA17OG2285

Report Period: 07/01/2002 – 12/31/2002

Project Title: Joint Hydrographic Center

Principal Investigator: Larry A. Mayer

Center for Coastal and Ocean Mapping

Joint Hydrographic Center

INTRODUCTION:

On 4 June 1999 the Administrator of NOAA and the President of the University of New Hampshire signed a cooperative agreement describing a Joint Hydrographic Center (JHC) at the University of New Hampshire. On 1 July 1999 a grant was awarded to the University of New Hampshire providing the initial funding for the establishment of the Joint Hydrographic Center. This center, the first of its kind to be established in the United States, was formed as a national resource for the advancement of research and education in the hydrographic and ocean mapping sciences. The activities of the center are focused on two major themes: 1- a research theme aimed at developing and evaluating a wide range of state-of-the-art hydrographic and ocean mapping technologies, and; 2- an educational theme aimed at establishing a learning center that will promote and foster the education of a new generation of hydrographers and ocean mapping scientists to meet the growing needs of both government agencies and the private sector. In concert with the Joint Hydrographic Center, the Center for Coastal and Ocean Mapping was also formed in order to provide a mechanism whereby a broader base of support (from the private sector and other government agencies) could be established for ocean mapping activities.

This report is the seventh in a series of bi-annual progress reports, highlighting the activities of the Joint Hydrographic Center during the period between 1 July and 31 December, 2002.

REVIEW OF RECENT PROGRESS:

Infrastructure:

Personnel:

The key to the success of any center will be the skills and talents of the individuals that make it up. Thus the primary task in establishing the Joint Hydrographic Center was to ensure that an appropriate team of people would be brought to the University of New Hampshire. This has been accomplished, and with the arrival of **Dr. Christian de Moustier** in January 2002, all positions outlined in the original Center proposal have been filled. Additionally, this year, **Dr. Lloyd Huff** has retired from NOAA and joined the Center as a Research Faculty member and **Brian Calder's** position was changed from Research Scientist to Research Faculty. Funding from external sources have allowed us to expand our staff to include a new laboratory manager (**Andy McLeod**) supported by ONR and NSF, two new Research Scientists (**Gareth Elston** and **Barbara Kraft**) supported by the USGS, ONR, and industrial sources, and a GIS specialist (**Pam McLeod**) supported by ONR as well as several hourly employees and **Ben Smith** who maintains research vessel.

Faculty:

Larry Mayer, Director of the Center for Coastal and Ocean Mapping and Co-Director of the Joint Hydrographic Center. Dr. Mayer's position is split between the Ocean Engineering and Earth Science Departments. Dr. Mayer has a background in marine geology and geophysics with an emphasis on seafloor mapping and the remote identification of seafloor properties from acoustic data. Before coming to New

Hampshire he was the NSERC Chair of Ocean Mapping at the University of New Brunswick where he led a team that developed a world-wide reputation for innovative approaches to ocean mapping problems.

Colin Ware, member of the Center for Coastal and Ocean Mapping and Director of the Data Visualization Research Lab. Dr. Ware's position is split between the Ocean Engineering and Computer Science Departments. Dr. Ware has a background in human/computer interaction (HCI) and has been instrumental in developing a number of innovative approaches to the interactive 3-D visualization of large data sets. As a member of the UNB Ocean Mapping Group, Dr. Ware was the developer of many of the algorithms that were incorporated into CARIS HIPS, the most commonly used commercial hydrographic processing package.

Chrisitan de Moustier is the newest addition to the faculty of the Joint Hydrographic Center/Center for Coastal and Ocean Mapping. His position is split between the Ocean Engineering and Electrical Engineering Departments. He is a world-renowned expert in the theory and engineering aspects of advanced sonar systems for ocean mapping. Christian comes to us from the Scripps Institution of Oceanography where he was responsible for the installation and operation of a number of multibeam and other sonar systems. His research interests focus on development of innovative sonar processing techniques and acoustic seafloor characterization.

Jim Gardner has been a senior marine geologist with the U.S. Geological Survey in charge of the Western Region's marine mapping program. He was been responsible for the multibeam sonar mapping of a number of areas off California and Hawaii and has pioneered innovative approaches to the dissemination and interpretation of these data. Jim has had a long and illustrious career making important contributions in a number of areas of marine geology and geophysics including leading the U.S. effort to map its EEZ with the GLORIA long-range side-scan sonar. Jim will be retiring from the USGS and joining the Center as a Research Professor in the late summer of 2003.

Lloyd Huff has over 37 years in private industry and the federal government, working with acoustic instrumentation and oceanographic equipment. He received his Doctorate in Ocean Engineering in 1976 from the University of Rhode Island and was one of the lead professionals in the Office of Coast Survey (OCS) working to bring multibeam side scan sonars and multibeam bathymetric sonars into standard practice for shallow water hydrography. He was Chief of the OCS Hydrographic Technology Programs from 1988-1999. Dr. Huff is working on new approaches for a range of hydrographic activities including the application of RTK techniques. Lloyd is now a Research Professor in Ocean Engineering.

Brian Calder with a Ph.D. in Computing and Electrical Engineering has changed his status from Research Scientist to Research Asst. Professor with an appointment shared between the Center and the Dept. of Electrical Engineering.. Dr. Calder also comes with a wide range of high-level computing skills. His work has focused on developing methods for textural analysis of seafloor sonar data, as well as exploring innovative

approaches to target detection and seafloor property extraction. More recently, Brian is focusing on statistically robust automated data cleaning approaches and tracing uncertainty in hydrographic data. Brian has begun to take a very active role in teaching and advising students prompting the change in position title.

Lee Alexander is a Research Associate Professor actively involved in applied research, development, test and evaluation (RDT&E) projects related to the implementation of electronic chart-related technologies. Lee chairs or participates on a number of international committees defining electronic chart standards, and serves as a technical advisor to U.S. Navy, U.S. Army, U.S. Coast Guard, and Coast Survey-NOAA.

NOAA has demonstrated its commitment to the new Center by assigning three NOAA employees to the Center:

Capt. Andrew Armstrong, Co-Director of the JHC, Captain Armstrong recently retired as an officer in the National Ocean Atmospheric Administration Commissioned Corps and is now assigned to the Center as a civilian NOAA employee. Captain Armstrong has specialized in hydrographic surveying and served on several NOAA hydrographic ships, including the NOAA Ship *Whiting* where he was Commanding Officer and Chief Hydrographer. Before his appointment as Co-Director of the NOAA/UNH Joint Hydrographic Center, Captain Armstrong was the Chief of NOAA's Hydrographic Surveys Division, directing all of the agency's hydrographic survey activities. Captain Armstrong has a B.Sc., in Geology from Tulane University and a M.S. in Technical Management from the Johns Hopkins University. Capt. Armstrong is overseeing the hydrographic training program at UNH and organized our successful certification submission to the International Hydrographic Organization.

Cdr. Gerd Glang is at the Center in two roles. He has been the NOAA Navigation Advisor for the Northeast Region, serving as an ambassador to the maritime community and directly supporting the NOAA strategic goal to "promote safe navigation" by helping to resolve charting and navigation questions, educating constituents on emerging charting technologies, and soliciting feedback on NOAA's navigation products and services. He is also a full-time graduate student. Cdr. Glang commanded the NOAA ship *Whiting* during its successful search for the wreckage of Egypt Air Flight 990 and John F. Kennedy, Jr.'s, downed Piper Saratoga.

Carl Kammerer, is an Oceanographer with the National Ocean Services' Center for Operational Oceanographic Products and Services (CO-OPS) now seconded to the Center. He is a specialist in estuarine and near-shore currents and presently the project lead or manager for two projects; a traditional current survey in Southeast Alaska, and a more robust survey to ascertain the effects of large bulk cargo ships in Las Mareas, Puerto Rico. Working out of the Joint Hydrographic Center, he acts as a liaison between CO-OPS and the JHC and provides expertise and assistance in the analysis and collection of tides. He has a B.S. in Oceanography from the University of Washington and is an MBA candidate at the University of Maryland.

Other Affiliated Faculty:
Dave Wells: world-renown in hydrographic circles, Dave Wells is an expert in GPS and other aspects of positioning, providing geodetic science support to the Center. Along with his time at UNH, Dave also spends time at the University of New Brunswick and time at the University of Southern Mississippi where he is participating in their new hydrographic program. Dave also helps UNH in its continuing development of the curriculum in hydrographic training and contributed this spring to a UNH course in Geodesy.

Visiting Scholars:

Jorgen Eeg (Oct – Dec, 2000) is a senior researcher with the Royal Danish Administration of Navigation and Hydrography and was selected as our first visiting scholar. Jorgen brought a wealth of experience applying sophisticated statistical algorithms to problems of outlier detection and automated cleaning techniques for hydrographic data.

Donald House (Jan – July 2001) spent his sabbatical with our visualization group. He is a professor at Texas A&M University where he is part of the TAMU Visualization Laboratory. He is interested in many aspects of the field of computer graphics, both 3D graphics and 2D image manipulation. Recently his research has been in the area of physically based modeling. He is currently working on the use of transparent texture maps on surfaces.

Rolf Doermer (March – September 2002) worked on techniques for creating self-organizing data sets using methods from behavioral animation. The method, called "Anaytic Stimulus Response Animation", has objects operating according to simple behavioral rules that cause similar data objects to seek one and other and dissimilar objects to avoid one another.

Research Scientists and Staff:
Yuri Rzhanov, with a Ph.D. in Physics and Mathematics, is a Senior Research Scientist in the Center. He has a very wide range of computing skills and has built a number of applications for higher education that are presently in use at universities around the world. Most importantly Dr. Rzhanov has been developing models for sonar-seabed interaction for bathymetric and sidescan sonars (including the Klein 2000/5000 systems) as well as software for automatic mosaicing of video imagery and sidescan sonar data.

Semme Dijkstra recently received a Ph.D. in Ocean Mapping from the University of New Brunswick. He is a certified (Cat A) hydrographer from the Netherlands who has several years of hydrographic experience with both the Dutch Navy and industry. From 1996 to 1999 he worked at the Alfred Wegner Institute where he was in charge of their multibeam sonar processing. He is an experienced CARIS user. His thesis work involved artifact removal from multibeam sonar data and development of an echo-

sounder processing and sediment classification system. He is now focusing on applications of single beam sonars for seafloor characterization and fisheries habitat.

Tianhang Hou was a Research Associate with the UNB Ocean Mapping for six years before coming to UNH. He has significant experience with the UNB/OMG multibeam processing tools and has taken part in several offshore surveys. In addition to his work as a research associate Mr. Hou has also begun a Ph.D in which he is looking at the application of wavelets for artifact removal and seafloor classification in multibeam sonar sonar data as well as developing algorithms for determining the "foot of the slope" for Law of the Sea issues and developing new techniques for sidescan sonar processing.

Roland Arsenault was an M.Sc. student and part-time research assistant with Human Computer Interaction Lab of the Dept. of Computer Sciences, UNB before coming to UNH. His expertise is in 3-D graphics, force-feedback and other input techniques and networking. He is currently working on the development of the GeoZui3D realtime 3-D environment.

Gareth Elston joined the Center as a Research Scientist in the fall of 2001. He has a background in sonar signal processing and recently received a Ph.D. from Heriot-Watt University where he developed sophisticated computer algorithms to simulate and visualize the interaction of sonars with the seafloor. Gareth is supported by the U.S Geological Survey and the Office of Naval Research and is focusing his efforts on the continued development of sonar models as well as exploring the applicability of LIDAR data for seafloor characterization.

Martin Jakobsson joined the group in August of 2000 as a Post-Doctoral Fellow. Martin completed a Ph.D. at the University of Stockholm where he combined modern multibeam sonar data with historical single beam and other data to produce an exciting new series of charts for the Arctic Ocean. Martin has been developing robust techniques for combining historical data sets and tracking uncertainty as well as working on developing approaches for distributed database management and Law of the Sea issues.

Rick Komerska joined the Data Visualization Research Lab in March 2001. His background includes degrees in Aerospace and Civil Engineering. Rick has worked on a wide range of systems engineering projects spanning several disciplines. Recently, he has been involved in the development of a simulation/visualization tool in support of cooperating AUVs. He is now investigating techniques for using haptic feedback in carrying out various generic and application-specific tasks, with the goal of transitioning these results into tools used by the ocean community.

Barbara Kraft (TYCO FELLOW) received a Ph.D. in Mechanical Engineering at the University of New Hampshire. Her dissertation research used optical tomography and interferometry to spatially resolve 3-D density fields of turbulent jets. She has taught several courses including digital signal processing and experimental measurement and data analysis. Most recently she has worked on the demodulation of voice and data

transmissions for digital radio communications. At CCOM she is working on the GEOCLUTTER program analyzing *in situ* measurements of seafloor acoutstic properties.

Pam McLeod received a B.Sc. in Electrical Engineering from the University of Wyoming and an M.S.Eng. in Geomatics/Civil Engineering from Purdue University.. Her area of expertise is Geographic Information Systems (GIS), and she holds a joint appointment at UNH between CCOM and the Climate Change Research Center (CCRC). She is currently working on internet information visualization with ArcIMS, GeoMedia, XML, and ColdFusion; geodatabase design with Oracle and ArcSDE; and application development with ArcObjects/VB and Avenue.

Andy McLeod Andy is our new Ocean Engineering Lab manager. Andy spent nine years in the U.S. Navy as a leading sonar technician and then earned a B.Sc. in the Dept. of Ocean Studies at Maine Maritime. He is just finishing his Masters degree in Marine Geology from the University of North Carolina. At UNH, Andy is responsible for maintenance and upgrading of the major laboratory facilities including the test tanks, small boat operations, local network administration and assistance with some courses.

In addition to the academic staff, **Abby Archila** is our full-time program assistant and the keeper of order.

Facilities and Equipment:

Our new 8000 square foot building is now more than fully occupied. Given the very rapid growth of the Center, space has become the limiting factor in our ability to take on new projects. We have arranged with the University for access to additional space; this will be addressed further in the budget discussion. Our original computing, networking and plotting facilities are in place and operational including a 4-processor Origin 2100 Silicon Graphic server with fiber channel disk stripe bringing our central server storage capacity to approximately 750 Gbytes of disc space. We also have an SGI Octane workstation, 3 SGI O2 workstations,42 high-end NT and Linux workstations and laptops and several Mac G4's. All computers are operational and fully integrated into both Center and University networks. All systems are interoperable regardless of host operating system and files are shareable between all systems.

A robust daily backup system is in place, with tapes held in a fire-safe. We have implemented a real-time log monitoring, filtering, and forwarding system to insure an audit trail is available. We have also acquired a full suite of commercial software packages for both data processing and presentation. In addition, we are developing a great deal of in house software (see Research Theme discussions below). For this software development, a cooperative code development environment is in place (CVS) which allows concurrent development on different platforms with multiple users.

We now have several dedicated servers (one to serve as a web-based GIS host and the other as host of the "Common Data Set" collected for Portsmouth Harbor (see below). and a full suite of peripherals (4mm, 8mm, DLT and DVD-R) so that we can re-distribute the data on a range of media. We are outfitting and upgrading an electronics lab and have

acquired a range of high-end test equipment. We have also built data acquisition systems and associated software in support of several research projects (see below). Arrangements have been made with the Research Computing Center to handle routine system maintenance and backup and system security has been increased significantly.

With funding shared between NOAA and the National Science Foundation, we have upgraded the acoustic test tank facilities at the Chase Ocean Engineering Lab, installing a motorized, rigid steel bridge and trolley system that allows a platform to be precisely positioned anywhere over the tank. We have also acquired and installed a computer-controlled rotary turntable that is mounted on the platform and used for sonar testing and calibration. With these upgrades, UNH has one of the largest and most advanced sonar calibration facilities in the Northeast. We have collaborated with researchers from several institutions and successfully used this facility to calibrate various sonars.

We have outfitted and put into service a very shallow draft pontoon boat for survey work in the local waters of Great Bay and received a very generous gift of a 40 foot, purpose-built survey vessel (The *Coastal Surveyor*) from **C&C Technologies** of Lafayette, LA. The *Coastal Surveyor* has seen heavy use supporting both research and class work, in each of the two field seasons we have had the vessel. In support of these research programs we have acquired several state-of-the-art positioning systems (Ashtech and Trimble), a Seabird CTD system and Vitel and Aandera tide guages. In addition TSS has kindly donated a TS-335B motion sensor and ODOM has donated a Digibar sound speed calibration system and a MKIII survey echosounder. We have also been busy building a range of specialized survey equipment including underwater videography capabilities using a Sea Sciences Inc. controllable tow body and pole camera techniques (Huff and Cutter).

Educational Program:

The Center has, under the guidance of Capt. Armstrong, developed ocean-mapping specific curricula that have now been approved by the University. We now offer both M.S. and Ph.D degrees with a specialization in Ocean Mapping through either the Dept. of Ocean Engineering or through the Dept. of Earth Sciences (now expanded to include the School of Natural Resources) and the Institute for the Study of Earth, Oceans and Space. The path chosen depends on the background of the student with physical scientists typically entering through the Oceanography program and engineers entering through the Ocean Engineering program. With the establishment of these programs we will now turn to our longer-term goal of establishing the training and certification programs that can serve both undergraduates and industry people. We have already begun by offering the Center as a venue for industry and government training courses and meetings (e.g., CARIS, Triton-Elics, GEBCO, IBCAO, FIG/IHO, NOAA). This has proven very useful as our students are allowed to attend and are thus exposed to a range of state-of-the-art systems and important issues. Finally and most importantly, our submission to the FIG/IHO International Advisory Board of Standard of Competence for

Hydrographic Surveyors has been accepted and our program was given a **Category A certification by the FIG/IHO Advisory Board** at their annual meeting in May 2001.

While our students have had a range of existing courses to take as part of the Ocean Mapping Program the Center now teaches several new courses specifically designed to support the Ocean Mapping Program.

JHC – originated Courses

Course	Instructors
Introduction to Ocean Mapping	Armstrong, de Moustier, Mayer
Hydrographic Field Course	Armstrong
Marine Geology and Geophysics	Mayer
Array Processing	de Moustier
Data Structures	Ware
Data Visualization	Ware
Seafloor Characterization	Mayer, Calder, de Moustier
Marine Geodesy	Wells, Dijkstra, Huff

Dave Wells and Semme Dijkstra are now working on a web-based version of the Geodesy course for distance education.

We have 12 students enrolled in the ocean mapping program, including three NOAA Corps officers and have already produced two Ph. D.s (Luciano Fonseca (2001) and Anthony Hewitt (2002)).

Student	Program	Advisor
Rick Brennen (NOAA)	M. S. OE	TBD
Daniel Brogan	M. S. EE	de Moustier
Randy Cutter	PhD, E. Sci.	Mayer
Gerd Glang (NOAA)	M.S., OE	TBD
Tianhang Hou	Ph.D. OE	Mayer, Huff
Mike Leo,	Ph.D. E. Sci.	Mayer, Calder, Huff
Malik Mashkoor	M. S. OE	TBD
Karthikeyan Natham	M. S. Comp. Sci.	Ware
Matthew Plumlee	Ph.D. Comp Sci	Ware
Richard Raymond	M.S., E.Sci	Mayer
Shep Smith (NOAA)	M.S, OE	Mayer
Arsen Zolskimovski	M.S. EE	de Moustier

Status of Research: 2001 - 2002:

In our initial proposal (1999) we identified five research programs, each of which combines long-range research goals designed to make fundamental contributions to the fields of hydrography and ocean mapping with short-term objectives designed to address immediate concerns of the hydrographic community in the United States. We outlined each of these programs, describing the major focus of each research task and identifying what resources (both in terms of people, including collaborators, and equipment) will be required to complete these tasks. Here, we briefly review the progress made on these tasks over the past year as well as describe progress made in several new initiatives.

Innovative sonar design and processing for enhanced resolution and target recognition

While this is the least active of our themes, we are seeing growing activity with the development of our sonar calibration facilities. This facility (funded in part by NSF) is now one of the best of its kind in New England with a rigid x,y positioning system, computer controlled transducer rotor (with resolution of 0.025 degree) and custom built data acquisition system. In the past year the new calibration facility was used to better understand the characteristics of the Simrad SM2000 mid-water multibeam sonar (in collaboration with researchers from Woods Hole Oceanographic Institution) as well as Reson 8101 multibeam sonar (in collaboration with researchers from the University of New Brunswick and Pennsylvania State University. Reson is expected to bring a new generation of dynamically focused sonar to our facility so that we can carefully measure its characteristics and ability be used to simultaneously map both the seafloor and mid-water targets. The capability to simultaneously map both the seafloor and water column is an important concern of NOAA with respect to the capabilities of their fishery research vessels.

New approaches to multibeam sonar data processing:

*Improved Bathymetric Processing***:**

An ongoing effort of the Center has been to develop improved data processing methods that would provide hydrographers with the ability to very rapidly and accurately process the massive amounts of data collected with modern multibeam systems. This data processing step is one of the most serious bottlenecks in the hydrographic "data processing pipeline" both at NOAA and throughout the industry. We have explored a number of different approaches for automated data processing (see earlier progress reports for descriptions of these approaches) and, in the past year focused our effort on a technique developed by Brian Calder that is both very fast (10's to 100's of times faster than the standard processing approaches) and statistically robust. The technique, known as CUBE (Concurrent Uncertainty and Bathymetric Estimator), is an error-model based, direct DTM generator that estimates the depth plus a confidence interval directly on each node point. Most importantly, the technique produces an estimate of uncertainty associated with each grid node, and, when the automated editing technique fails to

make a statistically conclusive decision, it will present multiple hypotheses to the operator for a subjective decision. The key is that the operator interacts only with that small subset of data for which there is some ambiguity rather than going through the current process of subjectively examining all data points.

This past year CUBE has been subjected to detailed verification studies in a cooperative research effort with NOAA that have compared the automated output of CUBE to equivalent products (smooth sheets) produced through the standard NOAA processing pipeline. Verification studies were done in three very different environments (Snow Passage Alaska, Woods Hole, Mass., and Valdez, Alaska) involving surveys in various states of completion and comparisons done by NOAA cartographers. In each case the CUBE-processed data agreed with the NOAA processed data within IHO limits. Cube processing took from 30 to 50 times less time than the standard NOAA procedures.

The next step is to implement CUBE processing in an operational processing path and this has led a series of software licensing agreements between the Center and several members of our Industrial Consortium that provide hydrographic processing software. In particular arrangements have been made to transfer this technology to CARIS, Interactive Visualization Systems and SAIC so that it can be implemented in their commercial products. In addition, SIMRAD and Triton-Elics have also expressed interest in securing the software. An "emergency" implementation of CUBE was provided to C&C Technologies in support of efforts to search for space shuttle pieces in a complicated (tree-filled) environment of Toledo Bend Reservoir in Texas. With implementaion by these industry leaders, CUBE is very likely to become the standard for hydrographic processing in the U.S.

Another aspect of the data processing-related research being conducted at the Center involves rethinking of the final output products of a hydrographic survey. We strongly believe that the standard chart product of selected soundings and contours does not at all do justice to the information content of high-resolution multibeam and sidescan sonar data. We are working on a series of new products that will better serve the mariner as well as many other constituencies. In this context, Lt. Smith has developed the concept of the "Navigation Surface" as part of his thesis work. The Navigation Surface is a data base that maintains bathymetric data sets at full resolution and thus can be used to display a series of derived products. Thus a single data base can be the source for hydrographic (safety of navigation) products as well as products for fisheries habitat or other studies that require full-resolution data. CUBE-processed data can be a component of the Navigation Surface and thus the verification exercise described above also involved the navigation surface and tested (positively) the veracity of the navigation surface as a source of hydrographic products. The combination of CUBE and the Navigation Surface set the stage for our new research effort "The Chart of the Future" described later.

As outlined above, there has been tremendous interest in bringing both CUBE and the navigation surface on-line into the standard processing streams. To address this we have already experimented with near real-time applications of CUBE processing in the

course of several 2002 field programs including work with the University of Washington on the Nootka Fracture Zone and the USGS in the Gulf of Mexico.

As a focal point for the broad interest in CUBE amongst the government and the private sector, the Center is fulfilling one of its prime mandates of serving as a national center of focus for ocean mapping activities. In bringing these groups together we become the focal point for more efficient and collaborative research efforts aimed at solving a national need.

In another data processing research program, Lloyd Huff and Tianhang Hou have been developing algorithms and software to clean and remove artifacts from more than 50 gigabytes of Klien 5000 sidescan sonar data collected by the Alaska Fisheries Research Center in the Bering Sea. By removing a series of degrading artifacts in the sidescan sonar records (caused by beam pattern effects tow-fish motion and other causes), Huff and Hou have been able to begin to develop techniques to quantify the impact of fishing gear on the seafloor.

New approaches to data visualization and presentation:

We continue a very strong focus on the development of innovative approaches to data visualization and the application of these approaches to ocean mapping problems. The visualization team (Arsenault, Plumlee, Komerska, and Natham) under the supervision of Lab Director Colin Ware has been actively developing a novel and innovative 3-D visualization environment, GeoZui3D. GeoZui3D is a highly interactive 3-D visualization system designed to support a number of different research projects and ocean mapping applications. GeoZui3D was described in detail in previous progress reports; during the current reporting period, GeoZUI3D has continued to develop and grow. It is has been made available to the public and more than 40 groups have downloaded the software. It is being used as a display and QC tool both on board NOAA survey vessels and in NOAA labs.

New enhancements to GeoZUI-3D include:

- Greatly increased rendering speed
- Ability to edit and place objects in 3-D scene
- Added ability to establish resolution priorities
- Event handling
- Multiscale labels
- Ability to view cross-sections in 3-D
- Masking ability
- Ability to handle time-varying data sets like currents and tides

GeoZUI-3D has become the basis for a prototype museum exhibit for Seacoast Science Center (GeoEXHIBIT-3D) and a very effective outreach mechanism demonstrating the importance of seafloor mapping. This exhibit allows visitors to pilot

themselves in an immersive 3-D environment up and under the Piscataqua River, stopping at interesting sights along the way.

The incorporation of flow visualization models into the GeoZUI-3D environment has opened of a range of applications and interest from ocean and current modelers both inside and outside of NOAA. Collaboration with modeling teams at Dartmouth and with NOAA's Coast Survey Development Lab is currently underway. The incorporation of time-varying data sets also has allowed us to explore the feasibility of creating "tide aware" 3-D bathymetric charts, laying the groundwork for the "Chart of the Future" discussed later.

Force-feedback (haptic) interfaces have been developed for GEOZUI-3D. These interfaces are being used for the exploration of the usefulness of clickless menus in haptic environment. In collaboration with the Deep Submergence Group at WHOI, realistic 3-D interfaces for their "Predator" manipulator arm are being developed for use with very fine-scale archaeological excavations.

Finally, a series of theoretical studies of perceptual and task-related frames of reference have been carried out that look at the mismatch between visual and haptic images of an object. These theoretical studies form the basis for the development of user interfaces for things like the Chart of the Future. This has been supported with NSF funding.

Seafloor Characterization:

We have a number of inter-connected research programs underway aimed at exploring the ability of our mapping systems to provide quantitative information on the make-up and character of the seafloor as well as its depth. These programs deal with a range of sensors (single beam, multibeam and sidescan sonars, lidar, video, etc.) and involve theoretical studies, the collection of remotely sensed data, and "ground-truth" samples.

Single beam sonar and Mapping and Characterization of Oyster Reefs: With additional funding from CICEET and Sea Grant, Semme Dijkstra is working in collaboration with scientists from the Jackson Estuarine Lab and the N.H. Dept. of Fish and Game, to explore the feasibility of using acoustic remote sensing techniques to map and monitor shellfish habitats. To date, several data sets, including single beam, multibeam and video data have been collected over local oyster reefs in Great Bay.

Semme has also been working closely with NOAA staff at the Olympic Coast National Marine Sanctuary in support of their efforts to monitor the effects of the emplacement of a fiber optic cable through the marine sanctuary.

In support of these and other seafloor characterization exercises, Dijkstra has continued the development of several software tools. The Lassoo tool is used for comparing multivariate data sets to imagery data sets in both geographic and multivariate feature space. It now supports various input data formats, visualization, active querying with text output, interactive selection of areas, and manual classification in both feature and geographic data spaces. All algorithms are now are geodetically correct and mouse coordinates are actively tracked.

Sidescan sonar: Lloyd Huff and Tianhang Hou are working with the Alaska Fisheries Science Center of NOAA/NMFS on a major Klein 5000 sidescan sonar survey in the East Bering Sea. A description of the sonar processing techniques developed to identify trawl marks was described in the sonar processing discussion above. Once the records have been corrected, an automated classification technique, developed by Rzhanov and Hou is being applied. In this technique the surveyed area is divided into small squares (typically 20 x 20 m). For each square the mean backscatter-vs-beamnumber "signature" is calculated. After application of corrections, a Chebyshev polynomial is fitted to the signature, and the polynomial coefficients are used as data vector for the clustering algorithm. When the clustering is performed, the mean signature for each cluster is calculated and then fed into an optimization algorithm for inversion for the seafloor property parameters. This technology development has the potential for a variety of sonar processing applications.

Multibeam and interferometric sonars: We have made substantial progress in developing approaches to multibeam classification on a number of fronts. These developments have been made using the EM1000, 1002 and EM3000 data collected in support of the ONR- and USGS-sponsored programs as well multibeam sonar data collected by NOAA and others in Portsmouth Harbor as part of the Shallow Water Survey 2001 “Common Data Set”. With the availability of these data sets, much of our recent effort in terms of seafloor characterization has focused on the enhancing our ability to extract quantitative information from our sonars (through better processing and modeling) and improving our ground-truthing abilities.

A new approach to seafloor characterization based on the automated segmentation of multibeam sonar bathymetric data into regions of common geomorphology has been implemented by Randy Cutter and Yuri Rzhanov. The technique uses texture-based segmentation techniques (local Fourier transforms and local Fourier histograms (LFH)). The technique is fully automated, except for the choice of the number of classes produced by cluster analysis of LFH results. The technique, which appears to be quite robust and repeatable, has been applied to several of the Portsmouth Harbor data sets as well as regions of the well-studied Stellwagen National Marine Sanctuary. The LFH appears to separate the morphology into regions that have significance in terms of the habitat of several species. In support of these studies as Cutter is developing innovative approaches to ground-truthing the sonar with samples and video data. These will be discussed more below.

If we are to use sonar backscatter data to correctly characterize seafloor properties, we want the backscatter that we measure to represent changes in the seafloor rather than instrumental changes or changes in the geometry of insonification. While many system and geometric corrections are applied by the manufacturers in their data collection process, a very important parameter – correction for local slope – is not. We have thus embarked on research effort aimed at using the detailed bathymetric data provided by multibeam sonar to calculate local incidence angles and correct backscatter for local slope. Once such corrections are made the resulting backscatter should be much more representative of true sea floor variability.

In order to better understand the relationship between remotely measured backscatter (with a sonar) and the physical properties of the seafloor, we have also

developed (with ONR funding) an instrument system designed to make *in situ* measurements of sound-speed, sound attenuation, and resistivity (along with video of the seafloor). Using these measurement as well as analyses of seafloor samples done by other investigators, TYCO Fellow Barbara Kraft has been exploring both the empirical and theoretical relationships between physical and acoustic properties and between these properties and backscatter. This theoretical and empirical work, feeds directly back into our attempts to interpret backscatter in terms of seafloor character or habitat.

Finally, Gareth Elston, with funding from USGS and ONR, has been looking at the waveform characteristic of LIDAR as a possible means for identifying seafloor properties. Gareth has analyzed data from Lake Tahoe, where we have both LIDAR and multibeam backscatter data and found a strong correlation between LIDAR waveform amplitude and multibeam backscatter level.

Video/photo image mosaicing and quantification: Yuri Rzhanov, Lloyd Huff and Randy Cutter have been quite active in the collection of seafloor video data as well as in developing sophisticated algorithms for processing these data. The team has developed a means of remotely controlling a digital camcorder and of recording positional information from a GPS and an attitude sensor on the audio track of the video tape to provide fully georeferenced video imagery that can then be digitally mosaiced. Further developments to acquisition algorithms have been implemented resulting improved corrections for perspective distortion and more rapid mosaic formation. Camera calibration has been thoroughly tested and demonstrated to provide a 30% improvement in mosaic quality. New software has been written to allow use of Firewire technology and Windows 2000. A new approach to deriving camera path and attitude from the sequence of transforms used to make the mosaic has been developed. This technique may lead to a means of extracting 3-D feature shape from the video imagery.

Cutter has demonstrated the applicability of Rzhanov's mosaicing algorithms to both seafloor video and "continuous profiling camera" video (a camera that collects video of a side view of the sediment water interface), and Mayer and Cutter have demonstrated the feasibility of texture mapping video mosaics over high-resolution 3-D multibeam bathymetry. Cutter has analyzed these mosaics for habitat features as well as developed automated techniques for segmentation and classification based on feature shapes, size and color. These techniques have been used to produce counts and abundance estimates of biogeoacoustic features. Cutter has also applied these techniques to a "lobster corral" area in the Piscataqua River to derive an automatic means of counting and identifying individual targets in the video. Rzhanov and Mayer are also looking at the applicability of using detailed image correlation techniques (dynamic space warping) as a means of generating ultra-precise positioning for sonar data and thus increasing the resolution achievable.

Huff and Cutter have worked with researchers from the Jackson Lab and completed the construction and testing of a robust, towed, video camera system that has already provided useful ground-truth data for Cutter's habitat mapping work. Finally, Huff has begun the development of a "swath video" system – a video system designed to collect continuous-coverage swath-like data from a surface vessel in shallow water.

Data Mining, Blending and Fusion:

The last of our original research themes is aimed at developing robust approaches to combining historical bathymetric data sets of varying quality and to tracking uncertainty in bathymetric data sets. To develop this approach the Arctic Ocean bathymetry database used by Jakobsson to generate the recently published International Bathymetric Chart of the Arctic Ocean, (IBCAO) was used. The details of this approach were described in earlier progress reports; a paper describing the technique has been published in The Journal of Geophysical Research.

Jakobbson has also applied the same approach to a more controlled, local database collected in Great Bay. As part of a CICEET project in which the Center is involved (see below), we have compiled all soundings collected over the last 100 years in Great Bay New Hampshire. Working with Armstrong, Alexander and Leo, Jakobbson has combined data sets from 1913, 1953 and 1954 into a single database and, after tracking the uncertainty associated with each data set, has concluded that real changes in the estuary channels can be seen. We have also produced a new, much more realistic, composite bathymetric chart of Great Bay that will be used for modeling flow and sediment transport within the estuary.

NEW PROJECTS:

The Center tries to be as responsive as possible to national needs and thus we begin new projects that go beyond the scope of our initial themes as the need demands. Several of these new efforts are currently underway:

Arctic Ocean bathymetry and Law of the Sea Issues:

Growing recognition that implementation of United Nations Convention on the Law of the Sea Article 76 could confer jurisdiction and management authority over large (and potentially resource-rich) areas of the seabed beyond our current 200 nautical mile (nmi) limit has renewed interest in the potential for a U.S. claim. In this context, Congress (through NOAA) funded University of New Hampshire's Joint Hydrographic Center to evaluate the content and completeness of the nation's bathymetric and geophysical data holdings in areas surrounding the nation's EEZ with emphasis on assuring their usefulness for substantiating the extension of resource or other national jurisdictions beyond the present 200 nmi limit. The initial portion of this complex study was carried out in less than 6 months and a report submitted to Congress on 31 May 2002 (http://www.ccom.unh.edu/unclos).

Working in collaboration with NOAA's National Geophysical Data Center, The U.S. Geological Survey and several consultants, the JHC collected and assembled all available relevant data, attributed it for error (using techniques developed at the Center) and put it into a sophisticated database and Geographic Information System (GIS) for analysis. This database is one of the most efficient of its kind and will be useful for a number of tasks beyond the Law of the Sea project. Using these tools we chose areas surrounding the U.S. where there is **potential** for a claim of an extended continental shelf under Article 76. Areas identified for detailed study included most of the U.S. east coast, the Gulf of Mexico, the Alaskan margin, the Arctic margin, and the areas around Guam and Palmyra Atoll. Each area was analyzed to determine the critical data sets required to

make a claim for an extended continental shelf under Article 76 (e.g., the 2500 m isobath, the foot of the slope, or the point where the sediment thickness is 1 percent of the distance back to the foot of the slope). In the course of this study we demonstrated that the collection of modern multibeam sonar data in certain regions can enhance a claim made by the U.S. and recommended a number of regions where new multibeam sonar data should be collected. We also suggested a research program aimed at developing interactive 3-D approaches for analyzing multibeam data in order to optimize a potential claim under Article 76.

In support of our Law of the Sea efforts, Martin Jakobsson has continued to update and support the International Chart of the Arctic Ocean (IBCAO). The Arctic is by far, our least explored ocean and thus the area where making a claim under UNCLOS Article 76 will be most difficult due to lack of bathymetric data. In this light we have also proposed to (and been funded by) the Ocean Exploration Program for a cruise on the icebeaker HEALY to the Chukchi Cap in order to explore the feasibility of collecting high-quality multibeam sonar data in ice-covered regions.

Shallow Water Survey 2001

In late September of 2001, the Center hosted **The Second International Conference on High Resolution Surveys in Shallow Water**, held at the Sheraton in Portsmouth. The meeting was a remarkable success attracting more than 225 participants representing at least 12 nations, 16 government agencies, and 52 companies. Fifty-four papers were presented, ten of them by members of the Center. Not only was the conference itself a success, but the data collected in support of the conference has been, and will be, invaluable to the community and to the growth of the Center. The concept of the Shallow Water Surveying conferences is that a "common data set" is collected well before the conference and then distributed to the international community. This presented a tremendous opportunity for the Center to "get its feet wet" and become directly involved with the collection and processing of a major data set. Thanks to the tremendous cooperation of NOAA's Office of Coast Survey the NOAA Ship *Whiting* to come to Portsmouth Harbor and collect multibeam and sidescan sonar data in early November 2000. NOAA also collected aerial photographs of the New Hampshire and Maine coasts and a NOAA tide station in Portsmouth Harbor was re-established to support the *Whiting* survey and future work.

The NOAA surveys generated a spectacular bathymetric and sidescan data set of Portsmouth Harbor as well as the opportunity for Center personnel to meet the NOAA survey teams and work hand-in-hand with them on the collection and processing of data. As a result of these interactions many ideas were generated and exchanged that will inevitably improve the NOAA data collection and processing flow. Following the NOAA surveys, at least 16 more data sets were collected in Portsmouth Harbor:

- Reson 8101 data collected by NOAA
- Klein 5000 sidescan sonar data collected by NOAA
- Submetrix interfermetric sidescan data collected by the USGS Woods Hole
- Navitronix sweep data collected by the Dept. of Public Works Canada
- Simrad dual head EM3000 data collected by Simrad
- Reson 8125 dual head and 8128 forward looking data collected by SAIC
- Triton-Elics 200 kHz multibeam data collected by Triton Elics

- Geoacoustics 125 and 250 kHz interferometric sidescan data collected by Geoacoustics
- Simrad EM3000 data collected by Simrad
- Odom Echoscan data collected by Odom
- Atlas Fansweep 20 data collected by Odom
- Elac 1180 data collected by Seabeam L3
- Reson 9001 data collected by the Army Corps of Engineers
- EdgeTech MPX multifrequency sidescan data collected by EdgeTech
- IKONOS satellite imagery provided by Space Imaging
- SHOALS LIDAR data collected by the Army Corps of Engineers
- Video mosaic data collected by CCOM
- A core sample database collected by the Jackson Marine Lab

With the exception of the NOAA, USGS, DPW, ODOM and ACoE surveys, all of the other sonar data was collected from our new survey vessel *Coastal Surveyor* operated by either Capt. Armstrong or Lt. Smith.

The data set collected in Portsmouth Harbor is unprecedented, representing the imaging of Portsmouth Harbor with virtually all high-resolution sonar systems in existence. In the summer of 2002, a number of follow up surveys were conducted, adding to the "common data set". More surveys are planned over the next few months and given the wealth of data already available in Portsmouth Harbor, it will continue to be a focal point for system inter-comparisons for years to come. The data collected in Portsmouth Harbor has also become a major focal point for UNH/JHC research projects. For example, Randy Cutter is analyzing sonar bathymetry and imagery from Portsmouth Harbor with the hope of extracting estimates of roughness and seafloor type that can then be compared to video mosaics and other habitat metrics. Lloyd Huff is using a remarkable time series of high resolution sidescan records collected over a sand wave field in Portsmouth Harbor (acquired over the last three years by Klein Associates during pre-delivery check-out cruises of their Model 5000 sonar system) to look at the migration of the bedforms and seafloor dynamics. We have also been able to leverage the Portsmouth Harbor data to access new ONR funds for a detailed study of the relationship between backscatter and seafloor properties.

Mapping of D-Day Beaches:

In collaboration with the Naval Historical Center (NHC), and Reson Inc., Mayer and Calder participated in an effort to explore the state of preservation and impact on the surrounding environment of a series of wrecks located off the coast of Normandy, France, adjacent to the American landing sectors. The survey augmented previously collected magnetometer and high-resolution sidescan sonar data using a Reson 8125 high-resolution focused multibeam sonar with 240, 0.5° (at nadir) beams distributed over a 120° swath. The team investigated 21 areas in water depths ranging from about three - to 30 meters (m); some areas contained individual targets such as landing craft, barges, a destroyer, troop carrier, etc., while others contained multiple smaller targets such as tanks and trucks. Of particular interest were the well-preserved caissons and blockships of the artificial Mulberry Harbor deployed off Omaha Beach. The near-field beam-forming

capability of the Reson 8125 combined with 3-D visualization techniques provided an unprecedented level of detail including the ability to recognize individual components of the wrecks (ramps, gun turrets, hatches, etc.), the state of preservation of the wrecks, and the impact of the wrecks on the surrounding seafloor

Ancillary Programs:

One of the goals of the JHC is, through its partner organization, the Center for Coastal and Ocean Mapping, to establish collaborative arrangements with private sector and other government organizations. We have already established liaisons with the private sector including Tyco, Klein Associates, C&C Technologies, AUSI, Interactive Visualization Systems, Triton-Elics, Reson and ODOM. Our involvement with Tyco has been instrumental in the University securing a 5 million dollar endowment; 1 million dollars of this endowment has been earmarked for support of post-doctoral fellows at the Center for Coastal and Ocean Mapping. Our interaction with the private sector has now been formalized into an Industrial Associates Program. At present members of the Industrial Associates Program are:

C&C Technologies
CARIS Inc.
Interactive Visualization Systems Inc.
Klein Associates
Kongsberg Simrad
ODOM
SAIC
SevenC's
Triton-Elics
Tyco

In addition, grants are already in place with the Office of Naval Research, The Naval Research Lab, The National Science Foundation, CICEET and the U.S. Geological Survey (see Appendix D). The USGS supports collaborative projects involving multibeam sonar mapping as well as a post-doctoral fellow at the Center (in addition to their seconding a senior scientist to the Center. Total funding from non-NOAA grant sources this past year is on the order of $2M.

Appendix A:
Coastal Surveyor

R/V Coastal Surveyor - The Coastal Surveyor is a purpose built vessel designed specifically for coastal multibeam hydrography. It is integrated with a robust, motor-driven ram system that provides and ideal mount for a range of multibeam and other sonar systems. The vessel incorporates an active roll stabilization feature to limit vessel motions detrimental to multibeam operations.

Dimensions:	40’ x 12’ x 3.7’
USCG:	Designated Research Vessel, subchapter “C”
Flag:	U.S.
Registry:	U.S. Coastwise and Registry
Official Number:	999206
Tonnage:	16 GRT
	11 DWT
Lab space:	9’ x 11’
	6’ x 10’
Speed:	10 knots
Minimum speed for full roll stabilization:	5 knots
Minimum survey speed:	2.5 knots
Propulsion:	1 x Cat 3116; 205 shp cont.”A”; 2.57:1 reduction
Auxiliary:	1 x Isuzu/Lima 20 kw; 240/120 V; 60 Hz;
Power distribution:	38 ea. 115 volt receptacles
	2 ea. 230 volt receptacles
	1 ea. 12 volt receptacles
	7 ea. 24 volt receptacles
Fuel capacity:	400 gallons
Potable water:	60 U.S. gallons
Roll stabilization:	Niad 173 active fins
Loran:	Micrologic Mariner
DGPS:	Magellan 1200XL GPS w/ Magellan 19019 DBR
Magnetic compass:	Ritchie 5”
Fluxgate compass:	Robertson RFC 300
Radar:	Furuno 1930
Depth sounder:	Standard DS 50
Autopilot:	Robertson AP 300DL
VHF:	Standard Omni 25 watt
Side Band:	Sea 222
Cellular phone:	Motorola 5 watt
Air conditioning:	3 x 1.25 tons
Heating:	3 x 16,000 BTU

Weather Tolerance:

Multibeam:	Beaufort 6; SS3
Sidescan:	Beaufort 5; SS2

Work completed on the COASTAL SURVEYOR this season included:

Stripped aged nonskid matting from outside surfaces and replaced it with non-skid impregnated epoxy and paint

Replaced malfunctioning conventional (sanitary) head with vacuum head Repaired holding tank and installed pump-out fitting

Rebuilt prop-shaft strutt and replaced cutlass bearing

Replaced worn and missing fixed fenders

Ran diagnositics and tuned up main engine (Catapillar)

Removed excess wiring
Replace tackle and pendant of mooring at Jackson Lab

Installed KVH gyro-fluxgate compass

Installed buffered multiplexor for distributing data from GPS Receivers

Completed connection between survey data resources and ships autopilot

Improved dual control of ship's computer so that it can be operated both in the lab and at the helm

Built transducer mounts for single beam and multibean

Improved automatic bilge pump switches and sensors

Completed vessel documentation and licensing

APPENDIX B:
Graduate Degrees in Ocean Mapping

The University of New Hampshire offers Ocean Mapping options on the Master of Science and Doctor of Philosophy degrees in Ocean Engineering and in Earth Sciences. These interdisciplinary degree programs are provided through the Center and the respective academic departments of the College of Engineering and Physical Sciences. The University has been awarded recognition as a *Category A* hydrographic education program by the International Federation of Surveyors (FIG)/International Hydrographic Organization (IHO).

Requirements for the Ph.D. in Earth Sciences and Engineering are described in the respective
sections of the UNH Graduate School catalog. M.S. degree requirements are described below.

Requirements for Master of Science in Ocean Engineering
Ocean Mapping Option

Core Requirements:	*Credit hours*
ESCI 858, Physical Oceanography	3
OE 990, 991, Ocean Engineering Seminar I, II	2
OE 810, Ocean Measurements Lab	4
OE 885, Underwater Acoustics	4
OE/ESCI 870 Introductory Hydrography	4
OE/ESCI 871 Geodesy and Geomatics	3
OE/ESCI 972, Hydrographic Field Course	4
Thesis - in addition to required coursework	6
At least 6 additional credits from the electives below:	
OE 854, Ocean Waves and Tides	4
ESCI 859, Geological Oceanography	4
ESCI 959, Data Analysis Methods in Ocean and Earth Sciences	4
OE 954, Ocean Waves and Tides II	4
OE/EE 985, Special Topic (Sonar Signal and Image Processing)	3
ESCI 907, Geostatistics	3
OE/ESCI 973, Seafloor Characterization	3
OE/CS 895, Special Topic (Interactive Data Visualization)	3
EOS 824, Introduction to Ocean Remote Sensing	3
NR 857, Photo Interpretation and Photogrammetry	4
NR 860 Geographic Information Systems in Natural Resources	4
OE 995, Graduate Special Topics	2 - 4

OE 998, Independent Study 1 - 4
Other related courses with approval

Where a course of equivalent content has been successfully completed as an undergraduate, an approved elective may be substituted.

Requirements for Master of Science in Earth Sciences
Ocean Mapping option

Required:	*Credit Hours*
ESCI 858, Introductory Physical Oceanography	3
ESCI 859, Geological Oceanography	4
OE 810, Ocean Measurements Laboratory	4
ESCI/OE 870, Introductory Hydrography	3
ESCI/OE 871, Geodesy and Geomatics	3
ESCI /OE 972, Hydrographic Field Course	4
ESCI 997, 998, Seminar in Earth Sciences	1-2
Thesis - in addition to required coursework	6
At least 6 additional credits from the electives below:	
ESCI 907, Geostatistics	3
ESCI 8yy, Seafloor Characterization	4
EOS 854, Ocean Waves and Tides	4
OE 885, Underwater Acoustics	4
OE/CS 895, Special Topic (Interactive Data Visualization)	3
OE/EE 995, Special Topic (Sonar Signal and Image Processing)	3
NR 857, Photo Interpretation and Photogrammetry	4
NR 860, Geographic Information Systems in Natural Resources	4
ESCI 8??, Nearshore Processes	3 or 4
EOS 824, Introduction to Ocean Remote Sensing	3
ESCI 895, 896, Topics in Earth Sciences	1 - 4
ESCI 959, Data Analysis Methods in Ocean and Earth Sciences	4
ESCI 996, Advanced Topics in Earth Sciences	1 - 4

Where a course of equivalent content has been successfully completed as an undergraduate, an approved elective may be substituted.

Specific Coursework Required to Complete FIG/IHO Category A Certified Program
(Either Degree Option)

University Academic Courses:	*Credit Hours*
ESCI 858, Introductory Physical Oceanography	3
ESCI 859, Geological Oceanography	4
OE 990, 991, Ocean Engineering Seminar I, II	2
OE 810, Ocean Measurements Lab	4
OE/ESCI 870 Introductory Hydrography	3
OE/ESCI 871 Geodesy and Geomatics	3
OE/ESCI 972, Hydrographic Field Course	4

Non-credit classes:	*Classroom Hours*
CARIS HIPS-SIPS Training Course	40
U.S. Power Squadrons/Joint Hydrographic Center Seamanship Class*	20

*For students who have not completed NOAA (or equivalent national service) Officer Training Class

Appendix C:
Field Programs

R/V Genesis, Normandy, France, 2002 (USNHC D-Day Project) NOAA Ship RAINIER, South Twin Bay and Valdez Narrows, AK, 2002 (Calder).

Gulf of Mexico 2002 USGS Cooperative Mapping, R/V Moana Wave (Calder, Gardner).

Mine Burial Program, Martha's Vineyard Coastal Observatory, R/V Cape Henlopen, August 2002 (Kraft).

ECDIS-AIS: Display Trials, St. Lawrence Seaway /St. Lambert Lock, Montreal/Port Colburne/ Welland Canal, September –November 2002 (Alexander).

OCNMS, 3-21 July 2002R/V Tatoosh Wave, Habitat Mapping (Dijkstra).

APPENDIX D:
Other Funding

Grant	PI	Grantor	FY Award	Total Award	Length
Geoclutter Program	L. Mayer	ONR	$330,434.00	$450,478.00	4 years
Uncertainty	L. Mayer	ONR	$178,264.00	$178,264.00	2 years
Collaborative High Resolution Mapping	L. Mayer	USGS	$1,407,205.00	$4,693,730.00	5 years
Mine Burial/Coastal Program Thru Web-Site	L. Mayer	ONR	$117,633.00	$128,572.00	3 years
ONR Mine Burial Proposal for FY02 & FY03	L. Mayer	ONR	$229,579.00	$339,840.00	3 years
Surveying Midwater Fish	L. Mayer & K. Baldwin	NSF	$342,946.00	$342,946.00	3 years
Multi-Scale Interaction w/3D Data Environment	C. Ware & L. Mayer	NSF	$446,844.00	$499,152.00	3 years
Alaska Fjords	L. Mayer	NSF	$57,471.00	$57,471.00	3 years
Seacoast Science Center	C. Ware & L. Mayer	SSC	$45,468.00	$45,468.00	
Multibeam Swath Bathymetry	C. de Moustier	SCRIPPS	$20,088.00	$40,314.00	2 years
Score Acoustic Survey Data Processing	C. de Moustier	SCRIPPS	$25,100.00	$25,100.00	1 year
TYCO Endowment interest from perpetuity	N/A	TYCO		$23,148.00	Perpetuity
Electronic Charting for Naval Operations	A. Alexander	NAVOCEANO	$16,000.00	$63,800.00	3 years
St. Lawrence Seaway AIS-ECDIS	A. Alexander	DOT	$10,000.00	$20,000.00	2 years
Inland Waterways for Electronic Charting	A. Alexander	USACE	$38,300.00	$71,400.00	2 years
Electronic Chart for OCS-NOAA	A. Alexander	OCS-NOAA	$50,600.00	$50,600.00	1 year
ECDIS Laboratory for Naval Operations	A. Alexander	University of Miss.	$55,000.00	$70,600.00	3 years

APPENDIX E: Visitors July 2002-December 2002

Amend	2002	NOAA Fishiers, Danta Cruz	Y. Rzhanov	Software for Laser Line Scan Processing
Brian Smith	2002	New Hampshire Fish and Game	S. Dijkstra	Discussions
Jorgen Eeg	8/3	Royal Danish Administration for Hydrography	B. Calder	Discussion and Implementation of CUBE
Goran Alm	11/28-1/31	Stockholm University	M. Jakobsson	Vertical Datrum
Peter Simpkin	8/2	IKB Technologies Limited	B. Kraft	Prepare for upcoming ONR Mine Burial Program, Martha's Vineyard (using Geoclutter probe)
Wendy Lull	8/8	Seacoast Science Center	JHC/CCOM	Coastal Surveyor cruise on River re Exhibit project
Tracey Frederick	8/8	Seacoast Science Center	JHC/CCOM	Coastal Surveyor cruise on River re Exhibit project
Michelle Wensman	8/8	Seacoast Science Center	JHC/CCOM	Coastal Surveyor cruise on River re Exhibit project
Jeff Proehl, Keston Smith Ata Bilgili	8/15	Dartmouth	C. Ware	Watch animation(s) of Great Bay 30000+ particle path data from the Dartmouth Sea Grant
John Hughes & C. Beaudoin	9/10-9/12	University of New Brunswick	J. Gardner	Work on Gulf of Mexico MBEC data
Quentin Huggett	9/20-9/21	Geotek	J. Gardner	Work on Gulf of Mexico
David Laidlaw	10/11	NSF Science and Technology Center for Computer Graphics and Visualization Brown University	C. Ware	Visual Toolsmithing: Evaluating Interdisciplinary Scientific
John Littlewood, Mike Donavon, Susan Harris & Dick Boyd	10/14	US Navy	Y. Rzhanov	Meeting Navy Video Processing
Megan Tyrrel	10/25	MA Coastal Zone Management	S. Dijkstra	Discussion: Benthic Habitat Mapping in MA
Greg Schmidt	10/31	ITT/NRL Washington, D.C.	C. Ware	Visualizing Battlespace Uncertainty
Ben Ramondi & Kendall Ferguson	10/29-11/1	XYZ s of GPS, Dickerson, MD	L. Huff & G. Glang	RTK GPS test on R/V Coastal Surveyor w/Iridium
Sam DeBow	11/8-11/9	NOAA	CCOM/JHC S. Smith & B. Calder	Update research, CUBE/Nav Surface
Capt. Nick Perugini	11/14	NOAA	CCOM	Shep Smith's Proposal/seminar/discussions
Mike Brown	11/14	NOAA	CCOM	Shep Smith's Proposal/seminar/discussions
Lindsay Gee	11/14-11/15	IVS	CCOM	Fledermaus Training
Dan Donnell	11/14-11/15	IVS	CCOM	Fledermaus Training
Alejo Hausner	11/15	UNH Computer Science Department	C. Ware	Dithering Random Points
Steve Intelmann	11/14-11/18	Olympic National Marine Sanctuary	S. Dijkstra	Discussions
Chris Casagrande	11/18	Sea Sciences, Inc.	L. Huff	Discuss Upgrade of the SSI Acrobat for towed video
Brad Barr	11/19	NOAA	CCOM	Mapping for Marine Sanctuaries Meeting
Ron Schaaf	11/20	TEI	Y. Rzhanov L. Huff	Video Mosaicing
Jonathan Howell, Pete Adamovich	11/20	US Navy	Y. Rzhanov	Video Mosaicing
Steve Schmidt	11/25	US Navy Historical Center	L.Mayer, B.Calder & Y.Rzhanov	Discuss Normandy Mapping, Video Mosaicing
Karl Kieninger Erick Hammerstad Terge Pedersen	11/26	Kongsberg Simrad	CCOM	Consortium discussions
Richard Byrd Steve Apsey	12/4	Odom Hydrographic	CCOM/JHC	Demo Echo-sounder Software & tour CCOM/JHC
Gert Buttgenbach Dan Pillich Bohdan Pillich	12/10-12/11	Seven C's Hamburg, Germany	L. Alexander	Discussions
Tom Reis	12/12	Substructure Diving & Marine Construction	L. Mayer/CCOM	Discussions
Steve Wolf	12/13	ENSR International	L. Mayer	Discussions
Ken Hinckley	12/19	Microsoft Research	C. Ware	Experiences & Techniques for Ubiquitous Sensors

Appendix F:
Papers, Reports, Abstracts and Talks
From July 2002 to December 2002

Publications:

Bacon, C.R., Gardner, J.V., Mayer, L.A., and Buktenica, M., Dartnell, P., Ramsey, D.W., and Robinson, J.E., 2002, Morphology, volcanism, and mass wasting in Crater Lake, Oregon, Geol. Soc. AM., Bull., V.114, no. 6., p. 675-692.

Bowditch, N., 2002,The American Practical Navigator, Pub. No. 9. (Alexander, L. author for chapter 14 – Electronic Charts). National Imaging and Mapping Agency, Bethesda, MD.

Calder, B.R., and Smith, S.M., A Comparison of the Automated Navigation Surface to Traditional Smooth Sheet Compilation. Proc. Canadian Hydro. Conf. 2002. Toronto, Canada, May 2002.

de Moustier, C. and Gallaudet, T.C., 2002, Detection of sonar induced measurement uncertainties in environmental sensing: a case study with the toroidal volume search sonar, in Impact of Environmental Variability on Acoustic Predictions and Sonar Performance, N.G. Pace and F.B. Jensen Eds, Kluwer A.P., 571-577.

Hecht, H., B. Berking, G. Buttgenbach, Jonas, M. and Alexander, L., 2002, The Electronic Chart*:* A Revolution in Marine Navigation, GITC Publishing Lemmer, The Netherlands.

Hovland, M., Gardner, J.V., and Judd, A.G., 2002, the significance of pockmarks
Irani, P. and Ware, C., (in press) Diagramming Information Structures using 3D Perceptual Primitives. ACM Transactions on CHI. ACM Press.

Jakobsson, M., Backman, J., Murray, A., and Løvlie, R., in press, Optically Stimulated Luminescence Dating Supports Central Arctic Ocean cm-scale Sedimentation Rates, Geochemistry Geophysics Geosystems.

Jakobsson, M., Grantz, A., Kristoffersen, Y., and Macnab, R., in press, Physiographic Provinces of the Arctic Ocean, GSA Bulletin.

Jakobsson, Calder, B.R., and Mayer, L.A., On the Effect of Random Errors in Gridded Bathymetric Compilations, J Geophys. Res. B (Solid Earth), 107(B12), p .ETG 14-1 – 14-11, 2002.

Kraft, B. J., Mayer, L. A., Simpkin, P. G., and Goff, J. A., 2002, "Comparison of in-situ compressional wave speed and attenuation measurements to Biot-Stoll model predictions," J. Acoust. Soc. Am. 112, p. 2254.

Laramee R., and Ware, C., 2002, Rivalry and Interference with a Head Mounted Display. ACM Transactions on CHI. 9(3) 1-14.

Mayer, L.A., Calder, B.R., Schmidt, J., and Malzone, C., Providing the Third Dimension: High-Resolution Multibeam Sonar as a Tool for Archaeological Investigations – an Example from the D-day Beaches of Normandy. Proc. US Hydro Conf., Biloxi, MS, 2003.

Plumlee, M. and Ware, C., 2002, Frame of Reference Interaction. User Interface Software Technology Demonstration UIST 2002 Companion, Paris, p. 41-42.

Smith, S.M., Alexander, L., and Armstrong, A.A., 2002, "The Navigation Surface: A New Database Approach to Creating Multiple Products from High-Density Surveys", International Hydrographic Review, vol. 3, no. 2, p. 12-16.
Soc. Amer., v. 114, p. 675-692.

Sternlicht, D.S., and de Moustier, C., 2002, "Near bottom sediment characterization offshore SW San Clemente Island"Proc. MTS-IEEE Oceans 2002, p. 2086-2092.

Ware, C. And Plumlee, M., 2002, 3D GeoVisualization and Structure of Visual Space.

Ware, C. and Plumlee, M., GeoVisualization Workshop. London, September. This paper is to be published as a book chapter.

Ware, C., (in press) Design as Applied Perception. In HCI Models, Theories and Frameworks. J Carroll Ed. Morgan Kaufman.

Ware, C., Purchase, H., Colpoys, L. and McGill, M., 2002, Cognitive Measurements of Graph Aesthetics. Information Visualization. v. 1, p.103-110.

Conference Proceedings:

Alexander, L and Darrell M. Smith. (2002) Warship ECDIS and Additional Military Layers (AMLs), Proceedings: MTS/IEE Oceans 2002, Biloxi, MS, 29-31 October 2002.

Alexander, L. (2002) NATO Warship ECDIS and Additional Military Layers (AMLs), Proceedings: CARIS 2002, Norfolk, VA, 2-4 September 2002.

Arsenault. R. and Ware, C. (2002) Frustum Angle View angle and Virtual Environment Navigation. SVR'02, Fortaleza, Brazil. September.

Gardner, J.V., (2002), UC Santa Cruz Marine Sciences Seminar: A reappraisal of deep-water reefs along the NW Florida outer continental shelf October.

Gardner, J.V., (2002), University of Sydney (Australia) Marine Seminar: Deep-water "reefs" of the northern Gulf of Mexico. August.

Rzhanov, Y., Huff, L., and Cutter, G.R., (2002), Seafloor video mapping: modeling, algorithms, apparatus, International Conference on Image Processing (ICIP'02) Rochester, New York, USA, September.

Rzhanov, Y., Huff, L., and Cutter, G.R., (2002), Underwater Video Survey: Planning and Data Processing, International Conference on Signal and Image Processing (SIP 2002).

Rzhanov, Y., Huff, L., Cutter, G.R., and Mayer, L., (2002), Sensor-assisted Video Mapping of the Seafloor, OCEANS 2002 Biloxi, Mississippi, USA, October.

Abstracts:

Alm, G., Macnab, R., Jakobsson, M., Kleman, J., and McCracken, M., 2002, An Integrated Bathymetric and Topographic Digital Terrain Model of the Canadian Arctic Archipelago, EOS Transactions, American Geophysical Union v. 83(47), Abstract G52A-0978.

Backman, J., Jakobsson, M., Løvlie, R., and Polyak, L., 2002, Rates of Sedimentation in the Central Arctic Ocean, EOS Transactions, American Geophysical Union, v. 83(47), Abstract GP71A-0986.

Calder, B.R., Fonseca, L. and Francolin, J.B., Automatic Estimation of the Seafloor Geomorphology of the Santos Basin, Brasil. EOS. Trans. AGU, 83(47), Fall Meet. Suppl., Abstract OS71C-0301, 2002.

Dijkstra, S., and Grizzle, R., Automated Interpretation of Sidescan and Single-Beam Sonar for Characterization and Mapping the Extent of Subtidal Oyster Reefs. 2002 National Shellfisheries Association Meeting, Mystic, CT, USA

Dijkstra, S., and Intelmann, S., Mapping Benthic Habitat at Various scales in the Olympic National Marine Sanctuary, WA. NSA Annual Meeting, New Orleans, LA 2003

Elston, G.R. and Gardner, J.V., 2002, Lake Tahoe bottom characteristics extracted from SHOALS lidar waveform data and compared to backscatter data from a multibeam echo sounder. Eos Trans. American Geophysical Union Suppl, abstract, v. 83.

Gardner, J.V., 2002, The seafloor off greater Los Angeles: Visualizing gigabytes of data. Eos Trans. American Geophysical Union Suppl, abstract, v. 83.

Gee, L., Reed, B., and Mayer, L. A., Interactive 3D Visualization: An Important Element in Dealing with Increasing Data Volumes and Decreasing Resources, EOS Trans. AGU, 83 (47), Fall Meet. Suppl., Abstract U52-04, 2002

Gelfenbaum, G., Gardner, J.V., et al, 2002, Assessing damage on the major submarine deltas of southern Puget Sound after the 2001 Nisqually earthquake using high-resolution seafloor multibeam mapping. Geol. Soc. Amer. Abstracts with Programs v. 34, no. 5.

Goff, J. A., Mayer, L. A., Schwab, B., Traykovski, P., Wilkins, R., Jenkins, C., Kraft, B. J., Evans, R., and Buynevich, I., 2002, Site survey of the Martha's Vineyard Coastal Observatory: Backscatter, Grain Size and Temporal Evolution of Rippled Scour Depressions, EOS Trans. AGU, *83*(47), Abstract OS61A-0181.

Jakobsson, M., 2002, Dynamic 3D-visualization of merged geophysical and geological data sets from the Arctic, EOS Transactions, American Geophysical Union, v. 83(47), Abstract OS12B-0275. AGU Fall Meeting in San Francisco, CA.

Jakobsson, M., 2002, Dynamic 3D-visualization of merged geophysical and geological data sets from the Arctic, EOS Transactions, American Geophysical Union, v. 83(47), Abstract OS12B-0275.

Jakobsson, M., Grantz, A., Kristoffersen, Y., and Macnab, R., 2002, Arctic Ocean Physiography, EOS Transactions, American Geophysical Union, v. 83(47), Abstract U52A-06.

Kent, G., Driscoll, N., Gardner, J.V., 2002, Lake Tahoe's submerged record of active faulting is characteristic of the Basin and Range (abs.) Geol. Soc. America, Abstracts with Programs v. 33, no. 4.

Kraft, B. J., Mayer, L. A., Simpkin, P. G., Goff, J. A., Schwab, B., and Jenkins, C., In-situ measurement of geoacoustic sediment properties: an example from the ONR mine burial program, Martha's Vineyard Coastal Observatory, poster presented at the American Geophysical Union Meeting, December, 2002.

Kraft, B. J., Mayer, L. A., Simpkin, P. G., Goff, J. A., Schwab, B., and Jenkins, C., 2002,"In-situ measurement of geoacoustic sediment properties: an example from the ONR mine burial program, Martha's Vineyard Coastal Observatory," *EOS Trans. AGU, 83*(47), Abstract OS61A-0182.

Løvlie, R., Jakobsson, M., and Backman, J., Paleointensity confirms cm-scale sedimentation rates and suggests intervals with non-uniform deposition on the Lomonosov Ridge, central Arctic Ocean, EOS Transactions, American Geophysical Union, v. 83(47), Abstract GP71A-0973.

Lewis, C.F.M., Blasco, S.M., Forsyth, D.A., Mayer, L.A., Dijkstra, S., Jacobi, R.D., Todd, B.J., Coakley, J.P. and King, J.W., Do Quaternary sediments register paleoseismicity or neotectonic rejuvenation of ancient faults beneath Lake Ontario?

Mayer, L A Raymond, R., Glang, G., Huff, L., Resolving the Ripples (and a Mine): High-Resolution Multibeam Survey of Martha's Vineyard ONR Mine Burial Program Field Area, EOS Trans. AGU, 83 (47), Fall Meet. Suppl., Abstract OS61A-0183, 2002

Wells, D., Richer, J., Dare, P., Santos, M., Dijkstra, S., Wiesenburg, D., Dodd, D., Howden, S., Monahan, D., Adams, R., and Gay, D., Hydrographic Learning 24/7.

Reports:

Alexander, L. 2002. Distribution Options Based on WEND. Report to Caribbean – Gulf of Mexico Hydrographic Commission – Electronic Chart Working Group, October, p.18.

Beaudoin, J.D., Gardner, J.V, and Hughes Clarke, J.E., 2002, Bathymetry and acoustic backscatter of selected areas of the outer continental shelf, northwestern Gulf of Mexico. US Geological Survey Open-File Report 02-396, p.34.

Gardner, J.V., Dartnell, P., Stone, J.C., Mayer, L.A., and Hughes Clarke, J.E., 2002, Bathymetry and selected perspective views offshore greater Los Angeles, California. U.S. Geological Survey Water Resources Investigation Report 02-2146, 1 sheet, scale 1:40,000.

Gardner, J.V., Hughes Clarke, J.E., and Mayer, L.A., 2002, Bathymetry and acoustic backscatter of the mid and outer continental shelf, head of De Soto Canyon, Northeastern Gulf of Mexico. US Geological Survey Open-File Report 02-396, p.51.

Gardner, J.V. and Dartnell, P., 2002, Multibeam Mapping of the Los Angeles, California Margin. US Geological Survey Open-File Rept. (CD-ROM) OF02-162.

Gardner, J.V., Dartnell, P., Sulak, K.J., 2002, Multibeam Mapping of the west Florida shelf, Gulf of Mexico, U.S. Geological Survey Open-File Report OF02-5 (CD-ROM).

Gardner, J.V., Dartnell, P., and Sulak, K.J., 2002, Multibeam mapping of the Pinnacles Region, Gulf of Mexico, U.S. Geological Survey Open-File Report, OF02-6 (CD-ROM).

Gardner, J.V., Beaudoiin, J.D., and Dartnell, P., 2002, Multibeam mapping of selected areas of the outer continental shelf, northwestern Gulf of Mexico-data, images, and GIS. US Geological Survey Open-File Report 02-411.

Jakobsson, M., A prototype 1:6 Million map, 2002, In: Macnab, R., and Edwards, M. (eds), Bathymetry Mapping of the North Polar Seas, Workshop Report, University of Hawaii, p. 5-7.

Jakobsson, M., and Macnab, R., 3D-Visualization of IBCAO, 2002, In: Macnab, R., and Edwards, M. (eds), Bathymetry Mapping of the North Polar Seas, Workshop Report, University of Hawaii, p. 40-43.

Talks:

Alexander, L. "Electronic Charting/Mapping in Great Bay, NH". Seminar Presentation: Sandy Point Discovery Center, Greenland, NH, 17 July 2002.

Alexander, L. "Marine Information Objects and Other Uses for Hydrograhic Data?" Seminar Presentation: Hydrographic Science Program, Univ. S. Mississippi, Stennis Space Center, MS, 2 October 2002.

Arsenault, R., 2002 VizLunch: The Future of OpenGL, 31 July 2002.

Cutter Jr., G. R., Rzhanov, Y., Mayer, L. A. and Grizzle, R. E., Ground Truthing Benthic Habitat Characteristics Using Video Mosaic Images. Submitted to American Fisheries Society for Proceedings Volume from Symposium on the Effects of Fishing Activities on Benthic Habitats: Linking Geology, Biology, Socio-economics, and Management. Tampa, Florida, 12-14 Nov. 2002.

de Moustier, C., Mogk, S., Hock, M., and Spain, G. D., "Effects of bathymetric and oceanographic variations on short range high frequency acoustic propagation in shallow water", 144th meeting of the Acoustical Society of America, Cancun Mexico 2-6 December, 2002.

Elston, G., Lidar Waveform Analysis: spatial patterns in pulse peak-amplitude data. 3rd Annual Airborne Hydrography Workshop, San Francisco, CA, 9-11 July 2002.

Gardner, J.V. and Mayer, L.A., 2002, Benthic habitat mapping with advanced technologies and their application. Symposium on effects of fishing activities on benthic habitats: Linking geology, biology, socio-economics, and management, Tampa, Florida.

Jakobsson, M., A prototype 1:6 Million map, 2002, In: Macnab, R., and Edwards, M. (eds), Bathymetry Mapping of the North Polar Seas, Workshop Report, University of Hawaii, p. 5-7.

Jakobsson, M., About Arctic Bathymetry for the US Arctic Research Commission meeting at CRREL Data visualization at the workshop on Global Bathymetry for Oceanography, Geophysics, and Climatology held at Scripps.

Mayer, L. A., Mapping the U.S. EEZ: Presentation to the U.S. Commission on Ocean Policy, 22 July, 2002

Mayer, L.A., UNH Study of Status of Data in Support of U.S. Law of the Sea Claim, Law of the Sea Working Group, NOAA HQ, Bethesda MD, Sept. 9, 2002

Mayer, L.A., Feasibility and technical limitations in sonar detection of time-dependent seafloor topography, Seafloor Geodesy Workshop, Deep Ocean Exploration Institute, Woods Hole, MA. 11 October, 2002

Kraft, B. J., C-COM Seminar (same presentations as presented at the Acoustic Variability conference), November 2002.

Reid, J.A., Jenkins, C.J., Field, M.E., Zimmerman, M. Williams, S.J., Currence, J.M., Box, C.E., and Gardner, J.V., usSEABED: towards unifying knowledge of geological controls on benthic habitats. Symposium on effects of fishing activities on benthic habitats: Linking geology, biology, socio-economics, and management, Tampa, Florida, 2002.

Rzhanov, Y., VisLab/CCOM, Detection and cataloging moving objects in underwater video taken by unconstrained camera. 2002.

Ware, C., Designing for the structure of visual space. International Conference on Information Visualization. Opening Keynote Speaker**.** London SOAS. 10 July 2002.

Ware, C., Introduction to VisLab/CCOM and GeoZui3D. IRB Bremen. Center July 2002.

Ware, C., Introduction to VisLab/CCOM GeoZui3D. Mitsubishi Electric Research Center (MERL) August 2002.

Ware, C., The use of motion for information display. NIMA ARDA Workshop on Intelligence mapping requirements. Washington, 7-8 November.