Performance and Progress Report:
UNH/NOAA Joint Hydrographic Center

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Principal Investigator: Larry A. Mayer

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.

While funding for the Joint Hydrographic Center was approved from 1 July 1999, the majority of the JHC staff did not arrive on site until January 2000. Thus, this report highlights the activities of the Joint Hydrographic Center during its third six months of fully staffed operations.

ACCOMPLISHMENTS TO DATE:

Infrastructure:

Personnel:

The key to the success of the new center will be the skills and talents of the individuals that make it up. Thus the primary task in proposing the new center was to ensure that an appropriate team of people would be brought to the University of New Hampshire. This has been accomplished in that all positions outlined in the original Center proposal were filled by January 2000. Unfortunately, one of the new faculty members, Dr. Laurie Linnett was forced to return to his native Scotland in June 2000, due to a family crisis. As soon as we learned that Dr. Linnett could not return to New Hampshire, we received permission from the University to re-advertise the position. The search is now complete and we are most pleased to announce that the position will be filled in January by **Dr. Christian de Moustier**, one of the world's leading experts on multibeam sonars. Other staff changes include the departure of Laurent Hellequin with the completion of his post-doc and the addition of Research Scientist **Rick Komerska** to our Visualization Lab, **Barbara Kraft** as our new TYCO Fellow, and **Pam McLeod** as our Stratafrom GIS specialist. We have hired a number of students as hourly employees including **Steve Vitali** and **Eric Lynskey** and **John Ahern** and recently hired **Ben**

Smith to take responsibility for the day to day maintenance of our new survey vessel (see below). During this reporting period, our visiting scholar, Dr. Donald House of the Texas A&M University, will complete his sabbatical stay at UNH. A brief description of the Center faculty and staff follows:

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.

Jim Gardner is a senior marine geologist with the U.S. Geological Survey in charge of the Western Region's marine mapping program. He has 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 remain a USGS employee but will be seconded to the Center for several months per year.

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/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 two senior NOAA employees to the new Center. Both are also Adjunct Faculty members:

Capt. Andrew Armstrong, Co-Director of the JHC, Captain Armstrong is an officer in the National Ocean Atmospheric Administration Commissioned Corps. 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.

Dr. 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 is 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.

Other Affiliated Faculty:

Dave Wells: world-renown in hydrographic circles, Dave Wells is an expert in GPS and other aspects of positioning. Dave spends part time at the University of New Brunswick and part time at the University of Southern Mississippi where he is participating in their new hydrographic program. Dave will be helping UNH establish its 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 brings 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) is spending 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.

Research Scientists:

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.

Brian Calder with a recent Ph.D. in Computing and Electrical Engineering is a Research Scientist in the Center. 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.

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. Since 1996, he has worked at the Alfred Wegner Institute where he has been in charge of their multibeam sonar processing. He is an experienced CARIS user. His thesis work has 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.

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.

Laurent Helliquin joined the Center as a Research Scientist in the fall of 2000. He has a background in signal processing and recently received a Ph.D. in France where he worked with Xavier Lurton at IFREMER on multibeam sonar processing and seafloor characterization. Laurent is supported by the U.S. Geological Survey and the Office of

Naval Research and is focusing his efforts on understanding multibeam sonar backscatter and its applicability for seafloor classification as well as exploring the applicability of LIDAR data for seafloor characterization. Laurent finished his term with us in May 2001.

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 (TYCOM FELLOW) recently 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 will be working on seafloor characterization and sonar enhancements.

In addition to the academic staff, two administrative staff positions have been assigned to the Center: **Jane Pittroff** will handle Center business affairs in her role as Marine Program Business Manager and **Lisa Creitz** is our full-time program assistant.

Facilities and Equipment:

Our new 8000 square foot building is complete and (more than) fully occupied. All major computing, networking and plotting facilities are in place and operational including a 4-processor Origin 2100 Silicon Graphic server. A new fiber channel disk stripe brings our central server storage capacity to 512 Gbyte of disc space. We also have an SGI Octane workstation, 3 SGI O2 workstations, 28 high-end NT and Linux workstations and laptops and several Mac G4's. Due the tremendous effort of Research Scientist Brian Calder, 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.

During the reporting period we continued with the acquisition of workstations including several high-end laptop computers and two 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). This machine has been outfitted with 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 near completion of the outfitting of 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

Most significantly we have completed the outfitting of 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 almost continuous operation in support of data collection for Shallow Survey 2001 (see below) since its arrival in June. A more detailed description of the *Coastal Surveyor* can be found in Appendix A.

Educational Program:

One of the major goals of the Center is to establish a viable training program in hydrographic and ocean sciences. To address this goal the center has, under the guidance of Capt. Armstrong developed preliminary curricula that have now been approved by the University (Appendix B). With these approvals we can now offer both M.Sc and Ph.D degrees with a specialization in Ocean Mapping through either the Dept. of Ocean Engineering or through the Dept. of Earth Sciences 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. 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, in September 2000, Center faculty began to teach several new courses specifically designed to support the Ocean Mapping Program. Captain Armstrong offered a Hydrography course and Colin Ware offered both a Data Structures course and a Data Visualization Course. In the spring semester, Larry Mayer taught a

Marine Geology and Geophysics course and Mayer and Brian Calder taught a course on Seafloor Characterization. Dave Wells, Lloyd Huff and Semme Dijkstra offered a Geodesy Course in the summer semester. We now have eight students enrolled in the program, including our first NOAA Corps Officer.

Student	Program	Advisor
Laura Muller	Ph.D OE	Mayer, Calder, Huff
Mike Leo,	Ph.D. ES	Mayer, Calder, Huff
Tony Hewitt,	PhD. ES	Mayer
Luciano Fonseca	PhD.,OE	Mayer
Randy Cutter	PhD, ES	Mayer
Matthew Plumlee	Ph.D. Comp Sci	Ware
Peter Runcimen	Ph.D, OE	Mayer, Rzhanov,Huff
Shep Smith	M.Sc, OE	TBD

Research Program – 2000 - 2001:

In our first biannual report 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 NOAA. 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 report on the progress made on these tasks during our third six months of operation as well as several new efforts that have begun.

Innovative sonar design and processing for enhanced resolution and target recognition

While this theme is one of our least active (its activity will be enhanced with the arrival of de Moustier in January), Rzhanov and Runciman continue with both theoretical and practical work on improved designs and processing algorithms for interferometric sonars. This work is presently being tested on new interferometric sonar being used on a NOAA/NMFS Alaska Fisheries Service cruise in the East Bering Sea under the supervision of Lloyd Huff (see below). Also under this theme is the continued development of an acoustic communication link based on "multichirps" and a modified fractional Fourier transform. A provisional patent application has now been filed by the University for this approach to digital communication.

New approaches to multibeam sonar data processing:

Binary format data access:

An initial component of this theme was the development of software that would allow us to read various forms of multibeam data. To date file descriptions for the Simrad EM 300, 1000, 1002 and 3000 multibeam systems have been tested, as well as those for the Reson SeaBat 8100 series, Hydrosweep DS-2 data (through GSF),

Klein 5000 series sidescan sonar, and the XTF-meta-format. The reader also provides:

- A direct input module for the bathymetric processing library. This should allow us to access manufacturer's data files directly (e.g., for backscatter corrections). This has been tested with the Simrad reader, although the code can be extended to a number of formats if required.
- A SB8101 reader tested with NOAA data wrapped in XTF format; this correctly regenerates parameters recorded in field logs. The NOAA data has been confirmed to contain fully populated Reson datagrams.
- An XTF reader tested in imagery mode, known to work at least for Reson 8101 and Klein 5000 sidescan. The XTF reader is now significantly more robust, dealing with truncated and interrupted packets in a reasonable fashion.
- Using data from the *Whiting's* SB8101 we have shown that we can go XTF to HDCS via CARIS; HDCS to GSF via HIPS; GSF to OMG/HDCS via a custom converter in order to support the NOAA to USGS path. This does not support imagery, which is an on-going problem. The current version of GSF has been obtained from NAVO; modifications and improvements for compilation of library on IRIX fed back to SAIC via NAVO for incorporation in next version.
- A module to parse real-time velocimeter readings from the XTF raw ASCII stream, and time-tag them based on GPS GGA strings.

Extensions have also been made to support alternate formats, to improve robustness, to support imager data and to support other call sequences (e.g from C++). Finally, the reader has been ported to the Windows environment.

Improved Bathymetric Processing:

Using the "data description language", as a means to read various data sets, Calder, Fonseca, Huff, Hou, and Rzhanov continue to make great progress in developing automated approaches to editing and cleaning multibeam data. The original focus of our effort was a remarkable EM3000 data set collected in support of an ONR DRI (SAX-99) off Panama City, Florida. The DRI was aimed at understanding the full suite of acoustic properties (at high frequency) of a small patch of the seafloor. In support of this effort, our team analyzed multibeam data collected in the area by Dr. Roger Flood of SUNY, Stony Brook. Three hundred and seven EM-3000 lines were collected (in several directions) within a 600 x 600 m area using a line offset of approximately 10 m. The tremendous overlap in swaths results in an average data density of 125 soundings per/m^2. This great redundancy provides for robust error analysis and extraction of a statistically realistic representation of the seafloor bathymetry thus allowing for true radiometric corrections. The overlapping geometry also allows us to evaluate mean backscatter as a function of grazing angle for any given piece of seafloor and thus obviates the need to assume a homogenous seafloor. Colleagues at the Naval Oceanographic Office have provided ground-truth samples to test our segmentation algorithms.

While we have investigated a number of approaches, two appear to be the most promising:

- An iterative hybrid mean/median binning cleaning approach that incorporates dynamic beam-by-beam weighting functions and the second derivative of the bottom surface at each point in the data set. This algorithm was able to process 6.4 Gigabytes of EM3000 data in 2.5 hours, a task that took 4 – 5 days when done manually (Hou, and Huff).

- The development of an error-model based direct DTM generator that is based around a grid node and which estimates the depth plus a confidence interval directly on each node point. A Kalman filter is used for integration of the estimates providing a recursive optimal solution to the estimation problem, noise suppression and mean/variance estimates. Initial tests using a crude error model for the soundings suggest the technique has promise but formal comparisons to other techniques need to be made (Calder).

Of these, the Kalman filter approach (which also acts as an area based processing scheme) appears to hold the most promise and has been upgraded and tested extensively. Details of this approach were described in the last progress report, during this reporting period, the following improvements have been made:

- The methodology has been reformulated according to the Bayesian Scheme of West & Harrison to facilitate this.
- The full MBES error model of Hare, Godin, and Mayer has been integrated and tested for the Reson 8101 system, and the Simrad EM3000 and EM1002. Targets for the next six months will be EM300, EM2000 and SB8125 systems, in order to support fieldwork in the next six to twelve month period.
- A scheme for monitoring the performance of the model has been implemented. This makes more certain that the initial outlier problem described in the last reporting period will be caught and contained, rather than corrupting the estimates. This also makes it less important to implement a median pre-filter queue, or Eeg's outlier removal algorithm, two 'threshold dependent' processes.
- A scheme for maintaining multiple simultaneous hypotheses has been implemented, which significantly improves the robustness of estimation and opens the way for object detection with the same algorithm. Under this scheme, each estimation node can hold information about a finite number of different depth hypotheses, a common situation with noisy data. At any estimation node, the hypotheses can be interrogated for the best current depth, using either a simple 'longest held is best' algorithm, or more sophisticated algorithms based on a pseudo-likelihood, or a pseudo-posterior with local search context (in order of increasing computational cost). With this method in place, outliers are typically collected into one or more alternate hypotheses, which are typically less successful (by any of the selection methods) than the correct hypothesis. In addition, a count of the number of hypotheses used is a good indicator of data problems, giving a useful operator feedback mechanism.
- Using these new techniques, data from the Portsmouth Harbor dataset (see below) are currently being processed, including the bad data from the first day of the survey. With simple depth and angle gates, and the multi-hypothesis tracker,

almost all of the data problems are eliminated, and where they are not, the hypotheses count indicates clearly the location of failures.

- A number of small sub-system improvements have been made, including a tides module, a general parameter file reader (so that all of the code can be configured from one archivable text file), and an implementation of IHO limits for hydrographic surveys to control the local bathymetric interpolation constants used in the code.

Both of these techniques were presented at the US Hydro 2001 Conference in Norfolk Va. and were extremely well received. We are now actively working on ways to incorporate these approaches into the standard NOAA data processing stream, Our first attempt at this will be on an upcoming USGS/NOAA cruise in the Gulf of Mexico. During this cruise NOAA, USGS, and UNH researchers will work in parallel collecting and processing data with the goal of evaluating approaches to incorporating automatic editing algorithms into the NOAA processing path. In addition, NOAA Lt. and graduate student Shep Smith is exploring the use of a gridded surfaces produced by a hydrographic surveys for navigation. This "navigation surface" has the potential to streamline cartographic production, make surveys more rigorous, and be of value for other marine users.

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 House) 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 the last progress report; during the current reporting period, GeoZUI3D had a major new release and excellent documentation has been generated: New additions to GeoZui3D include:

- More general point, line, and triangle plotting capabilities, with the ability to map colors (and in the case of the points, glyphs and sizes) to data attributes of each point.
- More general grids and axis objects
- Integration of the locking of a window to an object in the navigation: When you click on a moving object with the middle mouse button, you are automatically attached to the object's reference frame (your view moves and rotates with the object, so the object is fixed and the world moves).
- The ability to access objects and windows through a scripting interface. This allows one to write a script that will move objects and windows around, and lock them to each other.
- New "composite" objects: An "Averaging Overview "object that tracks several other objects, and a "Closest Proximity" object that identifies the closest two objects in a group of objects. These are intended to have

windows locked to them; these composite objects cause a locked window to move and rescale such that all the tracked objects (for the Averaging Overview) are visible in the window, or that the two closest objects (for the Proximity) are visible in the window. The Proximity composite object can also set off alarms when objects start getting too close.
- An interactive lighting widget (optional).
- Fixed the lighting of bathymetry objects.
- A context-sensitive menu, invoked with a right-click. This allows you to do things like hide, fuse, reconstitute object without bringing up the object panel.

GeoZui3D now has beginnings of a user group including NOAA, WHOI and MBARI. In particular, GeoZui3D is actively being used as a display and QC tool both on board NOAA survey vessels and in NOAA labs. Collaborative work with Skip Little and GLOBEC researchers at WHOI has led to the development displays for visualizing water column data. Work with Don House on using genetic algorithms to optimally display one transparent surface overlapping another, such that both surfaces can clearly be seen, may have important ramifications for displaying information on the electronic chart of the future.

Progress has also been made on real-time input into GeoZui3D and on the use of hybrid quad-trees/linked lists to allow real-time display and scaling of large data sets during data acquisition. Based on this progress, several collaborative projects have begun that involve GeoZui3D. Two of these projects involve AUV data – C&C Technologies has supplied data from their AUV, Hugin. GeoZui3D can now display the 3D position of the Hugin, the support ship and the realtime data received through an acoustic link. We have also integrated GeoZui3D with the Autonomous Undersea Systems Institute's (AUSI's) multiple underwater vehicle simulation environment (CADCON). Plans are also being made to work with the WHOI AUV "ABE" during exploratory cruises of the Juan de Fuca plate. Ideas are being developed for applying newly developed approaches for multi-scale interaction with 3-D data environments (including, stereo vision, head coupling and force feedback) to problems of AUV/ROV mission planning, submarine navigation, and deep sea cable route selection.

Finally, during this reporting period, we have launched a new visualization project with the N.H. Seacoast Science Center. This project will take advantage of the visualization tools developed in the Visualization Lab to design interactive museum exhibits that can help bring the wonders of ocean science to the general public.

Seafloor Characterization:

Single-beam echo sounders: In support of our efforts to use single beam echo sounders as a tool for seafloor characterization, the Center has acquired a specially designed (to allow chirp transmission and full wave-form recording) Knudsen echo sounder. This system is being deployed on our shallow water pontoon boat and other

small vessels in order to explore approaches for using acoustic signals to remotely identify oyster reefs. This project is being done collaboratively with researchers at the UNH Jackson Lab and with the New Hampshire Fish and Game Dept. and the Dept. of Environmental Services.

We have 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. Semme Dijkstra has been processing single beam and sidescan sonar data from the Sanctuary in order to remove navigation artifacts. Preparations are now underway for a second habitat mapping cruise in the Sanctuary that will also involve collaborative work with the Quester Tangent Corporation..

We have also developed an innovative new approach to shallow water seafloor classification based on physical contact with the seafloor which will be the subject of Laura Muller's thesis. The theoretical background for this study has been investigated (including friction theory and tribology) and a laboratory track system has been developed for testing different materials, approaches and sensors.

Sidescan sonar: Lloyd Huff is working with the Alaska Fisheries Service of NOAA./NMFS on a major sidescan sonar survey in the East Bering Sea. These data have now been collected and will be processed and analyzed by JHC scientists in the near future. Among the techniques to be used will be an automated classification technique developed by Rzhanov and Hou.. 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 (with requested number of clusters) is performed, the mean signature for each cluster is calculated and then fed into an optimization algorithm for inversion for the seafloor property parameters.

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 EM3000 data collected in support of the SAX-99 experiment (see above) as well as EM1002 data collected in conjunction with the USGS and EM1000 data collected for ONR.

Laurent Hellequin has developed an easily usable, Matlab based interface that uses the well-known Jackson algorithm to calculate backscatter as a function of angle of incidence. The ability to easily and interactively evaluate seafloor response to the range of parameters included in the Jackson model will greatly facilitate our seafloor characterization efforts.

Luciano Fonseca has used the automatic code generating software developed by Calder (see above) to develop an algorithm to interpret Simrad datagrams and extract beam position, beam angle, and raw backscatter coefficients. Once read, all

necessary corrections (Lambertian, TVG flattening near nadir, area of insonification and slope corrections) are done (for slope corrections, true grazing angle for each beam is calculated based on a terrain model of the area). Luciano has also implemented an algorithm to calculate the backscatter angular response based on Jackson and Mourad's (1986) model. This model has been tested against EM1000 backscatter data collected in support of the ONR STRATAFORM project off the Eel River, northern California, and against core samples with free gas measurements collected by researchers from the Monterey Bay Aquarium Research Institute. In each case (against the measured backscatter and the ground truth from cores), the model accurately predicts the effect of gas on backscatter.

Tianhang Hou and Lloyd Huff have been using the SAX-99 data to explore the variations in backscatter (and bathymetry) as a function of grazing angle and vessel heading as well as developing sophisticated wavelet based approaches to segmentation of backscatter data. Interpretation of azimuthally dependent backscatter levels led to the determination of the presence of sand waves with preferred east-west crest orientations. Subsequent ground truth data provided by NAVO supported this remotely determined conclusion. Tianhang has also developed and approach for inverting backcatter data to extract the "Jackson" parameters that describe aspects of seafloor properties.

Video/photo image mosaicing and quantification: Yuri Rzhanov, Lloyd Huff and Randy Cutter have been quite active in the collection and analysis of seafloor and other video data. The team has developed a means of remotely controlling the 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. Improved video and audio acquisition algorithms have been implemented resulting in decreased latency and fewer errors. A series of camera calibration experiments have been conducted to determine lens distortion and corrections for spatial perspective and laboratory experiments were carried out in order to develop a means of using roll/pitch information plus a mirror and stepping motor to control the orientation of underwater video images. Rzhanov has improved his mosaicing algorithms through the comparison of warping and affine featureless techniques.

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. Rzhanov's affine-motion mosaicing techniques have been coded into Matlab scripts and applied to seafloor imagery from Destin and Portsmouth Harbor. 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.

Huff and Cutter are also working with researchers from the Jackson Lab on designing a combination camera grab-core system that will be invaluable for ground-truthing our acoustic studies.

Data Mining, Blending and Fusion:

A relatively new focus our research is the development of 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. This chart is based on more than 13 different sources each of different quality. Two main problems have been addressed:

1) Estimation of the errors in a final gridded bathymetry model, a task that is not usually addressed in most bathymetric compilations
2) Establishing an algorithm which may be used in order to find the grid cell resolution that is justified by the input data

We have approached the problem via a direct-simulation Monte Carlo method. The final products of the error modeling are a collection of standard error grids at different resolutions, a measurement of estimation reliability, and an overall assessment of gridding algorithm stability as a function of grid resolution. The method was described in our last progress report. During this reporting period the method was presented at several scientific conferences and written up for publication in the Journal of Geophysical Research.

We are now beginning to apply this 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. We will use the approach described above to combine these into a single database as well as to discriminate between inaccuracies and real changes over time. On an even smaller but locally very relevant scale, Alexander, Leo and Smith will be compiling bathymetric data sets for the Oyster River.

NEW PROJECTS:

The Center tries to be as responsive as possible to the needs of NOAA and thus we begin new projects as the need demands. Several new initiatives have thus begun since the last progress report:

Arctic Ocean bathymetry

At the request of NOAA, we have focused some effort on critical areas of Arctic Ocean Bathymetry with respect to Law of the Sea. Martin Jakobbson has extracted the trackline sources used for the compilation of the International Bathymetric Chart of the Arctic Ocean (IBCAO) model in U.S. national waters near Alaska and produced a source distribution map for the region around the Northwind Ridge. A study was conducted for NOAA that estimated potential boundary lines in the region by several different approaches including automated algorithms designed to define the foot of the continental slope from the gridded IBCAO bathymetry. Given NOAA's growing interest in the Arctic, Martin Jakobbson has spent a significant amount of time producing upgraded

versions of the Arctic bathymetry through the inclusion of approximately 180,000 km^2 of new multibeam data from the Norwegian Oil Directorate and the Alfred Wegner Institute. In addition, the error model described above and reports from users, were used to identify (and remove) erroneous features from the bathymetric data base. The culmination of this effort was a meeting of the IASC/IOC/IHO Editorial Board for IBCAO at the University of New Hampshire on 27 – 28 May, 2001 and the release of the beta version of the IBCAO bathymetry.

Shallow Water Survey 2001

In September of 2001, the Center will be hosting the second International Meeting on Shallow Water Surveying. 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 has 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, arrangements were made by Capt. Armstrong and Lt. Smith for the NOAA Ship *Whiting* to come to Portsmouth Harbor and collect multibeam and sidescan sonar data in early November. It was also arranged for NOAA to collect aerial photographs of the New Hampshire and Maine coasts and for a NOAA tide station in Portsmouth Harbor to be re-established to support the *Whiting* survey and future work.

The NOAA surveys were conducted flawlessly providing 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. Most of the Center personnel will be working on various aspects of this data over the next few months and it has been the subject of a NOAA workshop (organized by Lt. Smith and Lee Alexander at UNH) aimed at defining the future of the cartographic pipeline in the Office of Coast Survey.

Since the *Whiting* survey, the common data set has expanded to include:

- 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

With the exception of the USGS Submetrix and the DPW Navitronix surveys, all of the other sonar data collected to date has been acquired from our new survey vessel *Coastal Surveyor* operated by either Capt. Armstrong or Lt. Smith.

In addition, Space Imaging Inc. has provided IKONOS images of the area.

More surveys are planned over the next few months and we expect that 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 will also become a major focal point for UNH/JHC research projects. For example, Randy Cutter is analyzing sonar bathymetry and imagery from Portsmouth Harbor to try to extract estimates of roughness and differing seafloor type that can then be compared to video mosaics and other habitat metrics and Lloyd Huff is using a remarkable time series of high resolution sidescan records collected over a sand wave field in Portsmouth Harbor (collected 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.

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-Simplex, Klein Associates, Maptech, C&C Technologies, AUSI, Interactive Visualization Systems, Triton-Elics, and STN-Atlas Marine of Germany. Our involvement with Tyco-Simplex 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. 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 2). The USGS supports collaborative projects involving multibeam sonar mapping as well as an additional post-doctoral fellow at the Center (in addition to their seconding a senior scientist to the Center). A brief description of the externally funded projects follows:

USGS-UNH Cooperative Agreement:

The U.S. Geological Survey's Western Coastal & Marine Geology Pacific Mapping Project (PMP) has an ongoing collaborative agreement with the Center for Coastal and Ocean Mapping at the University of New Hampshire. As part of this agreement, the CCOM will provide the PMP with high-resolution, multibeam and co-registered backscatter maps of selected offshore areas. Additionally, CCOM provides the USGS with a Post-Doctoral Research Associate whose work is focused on understanding the links between geological facies and backscatter collected by sonar and LIDAR. As part of this arrangement, Dr. Jim Gardner of the USGS PMP spends several months per year at the CCOM.

Planning is now in the process for a major USGS-sponsored cruise in the northeast, Gulf of Mexico to take place in September. This cruise, spearheaded by Dr. Jim Gardner, represents a prime example of inter-agency cooperation as objectives of the USGS Biological Resources and Geological Divisions, NOAA's NMFS and The MMS are all being addressed. These objectives revolve around the mapping of deep water reef complexes and 3 marine protected areas off the northwestern Florida shelf and upper

slope. In addition to these environmental mapping objectives we will also use this cruise as an opportunity to collaborate with representatives of NOS's Office of Coast Survey and explore ways to automate the multibeam data processing stream.

Mutually beneficial collaboration and cooperation with NOS Office of Coast Survey was also demonstrated in the highly successful multibeam mapping of Puget Sound immediately after the 2001 Nisquilly earthquake. Dr. Gardner took advantage of the presence and capabilities of the NOAA Ship *Ranier* to map the three delta fronts of Southern Puget Sound to search for evidence of sediment failure that may be a danger to the region. Although evidence for failure was found, it is equivocal whether these failures were caused by the 2001 earthquake or earlier events.

GEOCLUTTER – ONR (Mayer, P.I.)

In support of the ONR Defense Research Initiative (GEOCLUTTER), the Center of Coastal and Ocean Mapping has developed and built a system capable of making multiple, *in-situ*, measurements of seafloor sound speed and attenuation in water depths up to 300 m. The instrument will be deployed on the *R/V Cape Henlopen* in July of 2001. The measurements made with this system will be used to better understand the real distribution of seafloor acoustic properties and thus to improve methods for the interpretation of seafloor acoustic data and the remote characterization of seafloor sediments.

STRATAFORM – ONR (Mayer , P.I.)

The ONR STRATAFORM project is a multi-year, multi-investigator program aimed at understanding the origin of the stratigraphic record that interacts with Navy sonar systems. We collected multibeam sonar data in the study area off Northern California and have been analyzing the backscatter data from this area in an attempt to understand the processes responsible for changes in backscatter. We have also developed an ARCVIEW based GIS that contains most of the data collected in the STRATAFORM area and are working on converting this into an interactive, 3-D GIS. The STRATAFORM Project and another new Navy program (Mine Burial – see below) has supported the hiring of a new GIS specialist as well as the establishment of a web-based GIS server for the STRATAFORM and buried mine data sets.

Mine Burial – ONR (Mayer, P.I.)-

The Navy has called upon the mapping expertise of the Center to provide base maps and details surveys of a small area south of Martha's Vineyard where ONR will be conducting a multiyear experiment to explore the fate of mines deployed in a dynamic environment. A regional survey will be conducted by the USGS with a Submetrix system in late 2002 and from this survey a specific deployment site will be selected. The selected site will be surveyed in great detail with a Reson 8125 focused multibeam sonar and then instrumented mines (inert) will be deployed. Up to 4 resurveys of the mine deployment site will take place over the next year to monitor the fate of the mine. In addition to this work, the Center will also host a web-based GIS containing all data collected in the multi-investigator program.

Uncertainty – ONR – (Calder and Mayer, P.I.'s)

The Navy has recognized the limitations of their acoustic propagation models in shallow water and has embarked on a major effort to quantify the uncertainty associated with these models. Based on the work of Calder in producing real-time uncertainty maps of seafloor bathymetry (an important component of the propagation model) as well as our experience with both quantifying error sources in multibeam sonars and visualization of a range of complex geospatial data, ONR has asked that we participate in this program.

Great Bay bathymetry - CICEET (Mayer, Armstrong and Ware, P.I. s)

The finite element models that are used to predict the distribution and fate of effluents and contaminated sediments in Great Bay (and other) estuaries are based on the digitization of selected soundings and contours from NOAA charts. We believe that this provides an inappropriate database for flow models and have begun to gather all existing bathymetric data from Great Bay in order to produce a much more accurate bathymetric model for input into the finite element models. There are 8 historical data sets for the Bay and we are documenting the error sources associated with each generation of data collection in order to combine them using the error modeling techniques developed for the Arctic data set. When finished we will also produce a series of 3-D chart products based on this new bathymetry.

Multi-scale interaction with data environments – NSF (Ware, Mayer, P.I.s)

This three year project is aimed at developing new approaches to interactive visualization of environments that must encompass large changes in scale. An example is an AUV that may have only a coarse global bathymetric database to begin its mission but that collects detailed bathymetry as it goes along. A primary goal of this project is to investigate new techniques for 3D data exploration and object interaction. Our plan is to develop a fishtank VR system testbed to implement and test these new techniques, and which will also form the basis for development of useful CCOM tools. We plan to create the fishtank VR testbed using GeoZui3D and the Phantom force feedback device, coupled with stereo vision and head tracking.

Electronic Charting -- NAVO, St. Lawrence Seaway Dev, Corp., and others (Alexander, P.I.)

Externally-funded research, development, test and evaluation (RDT&E) projects associated with the implementation of electronic chart-related technologies are being performed for various U.S. government agencies. For the St. Lawrence Seaway Development Corporation, sea-trials will be conducted related use of electronic chart data and the display of AIS information with ECDIS onboard ships transiting the Seaway and into the Gt. Lakes. Technical advice is being provided to the Naval Oceanographic Office (NAVOCEANO) related to the U.S. Navy's goal of making a complete transition from reliance on paper charts to electronic charting within 3-5 years. Technical Advice is being provided to Army Corps of Engineers – New Orleans District related to the development and distribution of river ENC database for the Atchafalaya and lower Mississippi Rivers. A data format test specification has been completed for the Office of Coast Survey, NOAA associated with the use of NOAA/Maptech Raster Nautical Chart

data in ECDIS. Finally, technical assistance was provided to the Pacific Northwest Maritime Institute on the development of an IMO-compliant training course on the Operational Use of ECDIS.

Advanced aspects of GPS (Huff, P.I)

Lloyd Huff has also taken advantage of the "common data set" acquisition in Portsmouth Harbor and used data collected with the sweep survey vessel from the Canadian Department of Public Works. This activity was an attempt to survey beyond the shoreward bounds of the survey, which the NOAA Ship Whiting conducted in November 2000, to the zero depth curve. The survey was conducted using RTK-GPS 3-D positioning. An initial analysis of the time histories of the vessel's vertical position component was made to produce 6-min averages that were compared to water levels from the COOPS gauges at Seavey Island ME (Portsmouth Harbor) and Portland ME. The first two days of the survey were referenced to a benchmark at Fort Point NH (3 km from Seavey Is.) The third day of the survey was referenced to a benchmark near the forward range light of the Portsmouth inner harbor range, which is on the south side of the Piscataqua River and 0.5 km from Seavey Is. On all three days the GPS data were in good agreement with the tide gauges. In addition, Dr. Huff is developing the concept for an RTK-GPS demonstration project using the Portsmouth to Isles of Shoals ferry. The equipment has been assembled and is awaiting installation and operations which should begin in mid-August 2001.

ScapaMAP 2001 (Calder, P.I.)

Calder coordinated the organization of a number of archeological, heritage and technical groups from the U.K. in carrying out a very high resolution survey of the German Grand Fleet scuttle site in Scapa Flow. The survey. carried out between 12-16 June 2001, used the new Reson 8125 focused multibeam sonar, resulted in very detailed bathymetry over the wrecks and the general area. Data is currently being worked up to final quality, with the plan to generate a 3D virtual environment for the area, with higher resolution over the ships, and paper products for the general area and highlights for the ships themselves

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

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:

Icebreaker Healy Gorda Ridge	NSF	April 2001	Smith
ScapaMAP	June	2001	Calder
Puget Sound *Ranier*	NOAA/USGS	May 2001	Gardner
Portsmouth Harbor Surveys *Coastal Surveyor*	JHC	June 2001	Armstrong Smith Cutter Leo

APPENDIX D

Other Funding:

Grant Title	Grant P.I.s	Grantor	Total Awarded
Research and Development Plan for DARPA	Larry Mayer	ONR	$15,665.00
Multi-Scale Interaction w/3D Data Environment	Ware, Mayer	NSF	$499,152.00
Strataform Analysis	Larry Mayer	ONR	$65,006.00
Geoclutter Program	Larry Mayer	ONR	$143,747.00
A 3-D GIS	Larry Mayer	ONR	$79,914.00
Collaborative High Resolution Mapping	Larry Mayer	USGS	$4,693,730.00
Bathymertic Modeling and 3D Visualization	Mayer, Armstron	CICEET	$178,115.00
St. Lawrence Seaway AIS-ECDIS	Lee Alexander	US Dept. Transportation	$9,962.00
Surveying Midwater Fish	Mayer, Baldwin	NSF	$125,550.00
Training Course Development for ECDIS	Lee Alexander	MITAGS	$8,838.00
Electronic Charting for Naval Operations	Lee Alexander	Naval Oceanographic Office	$47,800.00
ECDIS and ECS Technical	Lee Alexander	DCS Corpotation	$21,500.00
Tyco Endowment interest earned on $ 1 million			$ 45,000.00
Mine Burial/Coastal Program Thru Web-Site	Larry Mayer	ONR	$ 43,544.00
Reconnaissance Mapping of Martha's Vinyard	Larry Mayer	ONR	$ 32,408.00
Estimation and Visualization of Uncertainty	Larry Mayer	ONR	$ 15,034.00
RNC Compliance Specification Development	Lee Alexander	NOS,NOAA	$ 10,001.00
Totals			**$6,034,966.00**

APPENDIX E

Visitors January 2001 –July 2001

Name	Date	From	Visiting	Purpose of Visit
Rick Fletcher	1/16/01	NOAA	Semme Dijkstra	Planning for, and evaluation of OCNMS mapping
Rick Brennan	1/15/01	NOAA Ship WHITING	Shep Smith, Lee Alexander	White Paper drafting for workshop
Guy Noll	1/8/01 - 1/9/01	NOAA Hydro Systems and Technology Program	Shep Smith	Participate in Cartographic Workshop
Jack Riley	1/8/01 - 1/9/01	NOAA Hydro Systems and Technology Program	Shep Smith	Participate in Cartographic Workshop
Dennis Hil	1/8/01 - 1/12/01	NOAA Pacific Hydrographic Branch	Shep Smith	Participate in Cartographic Workshop
Cathleen Barry	1/8/01 - 1/12/01	NOAA Pacific Hydrographic Branch	Shep Smith	Participate in Cartographic Workshop
Robbie Roberson	1/8/01 - 1/12/01	NOAA Atlantic Hydrographic Branch	Shep Smith	Participate in Cartographic Workshop
Castle (Gene) Parker	1/8/01 - 1/12/01	NOAA Atlantic Hydrographic Branch	Shep Smith	Participate in Cartographic Workshop
Rick Whitfield	1/8/01 - 1/12/01	NOAA Atlantic Hydrographic Branch	Shep Smith	Participate in Cartographic Workshop
LT Rick Brennan	1/8/01 - 1/12/01	NOAA Ship WHITING	Shep Smith	Participate in Cartographic Workshop
Crescent Clemens	1/8/01 - 1/12/01	NOAA Ship WHITING	Shep Smith	Participate in Cartographic Workshop
ENS Marc Moser	1/8/01 - 1/12/01	NOAA Ship WHITING	Shep Smith	Participate in Cartographic Workshop
LT Rick Sipos	1/8/01 - 1/12/01	NOAA Hydro Surveys Division	Shep Smith	Participate in Cartographic Workshop
Mike Gourley	1/8/01 - 1/12/01	Caris	Shep Smith	Participate in Cartographic Workshop
Duane Doucette	1/8/01 - 1/12/01	Caris	Shep Smith	Participate in Cartographic Workshop
Mike Brown	1/8/01 - 1/9/01	NOAA Marine Charts Division	Shep Smith	Participate in Cartographic Workshop
Ernie Monti	1/8/01 - 1/9/01	NOAA Marine Charts Division	Shep Smith	Participate in Cartographic Workshop
Kate Roise	1/25/01	NE Aquarium Video Productions	Mayer	Visualizing Bermuda
Ken Foote	1/25/01	WHOI	Mayer	Multibeam Sonar calibration
Gary Melvin	1/25/01	DFO St Andrews	Mayer	Multibeam Sonar calibration
H. Arnold Carr	2/1/01	Side Scan Sonar Expert	Armstrong	Multibeam Sonar calibration
Colin Ellis	2/4/01 - 2/5/01	Thompson Marconi Sonar - Australia	Mayer and CCOM	Petrel, sed classification MOU
Mark Matthew	2/4/01 - 2/5/01	RAN - Australia	Mayer and CCOM	Petrel, HML sed classification MOU
Lindsay Gee	2/5/01 - 2/6/01	IVS New Brunswick Canada	Mayer and CCOM	Visualization
Mark Paton	2/5/01 - 2/6/01	IVS New Brunswick Canada	Mayer and CCOM	Visualization
Nathan	2/5/01 - 2/6/01	IVS New Brunswick Canada	Mayer and CCOM	Visualization
Graham Sweet	2/5/01 - 2/6/01	IVS New Brunswick Canada	Mayer and CCOM	Visualization
Denny	2/5/01 - 2/6/01	IVS New Brunswick Canada	Mayer and CCOM	Visualization
Gary Smith	2/5/01 - 2/6/01	Vector Systems Ltd. Virginia	Mayer and CCOM	Petrel, RAN and others
Mary Sue Brancato	3/26/01	Olympic Coast National Marine Sanctuary (NOAA)	Semme Dijkstra	to explore venues for cooperation
Tom Reis	4/5/01	Substructure Portsmouth	Mayer.Armstrong	Portsmouth Harbor data – diving ops
Jeff Taylor	4/6/01	NH Fish and Wildlife	Mayer.Armstrong	Portsmouth Harbor data – book on river history
Jeff Bolster	4/6/01	UNH History Dept	Mayer.Armstrong, Smith	Portsmouth Harbor data – book on river history
Ted Knowles	4/13/01	Portsmouth Shipyard Pilot	Andy, Larry, Shep	View Portsmouth data
Ian Higginbottom	4/18/01	SonarData Pty Ltd	Larry Mayer, Gary Melvin	Discuss Fisheries Hydroacoustics
Dave Heatley	4/18/01	SonarData Pty Ltd	Larry Mayer, Gary Melvin	Discuss Fisheries Hydroacoustics
Jeff Taylor	4/18/01	State of New Hampshire	Larry Mayer, Shep Smith	Portsmouth Harbor Maps
Jeff Bostler	4/18/01	UNH History	Larry Mayer, Shep Smith	Portsmouth Harbor Maps
Basil Solaiman	4/23/01	ENST Bretagne	Larry and Lloyd	Inteferometric bathy from Klein 5000
Christophe Sintes	4/23/01	GESMA France	Larry and Lloyd	Inteferometric bathy from Klein 5000
Bill Key	4/23/01	Klein Sonar	Larry and Lloyd	Inteferometric bathy from Klein 5000
Ron McNab	4/23/01	Geological Survey of Canada	Armstrong	To discuss IBCAO and LOS issues.
Wen Ning	4/26/01	Guangzhou Marine Geological Survey	CCOM and Ocean Eng. Lab	To learn what we have done in the Center
Zhang Zai Chao	4/26/01	Guangzhou Marine Geological Survey, PRC	Larry	Learn about CCOM, exchange discussions
Zhang Ming, Sr. Geophysicist	4/26/01	Guangzhou Marine Geological Survey, PRC	Larry	Learn about CCOM, exchange discussions
Zhang Mao Lin, Director	4/26/01	Guangzhou Marine Geological Survey, PRC	Larry	Learn about CCOM, exchange discussions
Liang Guangsheng, Sr. Engineer	4/26/01	Guangzhou Marine Geological Survey, PRC	Larry	Learn about CCOM, exchange discussions
Prof. Wen Ning, Vice Director	4/26/01	Guangzhou Marine Geological Survey, PRC	Larry	Learn about CCOM, exchange discussions
Wang Da, Director	4/26/01	Guangzhou Marine Geological Survey, PRC	Larry	Learn about CCOM, exchange discussions
Lana	4/26/01	Guangzhou Marine Geological Survey, PRC	Larry	Learn about CCOM, exchange discussions
Li Xiao	4/26/01	Fairfield Industries, Beijing PRC	Larry	Learn about CCOM, exchange discussions
Doug Carmichael	4/25/01	DERA Bincleaves, UK	Lloyd and Brian	Demo sonar analysis software, visit CCOM
Stephen Takel	4/25/01	DERA Bincleaves, UK	Lloyd and Brian	Demo sonar analysis software, visit CCOM
Admiral Guiseppe Angrisano	5/10/01	President, Intl. Hydrographic Bureau	CCOM -JHC	learn about CCOM/JHC
Bill Key	5/31/01	President, Klein Sonar	Mayer, CCOM	collaboration with Thomson Marconi
Gary Smith	5/31/01	Thomsom Marconi	Mayer, CCOM	collaboration with Thomson Marconi
Keith Hall	5/31/01	Director Thales/Thomsom Marconi Programs	Mayer, CCOM	collaboration with Thomson Marconi
John Delaney	5/31/01	Univ of Washington	Mayer	Neptune Mapping
Nancy Perkins	6/1/01	NOAA/ Sen. Gregg's Office	Mayer, Armstrong, JHC/CCOM	collaboration with Thomson Marconi
Bill Joslin	6/1/01	UNH	Mayer, Armstrong JHC/CCOM	with Perkins
Robert Rines	6/21/01	Academy of Applied Science, Franklin Pierce Law	Mayer	Loch Ness discussions
David Rogers	6/22/01	NOAA Deputy Assistant Administrator for Weather and Air	Armstrong	Discuss CCOM/JHC

APPENDIX F

Publications, Talks, Abstracts – 2001

Six Month Progress Report Submissions

from January 2001 to July 2001

Submissions and Publications:

Calder

"Robust Automatic Multi-Beam Bathymetric Processing", Calder & Mayer, US Hydro 2001, Norfolk, VA, May 2001.

"Automatic Processing of High-Rate, High-Density Multi-Beam Echo-Sounder Data", Calder & Mayer, submitted, July 2001.

Cutter

Seafloor Habitat Mapping: Considering Techniques for Expansion of Spatial Scales. R. Cutter, L. Mayer, Y. Rzhanov. Presented at the Workshop on deep-seabed survey technologies, 31 Jan - 02 Feb 2001, Bergen, Norway.

Gardener

Submitted manuscript to EOS entitled "Mapping southern Puget Sound delta fronts after the 2001 Nisqually Earthquake".

Submitted manuscript to Gulf of Mexico Science entitled "Physiography and Late Quaternary-Holocene processes of northeastern Gulf of Mexico outer continental shelf off Mississippi and Alabama".

Submitted invited chapter to book entitled "Landslide tsunami scenerio off Palos verdes, CA" (second author).

Submitted invited chapter to book entitled "Submarine landslides of San Pedro Sea Valley, southwest of Long Beach, CA" (second author)

Submitted manuscript to Geological Society of America Bulletin entitled "Morphology, volcanism, and mass wasting in Crater Lake, OR" (second author).

Hewitt

Hewitt, A.T., and Mosher, D.C. Marine Geology. 2001. Seafloor Geology of the eastern Strait of Juan de Fuca, British Columbia and Washington. Vol. 177(3-4): 295-316.

Hewitt, A.T. and Mosher, D.C. 2001. Surficial geology of the eastern Juan de Fuca Strait. *in* Mosher, D.C., and Johnson, S.Y. (eds.) in press. Neotectonics of the eastern Juan de Fuca Strait; a digital geological and geophysical atlas. Geological Survey of Canada. Open File Report D3931.

Mosher, D.C., Kung, R., and Hewitt, A.T. 2001. Modern surface morphology of the eastern Juan de Fuca Strait. *in* Mosher, D.C., and Johnson, S.Y. (eds.) in press. Neotectonics of the eastern Juan de Fuca Strait; a digital geological and geophysical atlas. Geological Survey of Canada. Open File Report D3931.

Huff

Conducted a professional review of an article (A Comparison of the accuracy and precision of measurements from single and stereo-video systems) to be published in the *Marine Technology Society Journal*.

Principal author of the chapter on sonar for the book Digital Elevation Models: New Technologies and Applications to be published by the American Society of Photogrammetry and Remote Sensing.A paper proposal was prepared with two co-authors from JHC. The paper title is "Sensor-Assisted Video Moasicing for Seafloor Mapping"; the conference is ICIP-2001, sponsored by the IEEE Signal Processing Society. The venue for the conference is Thessaloniki, Greece, October 7-10, 2001.

Jakobsson

"Error Estimation of Bathymetric Grid Models Derived from Historic and Contemporary Datasets", Jakobsson, Calder, Mayer & Armstrong, US Hydro 2001, Norfolk, VA, May 2001.

"On the Estimation of Errors in Sparse Bathymetric Geophysical Datasets", Jakobsson, Calder, Mayer & Armstrong, Eos. Trans. AGU, 82(20), Spring Meet. Suppl., Abstract OS21A-08, 2001.

"On the Estimation of Errors in Sparse Geophysical Datasets", Jakobsson, Calder & Mayer, submitted to J. Geophys. Res., March 2001.

Mangerud, J., Astakov, V., Jakobsson, M. and Svendsen, J. I., *in prep*, Large ice-dammed lakes on northern Eurasia 90,000 years ago, to be submitted to *Nature*.

Jakobsson, M., Calder, B., and Mayer, L., On the Estimation of Errors in Gridded Bathymetric Compilations, submitted to Journal of Geophysical Research.

Komerska

Co-author of "Monitoring Distributed Autonomous Entities through Linkable 3D Windows" to be presented at the 12th International Symposium on Unmanned Untethered Submersible Technology (UUST01) to be held August 27-29, 2001 at the New England Center, Durham, NH. The paper will discuss some of the unique user interface concepts for data visualization as they are embodied in GeoZui3D and how these might be (and have been in some cases) applied to AUV mission simulation and real-time operations. We are currently planning to demonstrate GeoZui3D at the conference, using the AUSI simulation to provide an interesting underwater scenario.

Mayer

Mayer, L.A., Li, Yanchao, and Melvin, G., in press 3-D visualization for pelagic fisheries assessment and research, ICES Journal of Marine Science

Melvin, G., Li, Yanchao, Mayer, L.A., and Clay, A., in press, Automated tools for sonar logging on commercial fishing vessels, ICES Journal of Marine Science

Fenstermacher, L.E., Crawford, G.B., Borgeld, J.C., Britt, T., George, M., Klein, A., Driscoll, N., and Mayer, L.A., in press, Enhanced acoustic reflectivity due to high abundance of sand dollars, *Dendraster excentricus*, Marine Geosources and Geotechnology, v. 19

Mayer, L.A., Fonseca, L., Ware, C., Paton, M., Gee, L., Gardener, J., and Orange, D., 2001, Interactive 3-D Visualization and Exploration of Deepwater Geohazards, Paper No. 12955, Proceedings of the Offshore Technology Conference, Houston, TX., 11 pp.

Ware

Irani, P. and Ware, C. (journal paper submitted) Diagramming Information Structures using 3D Perceptual Primitives.

Ware, C., Arsenault, R., Plumlee, M. Mayer, L., and Smith, S. (2001) GeoZui3D: Data Fusion for Interpreting Oceanographic Data. Oceans 2001 (paper submitted and accepted)

Bartram, L., Ware, C., and Calvert, T., (journal paper submitted) Filtering and Integrating Visual Information with Motion.

Bartram, L., Ware, C., and Calvert, T., (journal paper submitted) Moticons: Detection, Distraction and Task.

Irani, P., Ware, C. and Tingley, M. (2001 in press) Using Perceptual Syntax to Enhance Semantic Content in Diagrams. IEEE Computer Graphics and Applications.

Bartram, L., Ware, C. and Calvert, T. (to appear) Moving Icons, Detection and Distraction,

Interact 2001, Tokyo. June. Proceedings.

Laramee, R., and Ware, C. (2001) Visual Interference with a Transparent Head Mounted Display. ACM CHI'2001 Seattle. Extended Abstracts.323-324.

GeoZui3D: Data Fusion for Interpreting Oceanographic Data. Paper accepted for Oceans 2000.

Monitoring Distributed Autonomous Entities Through Linkable 3D 3D windows. Paper accepted for UUST Conference.

Talks:

Jakobsson

Mangerud, J., Astakov, V., Jakobsson, M., and Svendsen, J-I., 2001, Large ice-dammed lakes in northern Russia during the last glaciation, 31st International Arctic Workshop, Program and Abstracts, Departments of Geosciences, University of Massachusetts, p. 74.

Jakobsson, M., Mangerud, J, Astakov, V, and Svendsen, J. I., 2001, Volumes and Areas of Early Weichselian ice Dammed Lakes in Northern Russia, EUG 11, Abstract Volume, p. 213.
Jakobsson, M., Murray, A., Backman, J., and Løvlie, R., 2001, Preliminary results from OSL dating supports "high" sedimentation rates on the Lomonosov Ridge, central Arctic Ocean, EUG 11, Abstract Volume, p. 206.

Eurasian Ice sheets project members, 2001, The maximum extent of the Saalian and Weichselian glaciations in Eurasia, EUG 11, Abstract Volume, p. 212.

Mayer

Mayer, Larry, Visions of the Seafloor, invited lecture of the Seacoast Science Center, Hampton, N.H., 18 Jan, 2001

Mayer, Larry, Interactive 3-D Visualization and Exploration of Deepwater Geohazards, Keynote Address, Deep-Sea Geohazards – Offshore Technology Conference, Houston, Texas, 30 April, 2001

Mayer, Larry, The Strataform GIS – invited presentation – Marine Geology and Geophysics Database Management Workshop, 15 May, 2001, La Holla California

Mayer, Larry, Future Directions in Seafloor Mapping and Visualization, Univ. of Mass. Seminar Series, 17 May, 2001

Mayer, Larry, Melvin, Gary, Li Yanchao, and Cochrane, Norm, Multibeam Sonars: Applications in Fisheries Research, Invited Tutorial, Acoustical Society of America Annual Meeting, Chicago, Ill., 4 June 2001

Mayer, Larry and Calder, Brian, Mapping and Visualizing Uncertainty in Multibeam Sonar Data, ONR Uncertainty DRI Meeting, Seattle, WA, 27June 2001

Ware

Ware, C. (2001) Technical Univerisity of BC. Vision Science, Visual Space and Visualization, June 22.

Ware, C. (2001) June 8 Washington. Mitre Corp. Vision Space and Information Visualization.

Ware, C. (2001) Vision Science, Visual Space and Visualization, AT&T Labs Visualization Days Invited Keynote. May 31.

Ware, C. (2001) Designing for the Human Visual System. Documentation and Training Workshop. Boston University. Invited Keynote. April 9

Ware, C. (2001) What Can Perception tell us about Visual Languages and the Display of Information Structures. University of Memphis. April 23.

Ware, C. (2001) Vision Science, Visual Space and Visualization. Presented to the Greater Boston Computer-Human Interaction Society. Feb 14.

Posters:

Calder

AGU Spring. Poster on Arctic error modeling.

Cutter

Geological Association of Canada Meeting, special session on The Geology of Marine Habitat, 27-31 May 2001. Poster presentation.

Marine Benthic Ecology Meeting, 16-18 Mar. 2001. Poster presentation, title: Seafloor video mosaicing for benthic habitat mapping at LEO-15. R. Cutter, Y. Rzhanov, R. Diaz, K. Able.

Presentations:

Armstrong

Presentations on JHC/CCOM to SW Florida Chapter of UNH Alumni Association in Naples and Sarasota, FL.

Presentation at Interagency (NOAA, State, NIMA, USGS, MMS, Arctic Research Commission) meeting on JHC capabilities and issues related to Article 76 of LOS, in Silver Spring, MD, Feb. 14.

Presentation to Pinkerton Academy high school on ocean mapping, April 11.

Presentation on UNH/NOAA graduate program in ocean mapping to FIG/IHO Board, Trieste, Italy, May 3 - 9.

Arsenault

Work with realtime data display with GeoZui3D has led to the development of a hybrid quadtree/linked-list structure for efficiently creating a growing surface from collected soundings. The paper "Real time 3D display of hydrographic data for QA and QC." was written and presented at USHydro 2001 in Norfolk Va.

Calder

Hydro 2001. Presented paper on basic bathymetric processing methodology.

IBCAO Editorial Board Meeting. Presented paper on Arctic error modeling.

Dijkstra

Dijkstra, Semme, Ray Grizzle, Larry Ward, “Initial Presentation of Data in the New Hampshire Great Bay/Piscataqua River System, Oyster (*Crassostrea virginica*) populations Mapping Project”. 2001 GAC/MAC Conference, St. John, Nfld. Canada

“TracEd: A Remote Acoustic Seafloor Characterization System for Use with Vertical Incidence Echosounders” 2001, Sea Technology Magazine

Mapping of Oyster Reef of Adams Point/Great Bay – Results presented at GAC/MAC conference – based on this work further work will be done in cooperation with UNH’s Jackson Estuarine Laboratory, the New Hampshire Fish and Game Department and the New Hampshire Department of Environmental Services.

Gardener

Attended Mapping Seafloor Habitats Conference at Menlo Park, CA in April, 2001. Presented an invited talk on "Mapping the seafloor with multibeam echosounders".

Attended the SEDRIS conference at South Lake Tahoe, CA in May, 2001. Presented an invited talk on Mapping Lake Tahoe.

Presented talk on Mapping southern Puget Sound delta fronts to invited State of Washington and local Washington agencies and NOAA personnel, Seattle, WA in April 2001.

Presented an invited talk on Mapping Lake Tahoe to SEDRIS conference, May, 2001.

Hou

Giving a formal presentation with the topic of 'High-Frequency Multibeam Data Processing –SAX99' authored by Tianhang Hou, Larry Mayer and Lloyd Huffat the FEMME 2001.

Summated a paper and gave a formal presentation with title 'Automatic Detection of Outliers in Multibeam Echo Sounding Data' authored by Tianhang Hou, Lloyd Huffand Larry Mayer at US Hydro Conference 2001 in Norfolk, Virginia. A quite few people showed their interests after our presentation on the conference.

Huff

Presented a paper at the HYDRO 2001 Conference that was held at the University of East Anglia, UK 27-29 March 2001. The paper was titled "Processing Algorithms to Aid in the Interpretation of Hydrographic Data".

Jakobsson

Jakobsson, M., and Calder, B., 2001, Error estimation of the International Bathymetric Chart of the Arctic Ocean (IBCAO) at Arctic GIS Workshop, Seattle.

Jakobsson, M., Calder, B., Mayer, L., and Armstrong, A., Error estimation of bathymetric grid models derived from historic and contemporary datasets at U.S. Hydro 2001 conference Abstract CD, 12 pp.

Jakobsson, M., Calder, B., Mayer, L., and Armstrong, A., 2001, On the Estimation of Errors in Sparse Bathymetric Geophysical Data Sets, EOS Transactions, American Geophysical Union, Boston, Massachusetts May 29-June 2, v. 83.

The National Science Foundation sponsored a workshop, held in Seattle 22-24th of January, on Arctic Geographic Information Systems. I was invited to give a presentation about the IBCAO project. The title of my presentation was: "GIS Tools for Collecting and Accessing Arctic Bathymetry: International Bathymetric Chart of the Arctic Ocean (IBCAO)"

Plumlee

AT&T Visualization Days. Presented a demo of GeoZui3D

Rzhanov

Presented paper at Fifth Underwater Science Simposium (Southampton, UK, March 2001): "Underwater video mosaicing for rapid seabed mapping", Y Rzhanov, R Forbes, H Mair, I Oxley (actual presentation was made by Colin Ware).

Accepted paper at the ISSPA2001 conference: "Improvement of Image Alignment Using Camera Attitude Information" Y Rzhanov, L Huff, G R Cutter, Sixth International Symposium On Signal Processing and Its Applications, Kuala Lumpur, Malaysia

Accepted paper at the ICIP2001 conference: "SENSOR-ASSISTED VIDEO MOSAICING FOR SEAFLOOR MAPPING: Y Rzhanov, G R Cutter, L Huff, International Conference on Image Processing, Thessaloniki, Greece