Performance and Progress Report:

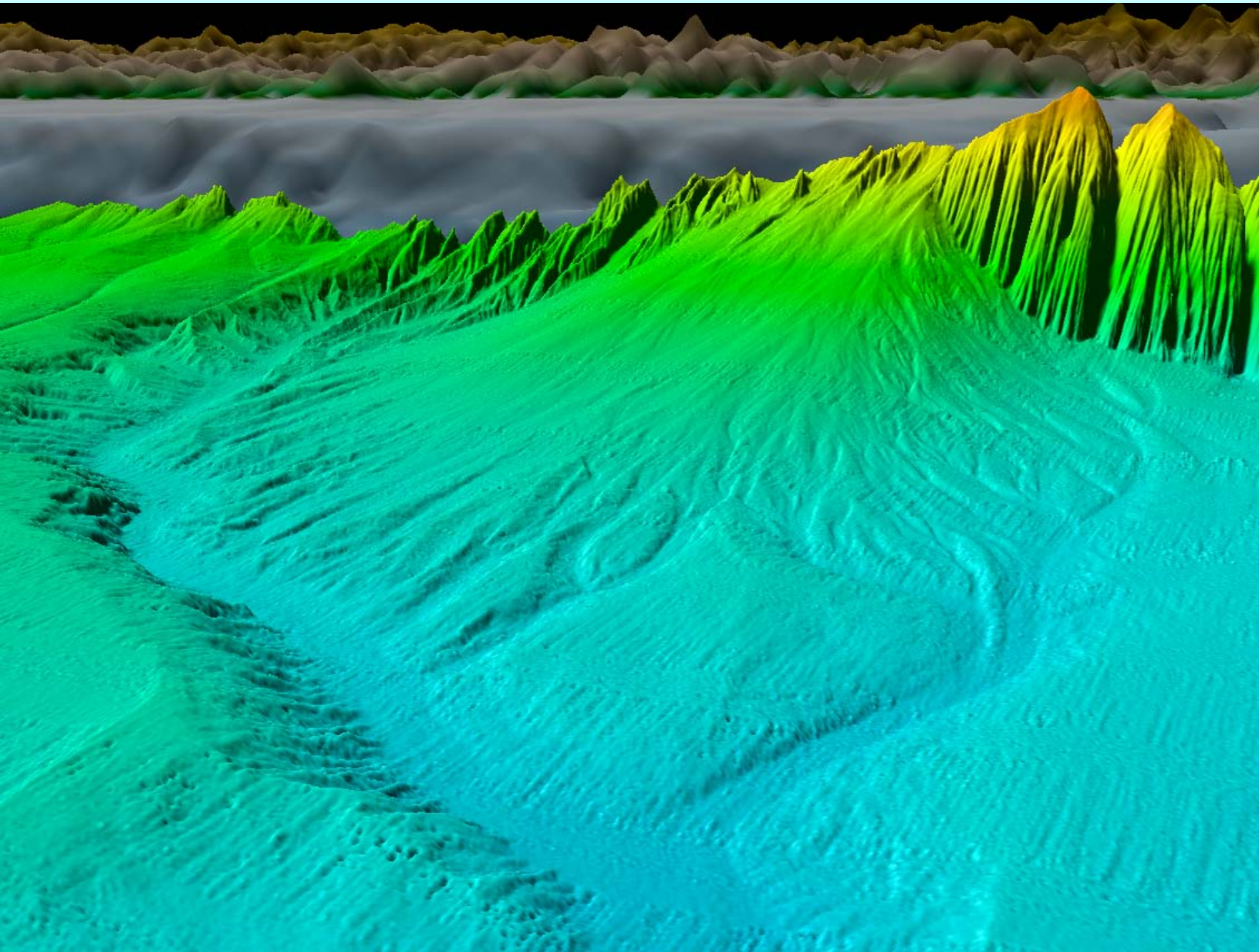
UNH/NOAA Joint Hydrographic Center

NOAA Ref No: NA17OG228

Report Period: 01/01/2005 – 12/31/2005

Project Title: Joint Hydrographic Center

Principal Investigator: Larry A. Mayer



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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 tenth in a series of what were until, December 2002, bi-annual progress reports. Since December, 2002, the reports have been produced annually; this report highlights the activities of the Joint Hydrographic Center during the period between 1 January and 31 December, 2005.

INFRASTRUCTURE:

Personnel*:*

The success of any organization will be dependent on 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. In 2003 **Dr. James V. Gardner**, a world-renowned marine geologist and leader of the USGS Pacific Mapping Group, retired from the U.S.G.S. and joined the Center as a research faculty member. In 2004 **Nathan Paquin** began a full-time position as our computer system manager and **Jim Case** joined our staff as a database specialist. Following his retirement from NOAA, **Dr. Lloyd Huff** joined our research faculty and **David Monahan** joined our faculty as Program Director for the GEBCO Bathymetric Training Program (funded by the Nippon Foundation). In 2005,

additions to our staff included **Brian Locke** as a programmer/information technologist, **Briana Sullivan** as a programmer and outreach specialist, **Shachak Pe'eri** as a post-doctoral scholar focusing on LIDAR issues, and **Will Fesenden** as our assistant system manager.

Faculty:

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.

Brian Calder has a Ph.D in Computing and Electrical Engineering, completing his thesis on Bayesian methods in sidescan sonar processing in 1997. Since then he has worked on a number of signal processing problems, including real-time grain size analysis, seismic processing, and wave-field modeling for shallow seismic applications. His research interests include methods for error modeling, propagation and visualization, and adaptive sonar backscatter modeling. 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. Dr. Calder is an Asst. Research Professor with the Center and the Dept. of Electrical Engineering focusing on statistically robust automated data cleaning approaches and tracing uncertainty in hydrographic data.

Jim Gardner is a world-renowned marine geologist and was leader of the USGS Pacific Mapping Group. He retired from the USGS and joined the center in the late summer of 2003. He presently is also an Emeritus Senior Geologist with the USGS, as well as an Honorary Associate in the School of Geosciences at the University of Sydney, Australia. 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. At the Center, Jim is a Research Professor with the Center and the Depts. Of Ocean Engineering as well as Earth Sciences. He is leading our field efforts in support of Law of the Sea studies.

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.

Larry Mayer, is Director of the Center for Coastal and Ocean Mapping and Co-Director of the Joint Hydrographic Center. Larry's faculty position is split between the Ocean Engineering and Earth Science Departments. He 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 worldwide reputation for innovative approaches to ocean mapping problems.

Dave Monahan is our new Program Director for the Nippon Foundation General Bathymetric Chart of the Oceans (GEBCO) training program in oceanic bathymetry. Prior to joining CCOM, he served 33 years in the Canadian Hydrographic Service, working his way down from Research Scientist to Director. During that time, he established the bathymetric mapping program and mapped most Canadian waters, built the Fifth Edition of GEBCO, led the development of LIDAR, developed and led the CHS Electronic Chart production program, and was Canadian rep on a number of International committees and boards.

Christian de Moustier is the newest addition to the faculty of the Joint Hydrographic Center/Center for Coastal and Ocean Mapping. His Professor 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.

Yuri Rzhanov, with a Ph.D. in Physics and Mathematics, is an Associate Research Faculty member in the Center and in the Dept. of Ocean Engineering. 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.

Colin Ware, is Director of the Center's Data Visualization Research Lab and a Professor in 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.

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

NOAA Employees:

Capt. Andrew Armstrong, Co-Director of the JHC, Captain Armstrong recently retired as an officer in the National Ocean and 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.

John "CAPT Jack" McAdam is Executive Director for Wage Mariner Activities NOAA Marine and Aviation Operations. He graduated From Massachusetts Maritime Academy in 1972 and sailed on NOAA Fisheries vessels for 32 years as a civilian wage mariner starting as a Second Mate on the Oregon II in Pascagoula, MS and ending as Master of the Albatross IV in Woods Hole. In April 2005 he started his present position, as an advocate for the civilian wage mariners who sail on the 18 NOAA vessels and liaison between NOAA's wage mariner employees, Marine Operations Center management, and NOAA's Workforce Management Office. One of his duties will be to provide the NOAA/UNH Joint Hydrographic Center with assistance in creation of a port office in preparation for deployment of a SWATH vessel to be home-ported at Newcastle, New Hampshire.

Dr. John G.W. Kelley is a research meteorologist and coastal modeler with NOAA/National Ocean Service's Marine Modeling and Analysis Programs within the Coast Survey Development Lab. John has a Ph.D. in Atmospheric Sciences from Ohio State Univ. and a M.S. in Meteorology from Penn State Univ. He is involved in the development and implementation of NOS' operational numerical ocean forecast models for estuaries, the coastal ocean, and the Great Lakes. He is also PI for nowCOAST, a NOAA Web mapping portal to real-time coastal observations and forecasts. John will be working with CCOM/JHC personnel on developing the capability to incorporate NOAA's real-time gridded digital atmospheric and oceanographic forecast into the next generation of NOS nautical charts.

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.

Since the end of its first year, the Center has had a program of visiting scholars that allows us to bring some of the top people in various fields to interact with Center staff for periods of between several months and one year:

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.

Ron Boyd (July – December 2003) spent his sabbatical at the Center. Ron is a professor of marine geology at the University of Newcastle in Australia and an internationally recognized expert on coastal geology and processes. Ron efforts at the Center focused on helping us interpret the complex, high-resolution repeat survey data collected off Martha's Vineyard as part of the ONR Mine Burial Experiment.

John Hall (August 2003 – Oct 2004) also spent his sabbatical from the Geological Survey of Israel with the Center. John has been a major player in the IBCM and GEBCO compilations of bathymetric data in the Mediterranean, Red, Black and Caspian Seas and is working with the Center on numerous data sets including multibeam sonar data collected in the high Arctic in support of our Law of the Sea work. He is also archiving the 1962 – 1974 data collected from Fletcher's Ice Island (T-3).

LCDR Anthony Withers (July – Dec 2005) was the Commanding Officer of the HMAS Ships LEEUWIN and MELVILLE after being officer in charge of the RAN Hydrographic School in Sydney Australia. He also has a Masters of Science and Technology in GIS Technology and a Bachelors of Science from the University of South Wales. LCDR Withers joined us at sea for the Law of the Sea Survey in the Gulf of Alaska and upon returning to the Center focused his efforts on developing error models for phase comparison sonars.

Research Scientists and Staff:

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.

Semme Dijkstra holds 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. 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.

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. Gareth returned to his native Scotland in the summer of 2005.

Luciano Fonseca received an undergraduate degree in University of Brasilia and his Ph.D. from the University of New Hampshire (he was the first PhD produced by the Center). Luciano's research is focused on developing tools for extracting quantitative seafloor property information from multibeam backscatter and on database support. He

is supported by the ONR Geoclutter Program a project aimed at understanding how multibeam backscatter may be used to remotely predict seafloor properties. The work is focused on local sites (Portsmouth Harbor and Great Bay) where we can take advantage of the Shallow Survey 2001 "common data set" and easily collect ground truth data.

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.

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. Dr. Jakobsson returned to a prestigious professorship in his native Sweden in April 2004 but will remain associated with the Center and continue to work here during the summers.

Barbara Kraft 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 and RIPPLES programs analyzing *in situ* measurements of seafloor acoustic properties and on upgrading our acoustic tank facilities.

Brian Locke has an M.S. in Engineering Mechanics, a B.S. in Physics, and a B.S. in Computer Science. He started his career as a Materials Engineer at BFGoodrich Aerospace's Aircraft Sensors Division in Burnsville, MN, where he developed and evaluated ceramics, metals, and plastics for use in pressure, temperature, and icing sensors. More recently, he worked as a Software Engineer at Enterasys Networks in Andover, MA. At Enterasys Networks, Brian developed network management software in C++ and Java, creating innovative user interfaces and network management algorithms. Brian's interests include application and system architecture, software project management, user interface design, and algorithms.

Andy McLeod Andy is our 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 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.

Nathan Paquin joined the Center in 2004 taking responsibility for the daily maintenance and upkeep of our ever-growing computer facilities. Nathan comes from a strong background in computing initially gained while serving in the U.S. Army and being responsible for providing secure servers and clients. This experience was expanded through work in the industrial sector for numerous small and large IT companies.

Shachak Pe'eri received his Ph.D. and M.Sc. from the Tel Aviv University in Geophysics. His Ph.D. research was on the monitoring the current uplift and deformation of Mt. Sedom salt diapir using Ineterferometric Synthetic Aperture Radar (InSAR). The research was done with Stanford University and the Hebrew University of Jerusalem. His M.Sc. research was measuring the current plate motion across the Dead Sea Fault using continuous GPS monitoring. Dr. Pe'eri's areas of interest are: Remote Sensing, Geophysics and Geodesy. Currently he is focusing on the Acoustic-LIDAR inter-comparisons.

Matt Plumlee became a research scientist with the Center after completing his Ph D. at UNH under Dr. Colin Ware. Matt is continuing his work on data visualization and human computer interaction focusing his efforts on the Chart of the Future project.

Ben Smith, is the Captain of CCOM-JHC research vessel *Coastal Surveyor*, and a research technician specializing in programming languages and UNIX-like operating systems and services. He has years of both programming and marine experience and built and captains his own 45 foot ketch , *Mother of Perl.*

Briana Sullivan received her undergraduate degree in Computer Science at the University of Massachusetts, Lowell in 2002 and finished her master's in computer science at UNH in 2004. She is now employed at CCOM full-time with two major responsibilities. The first one is in the Data Visualization Research Lab where she is currently working on human factors research and the chart of the future. Her second responsibility is being the CCOM outreach coordinator. In this capacity she is in charge of informing the public of the work going on here at CCOM-JHC. This is done through the design and maintenance of the web-site, adding an outreach section to the web-site (coming soon), and helping design and build museum exhibits for marine/science centers.

In addition to the academic, research and technical staff, **Abby Archila** and **Linda Prescott** are our Program Managers and keepers of order with the able assistance of **Lisa Czekanski**.

Facilities and Equipment:

With the startup of the Center, the University provided a new 8000 square foot building. Given the very rapid growth of the Center, space became the limiting factor in our ability to take on new projects. In 2003 we expanded into the second floor of the new building providing greatly needed additional office, graduate student and meeting space.

Our computing facilities have continued to grow in order to keep up with our expanding research team. We have added two new dedicated servers (one as a web/collaboration server, and the other as a domain controller for our new Active Directory domain) and an additional Network Attached Storage (NAS) device to bring our total raw storage capacity to more than 12 Terabytes and the total number of servers to 14. Our servers are consolidated into three full height cabinets with one Uninterruptible Power Supply (UPS) per cabinet. We have also deployed UPS's to all mission critical workstations. The interface between our internal gigabit local area network (LAN) and the internet is now protected by two NitroSecurity Intrusion Prevention Systems (IPS) and our existing Linux based firewall. We also have an SGI O2 workstation, 107 high-end Windows XP and Linux workstations and laptops, and several Macintosh G4's. We have established gigabit Ethernet connectivity in every office in the lab implemented on our own network equipment for enhanced speed, security and management. Two new enterprise-level Cisco wireless access points have been deployed to provide wireless internet connectivity for employees and visitors. In addition to enterprise level anti-virus scanners deployed to all computer systems in the Center, all inbound and outbound traffic is routed through our firewall and the two IPS devices where it is interrogated for malicious content (Fig. 1). A computer classroom has been created and populated with ten small form factor computer systems. All training that requires access to computers is now conducted there. Our research vessel, the Coastal Surveyor has been retrofitted with a new Dell Poweredge server and new radar and GPS LCD displays. A gigabit Ethernet network has also been deployed on the vessel to ensure increasingly demanding data transmission rates are sustained.

We have a full suite of printers and plotters including both 48 and 60 inch large format color plotters. Through the generous donation of visiting scholar Dr. John Hall, we also have a 54 inch wide, continuous feed, high-resolution scanner. All computers and peripherals 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. Recently written tapes are held in a fire-safe, while archived datasets are now sent offsite to an Iron Mountain data protection facility where they are stored in an environmentally controlled vault. In addition to our current DLT robotic tape changer, our tape backup system has been vastly improved with the installation of an LTO3 robotic tape changer. This unit can handle up to 25, 500GB tapes, while writing to two tapes simultaneously at a rate of nearly one terabyte per hour. We have implemented a real-time log monitoring, filtering, and forwarding system to ensure 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. A full suite of peripherals (4mm, 8mm, DLT, LTO and DVD±R) are available so that we can re-distribute the data on a range of media.

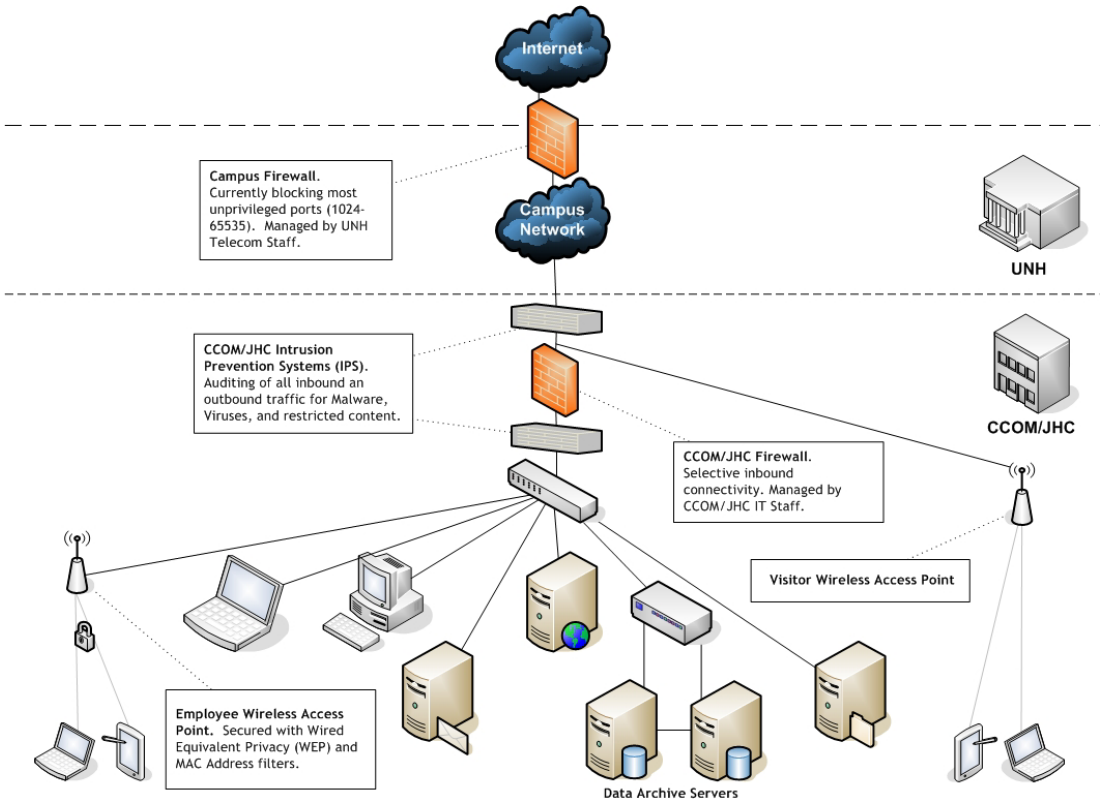

Fig. 1. Current topology of JHC computer network

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. **C&C Technologies** also kindly donated a C-Nav commercial GPS correction system to the Center. The *Coastal Surveyor* has seen heavy use supporting

both research and class work, in each of the five 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, a Digibar sound speed calibration system, and Vitel and Aandera tide gauges. We have also acquired a Knudsen 50 and 200 kHz chirp sounder, and a POS-MV320 inertial motion sensor. In addition **TSS** has donated a TS-335B motion sensor and **ODOM** has donated an Echotrac CV3 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 other camera techniques (Huff).

We have also completed acquisition of a suite of RTK GPS receivers and radio modems and established a PPK base station in Hampton Harbor. Originally installed in support of our Hydrographic Field Course, the phase differential base station has remained on site providing continuous GPS phase data from this site. With these systems we can now do all local surveying to Kinematic GPS accuracies.

Finally, we have completed construction and initial outfitting of an electronics workshop under the supervision of Andy McLeod and a complete machine shop under the supervision of Paul LaVoie.

Educational Program:

The Center has, under the guidance of Capt. Armstrong, has developed an ocean-mapping specific curricula that have been approved by the University. We offer both M.S. and PhD degrees with a specialization in Ocean Mapping through the Dept. of Ocean Engineering, the Dept. of Earth Sciences (now expanded to include the School of Natural Resources), the Dept. of Electrical Engineering , the Dept. of Computer Science, or 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 or Earth Science programs, engineers entering through Ocean or Electrical Engineering programs, and computer scientists through the Computer Science program.

We have also established a post-graduate certificate program in Ocean Mapping. This one-year program has a minimum set of course requirements that can be completed in one year and allows post-graduate students who cannot spend the two years necessary to complete a master's degree a means of upgrading their education and receiving a certification of completion of the course work. The first student (from NIMA – now NGA) started in the certificate program in September 2003.

In 2004 the Center was selected through an international competition (which included all of the leading hydrographic education centers in the world) to host the Nippon Foundation/GEBCO Bathymetric Training Program. UNH was awarded $1.6 M from the Nippon Foundation to create and host a one-year training program for seven international students (initial funding is for three years). Fifty-seven students from 32 nations applied and in just 4 months (through the tremendous cooperation of the UNH Graduate School and the Foreign Students Office) seven students were selected,

admitted, received visas and began their studies. This first class has graduated (receiving a "Certificate in Ocean Mapping" and we are now hosting our second class of GEBCO students. These students have added a tremendous dynamic to the Center both academically and culturally. Funding from the Nippon Foundation has allowed us to add Dave Monahan to our faculty in the position of program director for the GEBCO bathymetric training program. Dave brings years of valuable hydrographic, bathymetric and UNCLOS experience to our group and, in the context of the GEBCO training program has added several new courses to our curriculum.

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, SAIC, GEBCO, IBCAO, IVS, the Seabottom Surveys Panel of the U.S./Japan Cooperative Program in Natural Resources (UJNR), FIG/IHO, NAVO, NOAA, USGS). 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. Particularly important have been visits to the Center by a number of members of NOAA's Coast Survey Development Lab (in order to explore research paths of mutual interest) and the visit of 40 NOAA scientists to discuss NOAA priorities for multibeam sonar systems and surveys as part of a NOAA Multibeam Workshop.

Finally and most importantly, our program was given a **Category A certification by the FIG/IHO International Advisory Board of Standard of Competence for Hydrographic Surveyors** at their annual meeting in May 2001.

While our students have a range of more general science and engineering courses to take as part of the Ocean Mapping Program, the Center teaches several courses specifically designed to support the Ocean Mapping Program.

JHC – originated Courses

Course	Instructors
Introduction to Ocean Mapping	Armstrong, de Moustier, Mayer
Ocean Bathymetry	Monahan
Ocean Mapping Tools	Monahan, Gardner, Kraft, and others
Hydrographic Field Course	Armstrong
Marine Geology and Geophysics	Mayer and Gardner
Environmental Acoustics (I & II)	de Moustier, Baldwin
Data Structures	Ware
Data Visualization	Ware
Seafloor Characterization	Mayer, Calder, de Moustier
Geodesy and Positioning for OM	Wells, Dijkstra, Huff
Special Topics: Law of the Sea	Monahan

We have 25 students currently enrolled in the ocean mapping program, including the GEBCO students, one NOAA Corps officer and two NOAA physical scientists; we have already produced four Ph.D's: (Luciano Fonseca (2001); Anthony Hewitt (2002); Matt Plumlee (2004) and; Randy Cutter (2005). This past year we have graduated five more Masters students including another NOAA Corps Officer, Rick Brennan.

Student	Program	Advisor
Daniel Brogan	M.S. EE	de Moustier
Chuck Carline	M. Sc. EE	Calder/de Moustier
Rebecca Conrad	M.Sc. OE	Huff
Randy Cutter	PhD, E. Sci.(rcvd – June05)	Mayer
Gerd Glang (NOAA)	M.S., OE	Huff
Jim Glynn	M.S. EE	de Moustier/Huff
Fan Gu	M.Sc., EE	Rzhanov
Tianhang Hou	Ph.D. OE (PT)	Mayer, Huff
Gretchen Imoahori (NOAA)	M.Sc, E.Sc	Huff
Mike Leo	Ph.D. E. Sci.	Huff
Hugo Montoro	M.S. ESc.(rcvd Dec 05)	Armstrong/Mayer
Anton Mamaenko	M.S. O.E.	Rzhanov
Mashkoor Malik	M. S. OE (rcvd June 05)	Mayer
Mashkoor Malik	PhD. ESc.	Mayer, Calder
Peter Mitchell	M. S. C. Sci.	Ware
Karthikeyan Natham	M. S. C. Sci. (rcvd June05)	Ware
Chris Plumlee	M. S. EE	Calder
Matt Quinn	Ph.D. C. Sci (rcvd June05)	Ware
Lorraine Robidoux (NOAA)	M.S. O.E	Armstrong/Mayer
Luis Ruis	M.Sc. E.Sc.	Mayer
Stephan Schaeffer	Ph. D. C. Sci	Ware
Val Schmidt	M. Sc. OE	de Moustier/Mayer
Ed Sweeney	M.Sc. E.Sc	Gardner, Johnson

GEBCO Students: (2005-6)

Student	Institution	Country
Muhammad Bashir	Navy Hydrographic Dept.	Pakistan
Jorge Luis Heredia Bustamante	Navy Hydrographic Dept.	Mexico
Djoko Hartoyo	Agency for Tech Assessment	Indonesia
Apolonio Monreal Lagonsin	Nat. Mapping and Resource	Philippines
Tsuyoshi Yoshida	Coast Guard	Japan

STATUS OF RESEARCH: JAN – DEC. 2005:

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. As our research has progressed and evolved, the clear boundaries of between these themes have become more diffuse. For example, our data processing efforts (e.g. CUBE) are evolving into our data fusion and chart of the future efforts. The data fusion and visualization projects are also blending with our seafloor characterization and chart of the future efforts as we begin to define new sets of "non-traditional products." This is a natural (and desirable) evolution that slowly changes the nature of the themes and the thrust of our efforts. Nonetheless, for consistency, we will use the original theme categories to review our progress as well as introduce progress made in several new initiatives.

INNOVATIVE SONAR DESIGN AND PROCESSING FOR ENHANCED RESOLUTION AND TARGET RECOGNITION:

We continue to make progress in the upgrades to our sonar calibration facility (funded in part by NSF), now one of the best of its kind in New England, The facility is now equipped with a rigid x, y positioning system, computer controlled transducer rotor (with resolution of 0.025 degree) and custom built data acquisition system. Barbara Kraft and Glenn McGuillicuddy have reworked the software used for calibration. Measurements that can now be completed include transducer impedance (magnitude and phase) as a function of frequency, beam patterns (transmit and receive), open circuit voltage response (receive sensitivity), and transmit voltage response (transmit sensitivity). In addition, the A/D channel inputs have been optimized as a function of beam angle and the cross-correlation and RMS levels of the transmitted and received channels can be computed in real-time.

In addition graduate student Chuck Carsline, working under the supervision of Chris de Moustier, has been developing a precise positioning system for the x,y table that positions the transducers being calibrated. At present he is able to measure the position of one axis of the within 2 mm. The approach will now be expanded to all six axes necessary for complete and precise positioning of the transducer.

In past year the calibration facility was used to better understand capabilities of a number of sonars including:

SSPARR: (Seafloor Sounding in Polar and Remote Regions) a 12 kHz sonar to be deployed from autonomous buoys that are frozen into the ice pack to collect depth and position information that is transmitted by Iridium phone back to the lab. This is an NSF-funded collaboration between Lamont Doherty Earth Observatory, Univ. of Hawaii, and the Center.

Various Airmar transducers, Wesmar sidescan staves: these transducers are used in the lab for calibration and acoustics lab experiments.

ORION Diver pingers: These transducers are being calibrated to understand their potential for an ultra-short baseline acoustic tracking system under development by Chris de Moustier and Ward Testa from NOAA NMFS. The ultimate objective of this tracking system is to be able to track marine mammals.

ISSAP: (In-situ Sound Speed and Attenuation Probe) small transducers that are used on a larger instrument package to make *in-situ* measurements of seafloor acoustic properties that we use to "ground-truth" our sonar backscatter and seafloor characterization studies.

WASSP: (Wide Angle Sonar Seafloor Processor), a new, inexpensive, New Zealand-designed (by industrial associate ENL), multibeam sonar that is currently under development in cooperation with the Center (Chris de Moustier). The results of this calibration led to several redesigns by the manufacturer and subsequent field trials by Center personnel in Little Bay and Portsmouth Harbor. During these trials the system was, for the first time, integrated with motion sensors and positioning systems. As a result of these tests the sonar's timing accuracy was upgraded to 1 ms, allowing the level of position and motion sensing accuracy needed for hydrographic applications. We have also made progress on the development of improved bottom detect algorithms for the sonar. We continue to be encouraged by the potential of this relatively inexpensive sonar (target price ca. U.S. 25K) to produce data of use to a variety of NOAA applications.

*KLIEN 5410***:** Lloyd Huff has taken the lead in the test and evaluation of the Klein 5410, the interferometric version (capable of measuring depth as well as backscatter) of Klein's very successful 5000 series sidescan sonar. Initial tests involved the newly installed fiber optic interface. These tests, which included interconnecting power and communications between the topside processing unit and the towfish through 1200 m of fiber optic tow cable and a fiber optic slip ring, proved successful. Using a special adapting mechanism provided by Klein Associates, the sonar was brought into our test tank to measure the beam patterns of the transducers. The beam pattern measurements made by graduate student Jim Glynn under the supervision of Chris de Moustier produced a set of tank-calibrated measurements of differential phase vs. angle of arrival for three pairs of transducers per side. These calibrations revealed problems with transducer elements and array configuration. Simulations have been conducted to determine optimum design of the bathymetry channels and the specifications have been given to Klein who will fabricate new arrays. Models for the phase response of the bathymetry channels have also been generated and compared (favorably) to measured phase response of the system. The system was further tested in the course of our Summer Hydrography Field Class. As a result of these trials, the towfish and topside processing unit have been upgraded to ensure that they work with a Sonardyne Model 7970 transponder beacon and Sonardyne FUSION USBL tracking system. These modifications are essential for NMFS to be able to use the 5410 during their upcoming (July - August 2006) field season in the Bering Sea.

Also with respect to the Klein series of sonars is an effort underway to improve tow-fish stabilization by graduate student Beckie Conrad under the supervision of Lloyd

Huff. This effort is focusing on a dynamic stabilizing tail for the Klein 5000 series of sonars partially developed by the Royal Australian Navy. The Boeing Australia Stabilizing Tail (BAST) which was never completed by the Australians has been sent to the Center for further development and testing, as stabilization of tow fish "flight patterns" is of significant interest to NOAA and all users of high-speed sidescan sonars. Since arrival at the Center, the BAST has been outfitted with electronics to control communications and put through a sequence of tests including bench tests, tow-tank tests and field tests. The test data is being processed and compiled into a family of curves that relate towfish pitch angle, tow speed and control surface angle. A master look-up-table is being prepared that will allow design of a neural network controller that can automatically stabilize the tow characteristics of the sonar.

Finally, Dan Brogan has worked with Chris de Moustier on an NRL-sponsored project to further develop the capabilities of a volume search sonar for the AQS-20 system. A phase comparison bottom detection technique has been developed using groups of 2, 3, 4, or 6 beams. The technique increases the sampling density to nearly six times that of conventional magnitude-based detection techniques and effectively creates a 3-D patch of detected seafloor depths for each ping.

NEW APPROACHES TO MULTIBEAM AND SIDESCAN SONAR DATA PROCESSING:

IMPROVED BATHYMETRIC PROCESSING:

CUBE and Improved Uncertainty Management:

One of the major efforts of the Center has been to develop improved data processing methods that can 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" at NOAA, NAVO, and hydrographic agencies and industries worldwide. We have explored a number of different approaches for automated data processing (see earlier progress reports for descriptions of these approaches) and, over the past two years 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. When the automated editing technique fails to make a statistically conclusive decision, it will generate multiple hypotheses, attempt to quantify the relative merit of each hypothesis, as well as present them 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.

In 2003, CUBE was subjected to detailed verification studies in a cooperative research effort with NOAA that 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. Based on these verification trials and careful evaluation, Capt. Roger Parsons, director of NOAA's Office of Coast Survey has notified NOAA employees as well as other major hydrographic organizations in the U.S. (NAVO and NGA) of NOAA's intent to implement CUBE as part of standard NOAA data processing protocols. As described by Capt. Parsons in his letter to NAVO and NGA, CUBE and its sister development The Navigation Surface (see below) "*…promise considerable efficiencies in processing and managing large data sets that result from the use of modern surveying technologies such as multibeam sonar and bathymetric lidar. The expected efficiency gains will reduce cost, improve quality by providing processing consistency and quantification of error, and allow us to put products in the hands of our customers faster."*

In light of NOAA's acceptance of CUBE, most providers of hydrographic software are now implementing CUBE into their software packages (CARIS, IVS, SAIC, Kongsberg-Simrad, Triton-Imaging, Reson, QINSy, Fugro, GeoAcoustics and Sonartech Atlas). Dr. Calder continues to work with these vendors to ensure a proper implementation of the algorithms as well as working on new implementations and improvements. In particular, work is underway with GeoAcoustics to extend the principles of CUBE to phase comparison bathymetric sonars and based on a review of the implementation of CUBE on the NOAA vessel THOMAS JEFFERSON, to improve the uncertainty propagation equation for very shallow water and ultra-high resolution sonars. The phase comparison model was tested on trial data collected during NOAA's Phase Measurement Bathymetry Sonar trials held in Patuxent, MD. This trial was the outgrowth of NOAA student Caleb Gostnell's research project at the Center. The result of the certainty dilution study has been the development of a non-linear Chebyshev approximation method that significantly improves the fidelity of the uncertainty propagation.

Inherent in the CUBE approach is the need for a robust error model for the sonar being used. This model should be provided by the manufacturer but unfortunately only a few manufacturers publish an error model for their system. In an attempt to develop approaches to extracting an error model from an undocumented sonar as well as checking the manufacturer-provided models, Calder and graduate student Mashkoor Malik have been exploring field calibration methods for extracting error models directly from data. This approach has been applied to an EM3002 with POS/MV and C-Nav and appears to give realistic uncertainties, but further work is required. Within this context, Calder has also developed an "Uncertainty Patch Test" proposal – a methodology for capturing the data required to determine the uncertainties associated with a particular survey system. The proposal consists of a series of survey lines, much like a patch test, designed to

isolate (as much as is possible) one component of uncertainty for each line or line-pair. Malik and Huff have developed an interative approach that uses CUBE to minimize errors within a patch-test data set that has demonstrated a reduction of 5 – 20 percent in uncertainty. Additionally, Calder continues to work with Reson to develop an error model for their presently undocumented 8100 series sonars (many of which are used by NOAA) and has developed uncertainty models for auxiliary sensors on the survey vessels RAINIER and HI'IALAKAI in response to a specific request from NOAA.

Through our close collaboration (and shared field efforts) with NOAA hydrographers it has become clear that many of the sonar systems (and particularly the Reson systems) used by NOAA survey vessels suffer from a problem when operated in steeply sloping environments due to limitations in the bottom detection algorithm's ability to deal with low signal to noise ratio situations. Calder has made a concerted effort to address this "Downhill Problem" resulting in several component algorithms that have helped mitigate the problem including a Turning Angles algorithm to utilize phase information in beam-to-beam offset vectors (with ability to run with either GSF or HDCS data). An adaptive fusion system has also been developed to combine the component algorithms' results in order to improve the overall performance of the approach. The fusion algorithm is configured to automatically tune the weighting given to each of the component algorithms in real-time, and then combine them to give a probabilistic estimate of the best solution. In addition to the algorithmic approach to this problem an experiment was developed to determine the consistency of human operator performance on data affected by the downhill problem (so that the performance of the algorithm could be determined). Testing of these approaches on field data has shown that the fused solution is stronger and more robust than the individual component algorithm solutions. The University's Office of Intellectual Property Management has deemed the fusion algorithm (now called MASC'D – Multi-Algorithm Swath Consistency Detector) patentable and has filed an invention disclosure for it.

Another critical component of uncertainty management is the error induced by our ability (or inability) to accurately measure the spatial and temporal variability of the variations in water level due to tidal variations. While we can accurately measure the state of the tide at a single location (where we have a tide gauge), our surveys cover broad areas away from these discrete measurement points. Historically NOAA has used a process of tide-zoning, creating discrete steps in the tide correction in regions between tide gauges. This approach is not compatible with modern multibeam sonars and our ability to make continuous maps of seafloor depths as it creates artificial steps in the bathymetry at zone boundaries. To address this issue NOAA is investigating the use of a sophisticated hydrodynamic model – TCARI – Tidal Constituent and Residual Interpolation – to estimate the state of the tide at any point within a survey area. Graduate student and NOAA Corps Officer Rick Brennan has focused his thesis project on quantifying the uncertainty components of this model. The result of this effort will allow us to use much more realistic estimates when calculating the total propagated error for hydrographic surveys that use TCARI-derived tidal values.

The Navigation Surface and BAG'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 developed the concept of the "Navigation Surface" as part of his thesis work. The Navigation Surface is a database that maintains bathymetric data sets at full resolution and a rule base for producing a series of derived products. Thus a single database 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 a new research effort "The Chart of the Future" described later.

In support of the new adoption of CUBE and the Navigation Surface into NOAA and NAVO processing protocols, the Center has organized and hosted two workshops with industry, government and academic researchers to define and maintain an open format for Navigation Surface products that will ensure interoperability amongst the various vendors and agencies. The first workshop (in 2004) workshop defined the specifications for the Bathymetric Attributed Grid (BAG) Object, and obtained the commitment of many of those attending (NOAA, NAVO, CARIS, IVS, SAIC, 7C's) to provide source code and adopt the approach. Cross platform libraries for digital signatures have been built and tested and an example certificate construction and management scheme (based on HASP network dongles) has been implemented. In 2005, a DLL version of the Open Navigation Surface (ONS) library was created along with a Visual Basic support application to allow demonstration of the security principles of the ONS project in a graphical context. A second meeting of the Open Navigation Surface Working Group (ONSWG) took place in July resulting in a build-out of the source tree for the BAG and the linking of stand-alone applications to read and write BAG-format files. In addition this meeting adopted the digital signature system for BAG's (which supports simple XML files) using both private and public keys, with encryption and thus avoiding the need for hardware tokens. The BAG library was demonstrated at the Shallow Survey 2005 Conference in Plymouth England with trial integrations into IVS Fledermaus, CARIS HIPS, and SAIC SABER software packages. ESRI has now expressed interest in integrating the BAG format into their software (and becoming a member of our Industrial Consortium – see below) and NOAA OCS has recommended the BAG as the transmission form of data from OCS to NGDC. A website for the ONSWG has been established: http://www.opennavsurf.org The first official release of the BAG is scheduled for March 2006.

As a focal point for the broad interest in CUBE and the Navigation Surface 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 facilitate more efficient and collaborative research efforts aimed at solving a national need.

IMPROVED SIDESCAN SONAR AND BACKSCATTER PROCESSING:

Geocoder:

While our initial data processing efforts focused on improving bathymetric processing, it has becoming increasingly clear that there is also a great need for improved processing of backscatter data (both from multibeam sonars and sidescan sonars). With this in mind, we began a new effort aimed at improving the suite of backscatter processing tools available to us and NOAA. Our aim was two-fold: 1- to develop easy to use tools that will generate "pretty" images of sidescan sonar or multibeam backscatter that will be suitable for small object detection as well as geologic and habitat interpretation, and; 2- to develop tools that allow for the quantitative analysis of backscatter data in support of seafloor characterization and small object identification.

In an effort to meet these two objectives, we started a lab-wide effort to develop a new suite of backscatter processing tools. This effort is being led by Luciano Fonseca with input from many others. The goal is to create an integrated suite of tools that will allow us to import backscatter or sidescan data from a number of sensors (in various formats, including Reson snippet data), convert these data to an internal GFS format, correct these data (where possible) for source levels, beam patterns, gains, area ensonified, attenuation, and local slope, and then either analyze and/or display these data in a georeferenced mosaic. A number of modules have now been developed including GEOCODER, a C++ mosaicing tool that now reads directly from GSF or XTF files (including Reson snippet data), corrects data for gains and removes speckle. Data is then geocoded in a projected coordinate system using an interpolation scheme that emulates the acquisition geometry. GEOCODER also serves as the front end for a new approach to using multibeam backscatter data for seafloor characterization called AVO (Amplitude vs. Offset) Analysis. The AVO tool will be reported on in the seafloor characterization section.

In order to better understand the nature of backscatter data collected by NOAA survey vessels as well as to complete the development of the GEOCODER mosaicing algorithms, backscatter data from a Reson 8101 multibeam sonar collected on the NOAA vessel NANCY FOSTER was sent to the Center for analysis. Evaluation of these data revealed a number of issues including differences in acquisition mode, differences in the nature of the "snippet" data vs the sidescan mode of the Reson and changes in gain, power and pulse width. It was unclear from the data provided what corrections had or had not been applied to the data and there were unexplained differences between the apparent affect of gain changes relative to those described in the manuals. The problems encountered with these data led to the design of an experiment conducted jointly between Center personnel and the NOAA ship FAIRWEATHER off Alaska in May 2005 where data was recorded under controlled conditions through a range of gain settings, pulse-widths, etc. GEOCODER was used to quantify the backscatter differences in dB when

acquisition parameters were changed. The result showed that the power and gain settings have linear relationship to the backscatter response but that the measured dependencies were different from those published by the manufacturer. We are working with the manufacturer to resolve these differences. As a result of this wonderful example of collaboration between NOAA and Center personnel, we, and Reson, have learned much about how their sonars actually operate and GEOCODER is now able to fully process both backscatter snippets and sidescan time series acquired by Reson 8101, 8111 and 8160 multibeam sonars. A copy of GEOCODER was left on board the FAIRWEATHER and has been in regular use during hydrographic operations.

Along with the full time series backscatter data from both Reson and Simrad systems, GEOCODER now also fully supports average beam backscatter data from these systems. A feathering algorithm to smooth the transition between overlapping lines has been added along with an anti-aliasing algorithm that makes it possible to produce a lower resolution mosaic that is not degraded by aliasing, a process for slant-range correction based on actual bathymetry, and a trend-adaptive angle-varying gain that helps remove artifacts that appear when different bottom types are found along a single swath. Lines can be removed or remosaicked, and the overlap area between parallel lines can be controlled by filter parameters.

Special attention has been given to correcting for beam patterns. Normally, the empirical beam pattern correction is calculated as the residual necessary to flatten the angular response registered by the sonar system, i.e. to normalize the backscatter at 45 degrees, (sometimes adding a Lambertian correction). The new approach now used by GEOCODER calculates the beam pattern as the residual to the modeled angular response of the ensonified sediment which then reveals the actual non-linearity of the transducer angular response.

GEOCODER also now supports a statistical package that identifies patterns in the backscatter response that can be used in support of seafloor characterization (see below). Statistics calculated for backscatter bins include: mean, mode, range, minimum, maximum, standard deviation, variance, percentiles, quartile range, skewness, kurtosis, moments of any order, and also parameters extracted from a gray level co-occurrence matrix (contrast, homogeneity, dissimilarity, entropy and energy).

Monitoring Fishing Gear Impact:

In another backscatter-related data processing effort, Lloyd Huff and Tianhang Hou have been developing algorithms and software to clean and remove artifacts from Klein 5000 and 5410 sidescan sonar data collected by the Alaska Fisheries Research Center in the Bering Sea TRAWLEX experiments specifically with the goal of identifying fishing gear marks. This is a difficult problem as sidescan sonar data has historically been optimized for qualitative measurements rather than quantitative. In the instance of the TRAWLEX experiments this problem was compounded by the contamination of the background (reference) seafloor corridors by scientific trawls.

In this same context, Mashkoor Malik has developed a series of processing approaches that have led to the clear identification of bottom gear marks in very high-resolution multibeam bathymetric data from Jeffreys Ledge. The bottom gear marks found on Jeffreys Ledge are very subtle (only approximately 3 cm deep) and are thought to be caused by scallop dredges. These subtle bathymetric targets were often obscured by a residual heave artifact. Mashkoor designed a directional filter that was able to suppress the heave artifact and enhance the identification of the bottom gear marks. This will be discussed further in the seafloor characterization section.

NEW APPROACHES TO DATA VISUALIZATION AND PRESENTATION:

GEOZUI-4D:

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, Sullivan, Quinn, and Schaeffer) under the supervision of Lab Director Colin Ware developed 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 evolved to incorporate time-varying data opening up a world of new visualization possibilities evolving into what we now call GeoZui-4D. The GeoZui software 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. The GeoZui-4D task is also blending more and more with the Chart of the Future task – what we call GeoNAV (reported below). We will describe some of the new innovations in GeoZui-4D in this section but those related to the Chart of the Future will be described under that task heading.

AUV Mission Planning and Control:

Whereas much of our visualization effort has been focused on the 3-D interactive display of static features like the seafloor, last year saw the addition of dynamic, time-varying systems. In collaboration with researchers at Woods Hole Oceanographic and Johns Hopkins University, our visualization group is developing 3-D tools for the planning, monitoring and review of Autonomous Underwater Vehicle (SeaBed) and a Remotely Operated Vehicle (Jason II) missions. Progress has been slow owing to difficulties encountered re-engineering the core of GeoZui4D code base. It was found necessary to abandon this effort and start over with a simple, less ambitious solution. A major milestone took place this fall, however, when field trials of GeoZui-4D's AUV software were held aboard the research vessel THOMAS THOMPSON, in conjunction with a SeaBed AUV program of Hanu Singh. During these trials the playback and real-time monitoring capability of the GeoZui-4D were demonstrated. A more important milestone will be the use of GeoZui planning tools to plan an actual SeaBed mission; this

is scheduled for early 2006. We foresee that the techniques developed for these systems will be directly applicable to the newly acquired NOAA REMUS AUV.

Whale Tracking:

Another particularly exciting aspect of GeoZui-4D has been its application to visualizing the underwater behavior of humpback whales supporting both basic science and policy as humpback whales are an endangered species whose major causes of decline are ship collision and fishing gear entanglement. Understanding their underwater behavior is essential to mitigating both of these causes. NOAA and WHOI scientists have developed suction-cup-mounted tags that are attached to a whale and record depth, pitch, roll, and sound for as long as the tag remains on the whale (the record is now 22 hours). Our visualization team has taken these data and created a fully georeferenced 3-D display of the whale's diving and swimming behavior in the context of the bathymetry, other vessels, and ambient sounds. A vessel tracking component has been added that combines digital data from radar and AIS with visual sightings to better understand the effect of vessels on whale behavior. The result has provided unprecedented insight into the diving and feeding patterns of the whales as well as their response to the approach of vessels. Numerous papers on, and demos of, this technology have been presented at both scientific and policy meetings.

Flow Visualization:

The incorporation of flow visualization models into the GeoZui4D environment has opened of a range of applications and interest from ocean and current modelers both inside and outside of NOAA. Our goal is to provide tools that allow both researchers and members of the public to better understand the output from flow models. This is important to NOAA because of the increase in the number and quality of global, ocean, and estuarine flow models. These models are becoming critical to interpreting and generalizing physical oceanographic data, understanding marine ecologies, understanding weather and climate prediction.

The flow visualization work is being carried out by graduate students, Nathan, Quinn, and Mitchell, in collaboration with Ware; partial funding for this work has also been provided by NSF. There are three sub-projects within our flow visualization initiative:

Museum exhibits*:* Following on our successful development of a kiosk-based interactive 3-D museum exhibit for Seacoast Science Center (GeoExplorer) which allows an interactive tour through an immersive 3-D environment up and under the Piscataqua River, stopping at interesting sights along the way, Ware is working on exhibits for both the Smithsonian Museum of Natural History (as part of the work in redesigning the Oceans Hall) and the Seacoast Science Center (with Ata Bilgili: formerly of Dartmouth College. A prototype touch-screen display that that incorporates flow model for the Pisquataqua River, Great Bay and Little Bay Estuary has been built. The display shows the flow of water in the Estuary as a function of tides and currents. Wherever the screen is touched a bright dye is injected into the system and the observer can see the fate of the injected particles over several current and tidal cycles.

NOAA Nowcoast: Colin Ware and NOAA employee John Kelley have initiated a new project to create innovative and more effective ways of presenting NOAA flow model output (from the HYCOM system of models) to the general public. Pete Mitchell's master's thesis is the major research component. Briana Sullivan will be helping with evaluation and technology transfer.

Professional tools: Ware is also developing a set of tools that allow both modelers and members of the public to have better ways of interpreting output from a variety of sigma coordinate flow models. These tools will be designed initially for the NOAA operational forecast models, including those for Chesapeake Bay, Galveston Bay, and New York Harbor, and will probably also work for the Gulf of Mexico.

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. They are particularly relevant for the increasingly important topic of essential fisheries habitat characterization.

SINGLE BEAM SONAR AND MAPPING AND CHARACTERIZATION:

In general support of our seafloor characterization efforts, Semme Dijkstra has continued the development of several software tools. The TracEd tool provides a robust means of tracking, editing and parsing returns from single beam echosounders. This tool, which has the potential to be a very useful aid to single-beam hydrographic data processing, has now been ported to the Windows environment. Upgrades to TracEd include changes in the internal data structure to optimize operating speed, the addition of continuous display of the most current trace, the ability to display LIDAR data (see below), and the construction of interfaces for the ODOM suite of echosounders. The Lassoo tool which is used for comparing multivariate data sets to imagery data sets in both geographic and multivariate feature space has also undergone a number of upgrades including the development of a historical database for seafloor characterization and interfaces for the ODOM suite of sonars.

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 EM 300, 1000, 1002, 3000, 3002, and Reson 8101, 8111, 8160 and 8125 data collected in support of the ONR, NSF, USGS, and Icelandic-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" (see previous progress reports), on the NANCY FOSTER from the US Virgin Islands and on the FAIRWEATHER off Alaska . 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.

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 ensonification. While many system and geometric corrections are applied by the manufacturers in their data collection process, some are not (e.g. local slope), and for others, many questions remain about how and where they were applied (see discussion of Backscatter Processing above). As described in the Backscatter Processing section, we have been working closely with NOAA and the manufacturers to fully and quantitatively understand the nature of the backscatter data collected and to develop tools (GEOCODER) that can properly make the needed adjustments to the data. Once such corrections are made the resulting backscatter should be much more representative of true sea floor variability and thus be an important contributor to efforts to remotely characterize the seafloor.

AVO Analysis:

The GEOCODER software (which is designed to make fully corrected backscatter mosaics and calculate a number of backscatter statistics) has now been integrated with the AvoAnalysis software package – also developed by Luciano Fonseca – which is designed to analyze the angular response of the backscatter as an approach to remote seafloor characterization. The AvoAnalysis software has now implemented a fully constrained iterative inversion model that is based on both empirical data sets (Hamilton) and theoretical approaches (Jackson and Biot). There are many advantages derived from this integration, for instance, the prediction of the bottom type provided by the AVOAnalysis can help remove the backscatter angular response, which is sediment specific, making it possible to assemble backscatter mosaics with fewer angular artifacts. Additionally, the enhanced backscatter mosaics can be segmented based on texture and statistics, so that it will be possible to calculate an average angular response not just for a stack of consecutive pings, but also for a segmented region in the backscatter mosaic. Another benefit is that, with a certain number of assumptions mainly relating to backscatter offsets and beam pattern, the same AVO seafloor characterization can be applied to Simrad and Reson systems. The new data structure now makes it easier to extend the functionality of the backscatter mosaicing and analysis to other sonar systems.

Fonseca has been working with Barbara Kraft and others to better understanding the relationship of multibeam backscatter to seafloor properties in the well-controlled and easily accessible environment of Portsmouth Harbor, Great and Little Bays. This work, funded for the most part through ONR's Geoclutter program has involved the establishment of a GIS-based database of all existing data in the region (existing data includes all the data collected in support of Shallow Survey 2001, as well as data collected as part of our Hydrographic Field Course), the reanalysis of multibeam sonar-derived backscatter data (particularly data from the Simrad EM3000 and 3002 sonar) to correct for true backscatter values (including local slope) and the calculation of AVO

(Amplitude Versus Offset) parameters. The development of this approach and its adoption is an important component of fisheries habitat mapping.

Local Fourier Histogram Analysis:

Over the past three years a new approach to seafloor characterization based on the automated segmentation of multibeam sonar bathymetric data into regions of common geomorphology (roughness) 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 and to NOAA study areas around Saipan and the U.S. Virgin Islands. The LFH appears to separate the morphology into regions that have significance in terms of the habitat of several species. The research component of this work was completed with the submission of Randy Cutter's PhD thesis. It was tested in a real-world application for the NOAA NOS Biogeography group on data from Saint John western sub-area of the U.S. Virgin Islands. In this case the LFH classification was trained with diver observations and video ground truth. The results were robust, despite a substantial amount of noise and numerous data artifacts. Randy has now taken a position with NOAA's Southwest Fisheries Center, in La Jolla, Ca.

Ground-Truth Studies: ISSAP

In order to better understand the relationship between remotely measured sonar backscatter 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 -- ISSAP). In the past year, Barbara Kraft and Glenn McGuillicutty have calibrated the ISSAP transducers (to better understand the measurements made with them) and have written up results from Portsmouth Harbor, Little Bay and the New Jersey Margin. In the case of the Geoclutter work, ISSAP measurements have been compared with the AvoAnalysis model predictions of Fonseca with very encouraging results (reported above). Graduate student Lorraine Robidoux is currently comparing the results of AvoAnalysis in Little Bay relative to another commercial seafloor characterization package (QTC-View); in support of this study, Robidoux and Armstrong took another set of ground-truth samples in Little Bay.

LIDAR Waveform Analysis:

Finally, we continue our efforts to explore the potential of LIDAR data as a means to characterize the shallow coastal seafloors. Gareth Elston, with funding from JALBTCX, USGS and ONR, has been looking at the waveform characteristic of LIDAR as a possible means for identifying seafloor properties. Gareth has developed two methods for characterizing bottom-reflected lidar pulses by their peak amplitude and pulse width: one based on fitting gamma functions to the pulses and the other based on

finding the peak and inflection points through interpolated derivatives of low-pass filtered waveforms. In collaboration with Semme Dijkstra, the bottom slope corrected features are being ported for use in his Trace-Ed and Lasso tools where automatic clustering and segmentation can be applied (see description in Single Beam Characterization section). Initial analyses are indicating that this approach is separating areas with different water mass properties as well as bottom type. Over the past year the approaches described above (which were developed for Shoals 400 data) were extended to include the new Shoals 1000 system (at the prompting and with the cooperation of JALBTCX). Gareth returned to his native Scotland in the summer of 2005 and Shachak Pe'eri has taken up the task of LIDAR studies. Shachak has been focusing on accumulating LIDAR data (LADS-MKII and Shoals 1000) data collected locally (in the vicinity of Portsmouth Harbor and the Isles of Shoals), comparing these to the numerous sonar data sets that we have in the region (Reson 8101, 8125, Simrad EM3000, 3002, Triton Elics, GeoAcoustics, Atlas Fansweep, Navitronics, and Odom data) and to understanding and measuring (in collaboration with Ru Morrison at UNH/EOS) the optical properties of the local water masses.

VIDEO/PHOTO IMAGE MOSAICING AND QUANTIFICATION:

The Hubbard Camera:

Yuri Rzhanov, Lloyd Huff, Randy Cutter and graduate students Anton Mamaenko and Fan Gu have been quite active in the collection of seafloor video data as well as in developing sophisticated algorithms for processing these data. Huff has been particularly active with the development of the "Hubbard Camera" a towed video camera system with a diesel-powered stand-alone winch, which has become a vital part of seabed studies conducted by the UNH Marine Programs, including the Joint Hydrographic Center. Multiple cruises using the Hubbard Camera were conducted between July and October 2005. The system continues to function as intended, however experimentation continues to determine the "best" lighting arrangement for different seabeds. The next modification to the lighting will be to "frost" the inside of the glass ports on the strobe light housings. A mask was constructed to protect the outer annulus where the o-rings seat onto the glass port. During the winter down time the "frosting" will be performed along with a total mechanical check-up which involves removing all bolts, renewing their corrosion protection and then reassembly. Several desirable modifications have been identified for the electronics including: 1) the means to remotely control the intensity of the strobe lighting, 2) the means to remotely control a grab sampler device that is associated with the camera project, and 3) to convert the video uplink from MPEG-3 compression to full bandwidth fiber optic, which impacts the winch slip-ring and the cable.

The Hubbard Camera has been equipped with laser spots to provide scale in the images. Rzhanov and Mamaenko have been working on algorithms to detect and mask (if necessary) these spots and also to derive information about seafloor slope and roughness from the behavior of the spots. This work has been extended (in collaboration

with NMFS scientists Mary Yoklavich and Tom Ladig) to estimate the distance traveled by a submersible.

Video mosaics and image processing:

Rzhanov has continued the development and application of mosaicing algorithms including porting them to the Windows environment. He has completed the development of software for the global alignment of multiple images in a single mosaic. This software has been used to process still imagery from Alvin dives (Rosebud area) and hand-held video from the Morocco coast (with Lloyd Huff). In addition the development of an algorithm for non-iterative correction of image sequences that speeds up the global alignment process has been completed. Tests have shown that processing time drops from 4 hours to 6 minutes. A simple to use imagery mosaicing and georeferencing toolkit is also being developed (under funding from NSF) but with great relevance to NOAA. This has been demonstrated by the fact the Rzhanov has been called upon several times to lead training workshops at NOAA facilities that focus on imagery mosaicing tools. Enhancements to the mosaicing process are also being developed including the use of stereo imagery for automated seafloor roughness estimation (with Mamenko) and the formulation of optimal image blending techniques (with Gu).

Finally, Huff and Conrad have continued the development of a Swath Video Camera system. The objective of this system is to increase the usable width of imagery acquired on any single pass of underwater video. The electronic components (embedded computer, and LED impulse drivers) have been built and bench tested. The design and construction of the precise mechanism required to independently designate the zero reference angle for the camera pointing was completed during this reporting period.

With the completion of Mashkor Malik's thesis we continue (also Randy Cutter's thesis) our efforts to use the tools that we have developed in support of seafloor characterization for serious studies of seafloor habitat.. Mashkor has been able to use our characterization and processing software tools to identify seven habitats in the Jeffreys Ledge area as well as the unequivocal identification of bottom fishing gear impacts – thought to be the result of scallop dredges. This study has established a detailed basemap for a critically important fisheries area; it will be resurveyed in the coming year to determine temporal changes.

DATA MANAGEMENT:

With the arrival of Jim Case as our full-time data manager, we have begun a serious effort at organizing our data holdings and making them accessible both to internal and external users. Since his arrival Jim has evaluated the hardware and software data infrastructure at CCOM. A data management scheme has been designed and in support of this restructure, two new data servers have been purchased. In concert with the data management restructuring, Case and Calder are working on a "Knowledge Repository" database concept that will attempt to capture "expert opinion" form CCOM domain experts on relevant information in any particular field.

The primary focus of this effort has been developing code and procedures to support the mass migration of data from various locally-attached storage servers to a new Storage Attached Network (SAN – see facilities discussion). The key features of the system are automatic discovery and cataloging of data files by project, the harvesting of metadata whenever possible from well-known data files and the storage of all of the above in a data management schema within Oracle. All new code written for this project is either in C, C++ or C#. C# is being used as the wrapper for all legacy code and the language for all new code related to data management, metadata or Oracle I/O.

A pilot project focused on the Portsmouth harbor region was initiated in July. A major component of the project was the development of a CCOM portal by which all data would be discovered by the users. The technology chosen was Oracle Portal because it is tightly integrated with the data and metadata catalogs and has embedded Web Mapping technology that leverages the Oracle Spatial data warehoused in the system. Another pilot project was initiated in October in which the USUNCLOS survey metadata is being harvested from OMG-created "merged" files for inclusion in the CCOM metadata warehouse before being exported for archival at NGDC. This will demonstrate another method for data management and metadata building where the metadata records are built post-survey. It is important to note that field-level metadata was generated during the cruises; however, it does not match the post-processed data files. The majority of the field-level metadata will be reused in the master database template. The procedures and software used to build this post-survey metadata will be used in the field on the next USUNCLOS cruise to minimize the delay of transferring archival data to NGDC.

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:

Law of the Sea:

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 the 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).

Following up on the recommendations made in the UNH study, Congress funded the Center (through NOAA) to collect new multibeam sonar data in support of a potential

claim under UNCLOS Article 76. In 2003, Center staff participated in two separate cruises to collect data in support of a potential law of the sea claim. For the first cruise, under the supervision of Dr. Jim Gardner, NOAA contracted with Thales GeoSolutions Inc. to perform the surveys of portions of Bowers Ridge and the Beringian margin that may be claimed for an extension of US territory and a second cruise focused the Chukchi Cap in the high Arctic where permanent ice cover makes the collection of detailed bathymetry very difficult. Summaries of these cruises were presented in the 2003 progress report. In 2004 we returned to the Chukchi Cap and, under very difficult ice conditions mapped another 100 nm of the 2500 m contour as well as a 325 sq. nm region of the margin off Barrow Alaska. We also began mapping of the continental margin off the east coast of the U.S., covering approximately 38,000 sq nm in about 60 days of surveying. Details of these surveys can be found in last year's progress report and at http://www.ccom.unh.edu.

This year we conducted two more Law of the Sea cruises, one representing the completion of our work off the east coast of the U.S (two legs) and the other in the Gulf of Alaska (two legs). The survey work off the U.S. east coast took place on the NAVO vessel *USNS Pathfinder,* a 329-ft, 5000 ton vessel equipped with a hull-mounted Kongsberg Simrad EM121A multibeam sonar, under the supervision of Dr. Jim Gardner. In addition to the multibeam sonar, the *Pathfinder,* also carried an ODEC Bathy2000 3.5-kHz chirp sub-bottom profiler and a BGM-5 Bell Gravity Meter. NAVOCEANO was responsible for system calibration, data collection and quality control and overall cruise management whereas Science Applications International Corp. (SAIC) was contracted by NOAA to perform bathymetry processing aboard ship. The overall responsibility of cruise planning, both before and during the cruises, as well as processing MBES acoustic backscatter and 3.5-kHz profiler data were the responsibilities of the UNH/NOAA representative aboard ship.

The Atlantic Margin surveys were a continuation of the work (3 legs) completed last year covering the northern segment of the Atlantic Margin (see last year's progress report). The first leg of this year's operations (Leg 4) required a half-day transit to an area mapped in 2004 to perform a patch test prior to mapping operations. A patch test (exclusive of a yaw calibration) was performed in this area and was followed by 31 days of mapping the margin from the point left off in 2004 towards the south. Leg 4 was completed on May 23, 2005 and the ship transited to Charleston, SC for re-supply and a crew change. Leg 4 collected 6423 line km of MBES and 3.5-kHz profiler lines and mapped a total area of ~22,500 nm^2. Data collected on Leg 5 have been classified by the U.S. Navy and are not publicly available at this time.

Our second Law of the Sea cruise brought us to the Gulf of Alaska. NOAA contracted through NSF-UNOLS (National Science Foundation University National Oceanographic Laboratory System) with the University of Hawaii to conduct the Gulf of Alaska mapping using the 186-ft, 3060-ton RV Kilo Moana, a SWATH (small water area twin hull) vessel with a hull-mounted Kongsberg Simrad EM120 MBES as well as a Knudsen 320 B/R 3.5-kHz chirp sub-bottom profiler and a Carson gravimeter.
The planned schedule for the cruise called for 2 legs of approximately 30 days of

operations each. The University of Hawaii's Hawaii Mapping Research Group was responsible for systems calibrations, data collection and quality control and overall cruise management whereas the UNH group was responsible for bathymetry, acoustic-backscatter and 3.5-kHz processing. Gravity data were collected and processed by the University of Hawaii group.

The first leg of operations required a 7.5-day, 4200 km, transit from Honolulu, HI to an area ~70 km NW of Bowie Seamount. A complete patch test was performed in this area and then the mapping commenced with a dip line run up the margin in the southern portion of the area. Twenty-five days of continuous mapping the margin from south to north followed the patch test. Mapping during Leg 1 was halted on July 27, 2005 and the ship transited to Kodiak, AK for a scheduled re-supply and a crew change. Leg 1 collected 18,135 line km of MBES and 3.5-kHz profiler lines and mapped a total area of 47,586 nm^2. Leg 2 of the survey departed Kodiak, AK on August 2, 2005 and collected 8745 line km of MBES and 3.5-kHz profiler lines and mapped a total area of 46,138 nm^2. Leg 2 of the survey was completed on August 24, 2005 and the ship transited back to Honolulu, HI. The cruise mapped a total of 93,724 nm^2 in 42 days, with an average speed of 10 kts.

These cruises have not only provided data that will, unquestionably, add significant territory to the juridical continental shelf should the U.S. choose to file claim under UNCLOS Article 76, but from a scientific perspective they have provided tremendous new insights into the nature of continental margin processes. These data sets will be an invaluable addition to our fundamental understanding of marine processes and have already become the focus of several student theses

Details of both of these cruises can be found at: http://www.ccom.unh.edu/

Electronic Chart of the Future:

In FY2003, we began our "Chart of the Future" an evolution of the Navigation Surface concept that also takes advantage of our expertise in visualization. We are taking a two-pronged approach at trying to define the electronic chart of the future. One track is an evolutionary approach to see how additional, non-standard layers (i.e. the navigation surface bathymetric grid, real-time tide information, etc.) can be added to existing electronic charts. This approach requires careful attention to present day standards and the very restrictive constraints of today's electronic charts. This work is being done in conjunction with the standards committees (represented by Center faculty member Lee Alexander) and the electronic chart manufacturers and is intended to provide short-term solutions for the need to see updated electronic charts. In concert with this evolutionary development we also have embarked on a revolutionary development with researchers in our Visualization Lab exploring new paradigms in electronic chart design, unconstrained by existing standards or concepts. This exercise is taking full advantage of the psychology-based human-computer interaction expertise of our visualization researchers to explore optimal designs for displays, the role of 3-D, flow-visualization, stereo, multiple windows, etc. From this research we hope to establish a new approach to electronic charts that will set the standards for the future. Throughout this project (both

the evolutionary and revolutionary efforts) our experienced NOAA mariners are playing a key role, ensuring that everything that is developed will be useful and functional.

Evolutionary:

Within the context of the "evolutionary" approach Lee Alexander and Rick Brennan are working in collaboration with industrial consortium member 7C's and CARIS to investigate various tools and processing steps required to use the Navigation Surface database to produce a high-density bathymetric ENC.

A gridded test dataset that was compiled from existing and new hydrographic surveys of the Thimble Shoals Channel in the Port of Norfolk/Hampton Roads was used to produce two products:

1) an ENC based on the current ENC Product Specification as specified in IHO S-57 3.1, but containing a greater number of contours (depth areas) than what is normally produced by digitizing paper charts. This was primarily performed by *CARIS* using *CARIS HOM* tools.

2) a prototype, "Next Generation" ENC (vector-based) capable of dealing with x, y, z, and time. This was primarily performed by SevenCs using modified *ENC Designer/Optimizer* tools. The efforts of CARIS and SevenCs were accomplished in conjunction with the Industrial Consortium Agreement with CCOM. The next step is to conduct a functional cross-comparison of each type of ENC in an IMO-compliant ECDIS (i.e., existing, type-approved system) and more advanced ECDIS/ECS having additional capabilities.

In addition to ENC data, a high-resolution, gridded dataset will be produced. For both the ENC and gridded data, various options are being considered as to the best means to integrate a tidal model. Of particular interest is the *Tidal Constituent and Residual Interpolation (TCARI)* model investigated in Rich Brennan's MS Thesis. Other efforts include a suitable means to provide time-varying information (e.g., tidal/water level information) to underway vessels via shore-based AIS transponders). Initial focus will be to use the *St. Lawrence Seaway AIS Data Messaging Formats and Specifications* (Rev. 4.2A, 9 May 2002) that was developed by the US DOT Volpe Transportation Systems Center. When coupled with forecast or real-time information, these "Next Generation" ENC datasets can be used to display time-variant water levels, current flow, and other tactical or marine information object (MIO) information required for both display and decision-support.

A showcase/demonstration project in the Port of Norfolk/Hampton Roads, VA is being planned. A key target date would be in conjunction with the US Hydro Conference in Norfolk in Spring, 2007. Ideally, both the "Next Generation ENC" and the "Chart-of-the-Future" would be demonstrated on a variety of Government and commercial vessels. The goal is to inform maritime users on the capability/limitations of existing electronic charting systems, and enlighten them about new functional capabilities/innovative developments.

Revolutionary:

Within the context of the "revolutionary" effort, Colin Ware, Matt Plumlee, Roland Arsenault and Matt Quinn have been extending the capabilities of GeoZui4D (as described above) as well as developing specific applications for the chart of the future. The GeoZui4D version that has become the base for the Chart of the Future project is now called GeoNav4D. Many of the new capabilities were described in last year's progress report (and in the description of the flow visualization above); this year's effort has focused the development of predictive display as an aid to steering for novice helmsmen.

It is well known that inexperienced helmsmen of small vessels (30-100 ft) commonly over-steer with the result that they will fishtail across their intended course. The reason for this behavior is the lag that occurs between a steering change and a change in heading. Without an immediate feedback on the response to a steering change, inexperienced helmsmen often increase the helm displacement beyond what is needed.

A well-known solution to the lag problem is to incorporate a predictive display. This allows the person controlling the system to see the *predicted effect* of a control action with the result that their task becomes one of steering the predictor. Predictive displays have been used for large ships as well as remotely operative vehicles and spacecraft. They do not appear to have been used for small vessels such as survey launches. To investigate the value of a predictive display Matt Plumlee, under the supervision of Colin Ware has built a predictive model using ship-track, heading and rudder information from our own survey vessel COASTAL SURVEYOR. Briana Sullivan has carried out an evaluation study with 20 volunteer participants. The results show inexperienced helmsmen show a dramatic improvement in their ability to drive a planned course (and even experienced helmsmen show some improvement in turns). This may be useful in improving the quality of surveys.

As the Chart of the Future evolves we are beginning to demonstrate it to a range of mariners to gain feedback for its ultimate design. This effort will be spun-up in the coming year with the arrival of Kurt Schwehr, who will take responsibility for this project.

OTHER TIDBITS:

The Center has also made progress in several other areas that do not necessarily fall into one of the above categories, but that deserve reporting:

Tele-presence Console – Real-time Remote processing of Multibeam Sonar Data:

In collaboration with Robert Ballard's Institute for Exploration, the University of Rhode Island, the University of Washington, and NOAA's Ocean Exploration Office, the Center took part, this past summer, in a "virtual expedition" an exploration of the "Lost City" in the mid-Atlantic by technical teams on board the NOAA vessel RON BROWN with the scientists remaining on shore at UW, URI and UNH. In support of this effort,

the Center installed a large "telepresence console" which allowed us full two-way high-bandwidth communication (both video and audio) with the vessel, the ROV's, and other scientists around the country. Multiple high-definition video screens allow an immersive experience for all involved. In this summer's scenario, the chief scientist and most of the scientific party were at the University of Washington (with a similar telepresence console) with UNH providing multibeam sonar processing and data visualization support. A dedicated satellite link plus internet-II connectivity allowed multibeam data to be transferred to UNH where it was processed in a few minutes and returned to the survey vessel as processed 3-D objects. In addition, based on navigation provided from the survey vessel we were able to position the ROV's in the context of the 3-D bathymetry. This effort went on for almost two weeks with a regular watch schedule maintained by all centers (i.e., there was someone on watch at all times). Interspersed with the scientific efforts were a number of broadcasts aimed at a much wider audience.

The ramifications for this sort of facility are manifest. Not only does this open up many new opportunities for shore-based scientists to participate in sea-going programs it also has a tremendous outreach component as groups can be brought in (or the video transferred) to share the real-time exploration experience. Most importantly, from a NOAA perspective, it opens up the opportunity for providing real-time support for sea-going programs where a processing (or other) problem arises. Data can be transferred back to shore-based experts, evaluated and feed back provided to the vessel with minimal delay.

Motion-Sensor Trials:

In collaboration with Duncan Mallace of NetSuvey, UK, and in support of the Shallow Water Survey Conference held in Plymouth UK, we made available the COASTAL SURVEYOR and Center staff to support a head-to-head comparison of various motion sensors commonly used for hydrographic surveys. Mallace reported this comparison at the Shallow Survey conference (not without controversy) but the results have provided important insights to both users and manufacturers of these systems.

Training:

In addition to the formal training for NOAA and non-NOAA personnel done at the Center, Center staff have also been called upon to provide training or input for a number of groups and organizations within NOAA (e.g., Calder called upon to provide input at the Field Procedures Workshop, Alexander called upon for input to many organizations on ENC standards; IHO held its Open ECDIS forum at the Center, Rzhanov asked to give workshops on imagery mosaicing, Open NAV Surface meeting at the Center, etc.). Calder was also called upon to edit and author DVD's from the NOAA Hydrographic Training programs in order to supply reference material for ships that could not send representatives to the training sessions.

Outreach:

We have formalized our outreach activities (with the addition of Briana Sullivan to the staff) and are actively working to increase the usefulness of our website

(http://www.ccom.unh.edu) as well as develop museum displays (see visualization section above), and materials and programs that will help share the results of our efforts with the broader community. We have hosted a number of community groups (high-school students, marine docents, etc.) and the activities of the Center have, this year, been featured in the N.Y. Times, Newsweek, The Discovery Channel, BBC, NPR, and many other international (and local) media outlets.

PARTNERSHIPS AND 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. 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.
ENL
IVS-3D Inc.
Kongsberg Simrad
L3/Klein Associates
ODOM
Reson
SAIC
Sonartech Atlas
SevenC's
QPS
QinetiQ
Quester Tangent
TENIX/LADS
Triton-Elics
Tyco

In addition, grants are in place with the Office of Naval Research, The Naval Research Lab, The Naval Oceanographic Office, IEEE, The National Science Foundation, Fugro, The Nippon Foundation, CICEET and the U.S. Geological Survey (see Appendix E). The USGS supports collaborative projects involving multibeam sonar mapping as well as a post-doctoral fellow at the Center. Funding beyond this grant this past year is on the order of $1.81M from a total commitment from other sources of approximately $9.58M (see Appendix E).

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/ODOM
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:

1. Ground-based survey of all offsets with Laser Total Station
2. Installation and Calibration of new POS/MV processor
3. Installation of new radar processor with Automatic Vessel Tracking (ARP) and combined radar and chartplotter images. Phosphor tube replaced with flat panel color display.
4. Updated timestamping on ships data system

Major Projects on *Coastal Surveyor* in 2005

1. Ground-based survey using Total Station to establish offsets
2. Summer Hydro Field Camp
3. Isle of Shoals survey in support of LIDAR study
4. Ocean Measurements Class
5. Vessel Predictor Studies in support of Chart of the Future
6. Secchi disk tests in support of LIDAR studies
7. WASSP mulitbeam trials
8. Seamanship Class
9. Grab sampling for ground truthing backscatter studies (Robidoux)
10. Motion Sensor Intercomparison

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	1,1
OE 810, Ocean Measurements Lab	4
OE 845, Environmental Acoustics I	4
OE 846 Environmental Acoustics II	4
OE/ESCI 870 Introductory Ocean Mapping	4
OE/ESCI 871 Geodesy and Positioning for Ocean Mapping	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 Topics	3
ESCI 907, Geostatistics	3
OE/ESCI 973, Seafloor Characterization	3
ESCI 895,6 Special Topics in Earth Science	1-4
ESCI 959 Data Analysis Methods in Ocean and Earth Science	4
ESCI 898 Directed Research	2
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/CS 867 Interactive Data Visualization	3
OE 995, Graduate Special Topics	2 - 4
OE 998, Independent Study	1 – 4
Other related courses with approval	

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, Introduction to Ocean Mapping	3
ESCI/OE 871, Geodesy and Positioning for Ocean Mapping	3
ESCI /OE 972, Hydrographic Field Course	4
ESCI 997, Seminar in Earth Sciences	1
ESCI 998, Proposal Development	1
Thesis - in addition to required coursework	6
At least 6 additional credits from the electives below	
OE 854, Ocean Waves and Tides	4
ESCI 959, Data Analysis Methods in Ocean and Earth Sciences	4
OE 954, Ocean Waves and Tides II	4
OE/EE 985, Special Topics	3
ESCI 907, Geostatistics	3
OE 845, Environmental Acoustics I	4
OE 846 Environmental Acoustics II	4
OE/ESCI 973, Seafloor Characterization	3
ESCI 895,6 Special Topics in Earth Science	1-4
ESCI 959 Data Analysis Methods in Ocean and Earth Science	4
ESCI 898 Directed Research	2
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/CS 867 Interactive Data Visualization	3
OE 995, Graduate Special Topics	2 - 4
OE 998, Independent Study	1 – 4
Other related courses with approval	
Non-Thesis Option (in addition to courses listed above):	
ESCI 898, Directed Research	2
Approved Electives	8

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 Ocean Mapping	4
OE/ESCI 871 Geodesy and Positioning for Ocean Mapping	3
OE 895 Special Topics: Seamanship for Ocean Scientists and Engineers*	2
OE/ESCI 972, Hydrographic Field Course	4
OE 990 Ocean Seminar I/or ESCI 997 Seminar in Earth Science	1
OE 991 Ocean Seminar II/or ESCI 998 Proposal Development	1

Non-credit classes:	*Classroom Hours*
CARIS HIPS-SIPS Training Course	40

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

Coursework Required for the Graduate Certificate in Ocean Mapping

Program Requirements

A Graduate Certificate in Ocean Mapping is awarded for completion of three required courses and four elective courses.

Basic Certificate		Credits
Required Courses:		
ESCI/OE 870	Introduction to Ocean Mapping	4
ESCI/OE 871	Geodesy and Positioning for Ocean Mapping	3
ESCI/OE 972	Hydrographic Field Course	4
OE 810	Ocean Measurements Lab	4

Advanced Certificate: (three additional courses from the following):		
ESCI 859*	Geologic Oceanography	4
ESCI 973	Seafloor Characterization	3
ESCI 858*	Introduction to Physical Oceanography	4
EOS/OE 854	Ocean Waves and Tides	4
OE 845	Environmental Acoustics I	4
OE 885	Environmental Acoustics II	4
OE/CS 867	Data Visualization	3
OE	Special Topics	4
NR 857	Photo Interpretation and Photogrammetry	4
NR 860	GIS in Natural Resources	4
ESCI 895,896	Topics in Earth Sciences	1-4
OE 895*	CARIS Training and Seamanship	4

**Required Advanced Certificate courses for Category A Certification

Appendix C:

Papers, Books, Conference Proceedings, Abstracts, Thesis, Reports and Talks From January 2005 to December 2005

Journal Articles

Alexander, L., Brown, M., Greenslade, B., and Pharaoh, A., 2005, Future Edition of IHO S-57 (4.0): International Hydrographic Review, v. 6, p. 66-72.

Calder, B.R., 2005, On the Uncertainty of Archive Hydrographic Datasets: IEEE Journal of Oceanic Engineering.

Calder, B.R., Byrne, J.S., Lamey, B., Brennan, R.T., Case, J.D., Fabre, D., Gallagher, B., Ladner, R.W., Moggert, F., and Paton, M., 2005, the Open Navigation Surface Project: Int. Hydro. Review, v. 6 (2)

Cutter Jr., G.R., Rzhanov, Y., Mayer, L.A., and Grizzle, R.E., 2005, Ground-truthing benthic habitat characteristics using video mosaic images: Benthic Habitats and the Effects of Fishing, American Fisheries Society Symposium 41, v. American Fisheries Society, p. 171 -179.

Foote, K.G., Chu, D., Hammar, T.R., Baldwin, K.C., Mayer, L.A., Hufnagle Jr., L.C., and Jech, J.M., 2005, Protocols for calibrating multibeam, sonar: J. Acoust. Soc. Am, v. 117, p. 2013-2027.

Gardner, J.V., Dartnell, P., Mayer, L.A., Hughes Clarke, J.E., Calder, B.R., and Duffy, G., 2005, Shelf-edge Deltas and Drowned Barrier-island Complexes on the Northwest Florida Outer Continental Shelf: Geomorphology, v. 64(3-4), p. 133-166.

Gardner, J.V., Mayer, L.A., and Armstrong, A., 2005, U.S. Law of the Sea Mapping: Hydro International, v. 9, p. 42-45.

Jakobsson, M., Armstrong, A., Calder, B.R., Huff, L.C., Mayer, L.A., and Ward, L.G., 2005, On the Use of Historical Bathymetric Data to Determine Changes in Bathymetry: An Analysis of Errors and Application to Great Bay Estuary, New Hampshire: Int. Hydro. Review, v. 6 (3).

Jakobsson, M., Gardner, J.V., Vogt, P., Mayer, L.A., Armstrong, A., Backman, J., Brennan, R.T., Calder, B.R., Hall, J.K., and Kraft, B.J., 2005, Multibeam Bathymetric and Sediment Profiler Evidence for Ice Grounding on the Chuckchi Borderland, Arctic Ocean: Quaternary Research, v. 63, p. 150-160.

Kent, G.M., Babcock, J.M., Driscoll, N.W., Harding, A.J., Dingler, J.A., Seitz, G.G., Gardner, J.V., Mayer, L.A., Goldman, C.R., Heyvaert, A.C., Richards, R.C., Karlin, R., Morgan, C.W., Gayes, P.T., and Owen, L.A., 2005, A 60 ka record of extension across the western boundary of the Basin and Range Province: Estimate of slip-rates from offset shoreline terraces and a catastrophic slide beneath Lake Tahoe: Geology, v. 33 no.5, p. 365-368.

Mayer, L.A., 2005, Frontiers in seafloor mapping and visualization: Marine Geophysical Researches. *In press*

Mayer, L.A., Raymond, R., Glang, G., Richardson, M.D., Traykovski, P., and Trembains, A., High, Resolution mapping of mines and ripples at the Martha's Vineyard Coastal Observatory: IEEE Journal of Oceanic Engineering, *in press*

Monahan, D., Poll, R.v.d., and Cockburn, S., 2005, Applying the Test of Appurtenance Globally: a new inventory of wide margin states from public domain data: International Hydrographic Review, v. 6 (2), p. 77-84.

Traykovski, P., Richardson, M.D., Mayer, L.A., and Irish, J.D., 2005, Mine Burial Experiments at the Martha□s Vineyard Coastal Observatory: IEEE Journal of Oceanic Engineering.

Ware, C., and Bobrow, R., 2005, Supporting visual queries on medium sized node-link diagrams: Information Visualization, v. 4, p. 9-58.

Book and Book Chapter

Fuhrmann, S., Ahonen-Rainio, P., Edsall, R., Fabrikant, O.S., Koua, E.L., Tolon, C., Ware, C., and Wilson, S., 2005, Making Useful and Useable Geovisualization: Design and Evaluation issues, in Dykes, J., MacEachren, A.M., and Kraak, M.J., eds., Exploring Geovisualization: Amsterdam, Oxford:Elsevier, p. 541-554.

Gardner, J.V., and Mayer, L.A., 2005, Benthic habitats and the effects of fishing, in Barnes, P.W., and Thomas, J.P., eds., Benthic habitat mapping with advanced techniques and their applications, American Fisheries Society Symposium 41, p. 139-140.

Hecht, H., Berking, B., Buttgenbach, G., Jonas, M., and Alexander, L., 2005, The Electronic Chart. Functions, Potential and Limitations of a New Navigation System: Lemmers, The Netherlands, GITV Publishing, 293 p.

Mayer, L.A., Jakobsson, M., and Hall, J.K., 2005, Challenges of collecting Law of the Sea data in the Arctic: the Arctic and Law of the Sea, in Nordquist, M., Moore, J.N, and Skarirdov, A.S, ed., International Energy Poligy: Leiden, Netherlands, Martinus and Nijhoff, p. 125-140.

Ware, C., 2005, Visual Queries: the foundation of visual thinking, in Tergan, S.O., and Keller, T., eds., In Knowledge and information visualization: Searching for synergies, Heidelberg: Springer-Verlag, p. 25-33.

Ware, C., and Plumlee, M., 2005, 3D Geovisualization and the Structure of Visual Space, in Dykes, J., MacEachren, A.M., and M-J. Kraak, M.-J., eds., Exploring Geovisualization: Oxford, UK, Elsevier Ltd, p. 555-564.

Conference Proceedings and Abstracts

Alexander, L., 2005, North American European Inland ENC Harmonization Group: Building on IHO S-57 for an International Brownwater Standard, 2005 RTCM Annual Assembly Meeting: St. Petersburg Beach, FL.

Alexander, L., Brown, M., and Greenslade, B., 2005, Next Edition of IHO S-57 (Edition 4): Much more than ENCs, US Hydrographic Conference 2005: San Diego, CA.

Alexander, L., and Ries, K.L., 2005, Coral Reef Electronic Chart Initiative, Protecting Corals, Saving Ships, US Hydrographic Conference: San Diego, CA.

Anderson, R., Jakobsson, M., Monahan, D., Hall, J.K., Montoro-Dantes, H., and Mustapha, A., 2005, GEBCO: A new 1:35,000,000 scale printed map, Fall AGU: San Francisco, CA.

Arsenault, R., Wiley, D.N., Ware, C., Barton, K., Shorter, K.A., Johnson, M.P., Moller, J.C., Plumlee, M., and Sardi, K., 2005, Geozui4d: A New Method for Viewing Multisensor Tag-Derived Data to Investigate the Underwater Behavior of Marine Mammals, The 16th Biennial Conference on the Biology of Marine Mammals: San Diego, California, p. 18.

Bair, A., House, D., and Ware, C., 2005, Perceptually optimizing textures for layered surfaces, ACM SIGGRAPH Symposium on Applied Perception in Graphics and Visualization, p. 67-74.

Blasco, S., MacLean, B., Mudie, P., Sonnichsen, G., Bennett, R., Rainey, W., Scott, D., Praeg, D., Hughes Clarke, J.E., Barglett, J., Mayer, L.A., and Monahan, D., 2005, Northwest Passage marine sediments: a record of Quaternary history and climate change, 35th Annual Arctic Workshop.

Brennan, R.T., Byrne, J.S., Calder, B.R., Case, J.D., Fabre, D., Gallagher, B., Ladner, R.W., Lamey, B., Moggert, F., and Paton, M., 2005, The Open Navigation Surface Project, US Hydro. Conf. 2005: San Diego, CA.

Brogan, D.S., and de Moustier, C.P., 2005, 3D spatial sampling with a cylindrical multibeam sonar, 149th Meeting, Acoustical Society of America: Vancouver, British Columbia, Canada, 16-20 May 2005.

Brogan, D.S., and de Moustier, C.P., 2005, 3D spatial sampling with a cylindrical multibeam sonar: The Journal of the Acoustical Society of America, v. 117, p. 2447.

Calder, B.R., 2005, Multibeam Swath Consistency Detection and Downhill Filtering from Alaska to Hawaii., US Hydro. Conf. 2005: San Diego, CA.

Calder, B.R., and Malik, M.A., 2005, Field Verification of MBES Error Models, 4th Int. Conf. on High-Resolution Survey in Shallow Water: Plymouth, UK.

Cutter Jr., G.R., 2005, Benthic Habitat Classification and Characterization Using Multibeam Sonar

Data: the Provisional Truth of Ground-truth. Paper presented at the International Conference for Underwater Acoustic Measurements: Technologies and Results, F.O.R.T.H.: Heraklion, Crete.

Fonseca, L., and Calder, B.R., 2005, Geocoder: An Efficient Backscatter Map Constructor, US Hydro. Conf. 2005: San Diego, CA.

Fonseca, L., Mayer, L.A., and Kraft, B.J., 2005, Seafloor Characterization through the Application of AVO Analysis to Multibeam Sonar Data, Boundary influences in high frequency, shallow water acoustics: University of Bath, UK.

Gardner, J.V., Mayer, L.A., and Armstrong, A., 2005, New views of the U.S. Continental Margins, U.S. Hydro 2005: San Diego, CA.

Gardner, J.V., Mayer, L.A., Armstrong, A., Donaldson, P., Infantino, J., Davis, G., Smith, D., Lobercher, M., Cartwritht, D., Iwachiw, J., Farr, S., Meadows, D., Dorsey, S., Marsh, G., and Owen, W., 2005, New Views of the Gulf of Alaska Margin Mapped for UNCLOS Applications, AGU: San Francisco.

Hiller, R., Calder, B.R., Hogarth, P., and Gee, L., 2005, Adapting CUBE for Phase Measuring Bathymetric Sonars, 4th Int. Conf. on High-Resolution Survey in Shallow Water: Plymouth, UK.

House, D., Bair, A., and Ware, C., 2005, The Optimization of Visualization of Complex Phenomena, IEEE Visualization: Minneapolis, p. 87-94.

Kraft, B.J., Ressler, J., Mayer, L.A., Fonseca, L., and McGillicuddy, G., 2005, In-situ measurement of sediment acoustic properties, Int. Conf. Underwater Acoustic Measurements: Technologies & Results: Heraklion, Crete, Greece.

Malik, M.A., and Mayer, L.A., 2005, Bottom fishing impacts on benthic structure using multibeam sonar, sidescan and video, US Hydrographic Conference: San Diego, CA.

Martin, S.C., Whitcombe, L.L., Arsenault, R., Plumlee, M., and Ware, C., 2005, A system for real-time spatio-temporal 3-D Data Visualization in Underwater Robotic Exploration, International Conference on Robotics and Automation: Barcelona, Spain.

Mayer, L.A., Gardner, J.V., Armstrong, A.A., Calder, B.R., Malik, M.A., Angwenyi, C., Karlpata, S., Montoro-Dantes, H., Morishita, T., Mustapha, A., van Waes, M., Wood, D., and Withers, A., 2005, New Views of the Gulf of Alaska Margin Mapped for UNCLOS Applications: EOS Trans, v. 86, p. 52.

Monahan, D., 2005, An in-depth look at shallow water multibeam, Shallow Water Multibeam Sonar Training and Operations: The past decade and future prospects: St. Andrews, NB Canada.

Monahan, D., 2005, Tsunamis and bathymetry- A little on their relationship, Third Extraordinary International Hydrographic Conference, IHO: Monaco.

Monahan, D., Angwenyi, C., Karlapati, S., Montoro-Dantes, H., Morishita, T., Abdullahi, A., Peralta-

Reynoso, W., and Sharma, S., 2005, Multi-dimensional, multi-national, multi-faceted hydrographic training: the Nippon Foundation GEBCO training program at the University of New Hampshire, United States Hydrographic Conference.

Neufeld, E.M., Kristtorn, S.K., Guan, Q., Sanscartier, M., and Ware, C., 2005, Univ. of New Hampshire Exploring causal influences, SPIE Converence on Visualization and Data analysis, Volume January: San Jose, p. 52-62.

Niles, A.R., Alexander, L., and Scheid, R.A., 2005, Inland ENC Development and Standardization: San Diego, CA.

Plumlee, M., Ware, C., Arsenault, R., and Brennan, R.T., 2005, Panoramic Images for Situational Awareness in a 3D Chart-of-the-Future Display, U.S. Hydro 2005: San Diego, CA.

Rzhanov, Y., Mamaenko, A., and Yoklavich, M., 2005, UVSD: Software for Detection of Color Underwater Features, OCEANS 2005 MTS/IEEE: Washington, DC.

Rzhanov, Y., Mayer, L.A., Beaulieu, S., Soule, A., Shank, T., and Fornari, D., 2005, Automated generation of geo-referenced mosaics from video data collected by deep submergence vehicles: preliminary results, Fall AGU conference: San Francisco, CA.

Stimpert, A.K., Wiley, D.N., Shorter, K.A., Barton, K.L., Johnson, M.P., Ware, C., Arsenault, R., Lammers, M.O., and Au, W.W.L., 2005, A Novel Sound Recorded in Association with Bottom Feeding in Humpback Whales, The 16th Biennial Conference on the Biology of Marine Mammals: San Diego, California, p. 269.

Ware, C., Arsenault, R., and Plumlee, M., 2005, Interactively Visualizing Oceanographic Time-Varying Oceanographic Data, Offshore Technology Conference: Houston, Texas.

Ware, C., and Mitchell, P., 2005, Reevaluating Stereo and Motion Cues for Visualizing Graphs in Three Dimensions, ACM SIGGRAPH Second Symposium on Applied Perception in Graphics and Visualization: Coruna, Spain, p. 51-58.

Wiley, D.N., Ware, C., Barton, K.L., Shorter, K.A., Johnson, M.P., Arsenault, R., Moller, J.C., and Weinrich, M., 2005, Underwater behavior of humpback whales in a western North Atlantic foraging area, The 16th Biennial Conference on the Biology of Marine Mammals: San Diego, California, p. 304.

Reports

Alexander, L., 2005, Inland ENC Encoding Guide, ftp://ftp.usace.army.mil/pub/ERDC/tec/IEHG: Durham, Center for Coastal and Ocean Mapping, University of New Hampshire.

Brogan, D.S., and de Moustier, C.P., 2005, 3D spatial sampling with a cylindrical multibeam sonar array, final report on bathymetry and co-registered backscatter extraction from the volume search sonar of the AQS-20 mine countermeasure system: Durham, Center for Coastal and Ocean Mapping, University of New Hampshire, p. 61.

Cutter Jr., G.R., 2005, Demonstration Project: Supervised LFH Texture Feature Classification Of Gridded Bathymetric Data From Saint John, U.S. Virgin Island Survey, Western Subarea for Habitat Structure Class Prediction (Saint John West - LFH): Durham, Center for Coastal and Ocean Mapping, University of New Hampshire.

de Moustier, C., WASSP sea trials, Aug. 5-15, 2005, Durham, Center for Coastal and Ocean Mapping, University of New Hampshire.

de Moustier, C., R/V Kilo Moana EM1002 status report Oct 1, 2005, Durham, Center for Coastal and Ocean Mapping, University of New Hampshire.

Elston, G.R., 2005, Shoals lidar waveform characterization and bottom classification: final report: Durham, Center for Coastal and Ocean Mapping, University of New Hampshire.

Gardner, J.V., and Mayer, L.A., 2005, U. S. Law of the Sea cruise to map the foot of the slope and 2500-m isobath of the Gulf of Alaska continental margin: Durham, Center for Coastal and Ocean Mapping, University of New Hampshire, p. 30.

Mayer, L.A., de Moustier, C.P., Kraft, B.J., and Calder, B.R., 2005, High-Resolution Mapping and Backscatter Studies in Support of the Ripples DRI, Ripples DRI Program: Durham, Center for Coastal and Ocean Mapping, University of New Hampshire.

Mayer, L.A., Fonseca, L., and Kraft, B.J., 2005, Measurement of in-situ acoustic properties for the ONR Geoclutter program, Annual Report, Geoclutter Program: Durham, Center for Coastal and Ocean Mapping, University of New Hampshire.

Smith, W., and Monahan, D., 2005, ABYSS-Lite: A radar altimeter for bathymetry, geodesy and mesoscale oceanography, A mission concept submitted to the NRC Decadal Survey: Durham, Center for Coastal and Ocean Mapping, University of New Hampshire.

Thesis

Cutter Jr., G.R., 2005, Seafloor Habitat Characterization, Classification and Maps for the Lower Piscataqua River Estuary [Doctor of Philosophy thesis]: Durham, University of New Hampshire.

Malik, M.A., 2005, Identification of bottom fishing impacted areas using multibeam sonar and videography [Master of Science thesis]: Durham, University of New Hampshire.

McGillicuddy, G., 2005, Characterization of Weak Rope through the Design and Construction of a Portable Tensile Testing Machine [Masters of Science thesis]: Durham, University of New Hampshire.

Nathan, K.A., 2005, A New Method for Perceptually Optimized Visualization of Two Layered Flow Fields [Master of Science thesis]: Durham, University of New Hampshire.

Quinn, M., 2005, Automatic Illustration of Ocean Currents [Master of Science thesis]: Durham, University of New Hampshire.

Talks

Calder, B. R., Tackling Modern Multibeam Data with CUBE. NOAA Field Procedures Workshop 2005, Norfolk, VA, 24-28 January 2005 (Invited).

Calder, B. R., Uncertainty in Hydrographic and User Space. US Hydrographic Conference 2005 Uncertainty Workshop, San Diego, CA, 28 March – 1 April 2005 (Invited).

Calder, B. R., Open Navigation Surface, TSMAD Workshop on S57 Ed 4, CCOM/JHC, May 2005 (Invited).

Calder, B. R., Downhill Filtering and Swath Consistency Detection, NOAA Ship FAIRWEATHER, At sea in the Gulf of Alaska, 1 June 2005. (Invited).

Calder, B. R., Granite State Distance Learning Network, Durham, NH. "Marine Research over Internet 2: The Lost City Virtual Cruise, 2005" (2005)

Calder, B. R., UNH Marine Docents, Durham, NH. "Virtually at Sea: Lost City, 2005" (2005)

Cutter, G. R., Classification and characterization of benthic habitat attributes. Lecture for the Seafloor Characterization class. Feb., 2005.

Hou, T., CCOM Friday lecture series. "Seabed Characterization Using Normalized Backscatter Data by Best Estimated Grazing Angles". March 25, 2005

Kraft, B. J., In-situ measurement of sediment geoacoustic properties with ISSAP, Seminar Presentation: CCOM, 8 April, 2005.

Kraft, B. J., Three classes of MATLAB instruction to ESCI 895 (Research Tools in Ocean Mapping)

Leo, M., "Multi-sensor Fusion: Methods using Bathymetric and Magnetic Gradiometer Data to Improve Anomaly Detection" Seminar Presentation: Center for Coastal and Ocean Mapping, University of New Hampshire, April 15th, 2005

Fonseca, L., "Introduction to GIS – Part I", UNH – CCOM GIS Training for Bathymetric Mapping Course, February 14 2005.

Fonseca, L., "Introduction to GIS – Part II", UNH – CCOM GIS Training for Bathymetric Mapping Course, February 21 2005.

Fonseca, L., "Introduction to GIS – Part III", UNH – CCOM GIS Training for Bathymetric Mapping Course, February 28 2005.

Fonseca, L., “Seafloor Characterization though the Application of AVO Analysis to Multibeam Sonar Data”. UNH- CCOM - Seafloor Characterization Course, 25 Mar 2005.

Fonseca, L., “Remote Seafloor Characterization with Multibeam Sonars”. NOAA Fairweather 02 June 2005.

Fonseca, L., “Introduction to GIS – Part I, II, II and IV”,UNH – CCOM GIS Training for Bathymetric Mapping Course, October-November, 2005.

Fonseca, L., “Introduction to GMT”, UNH – CCOM GIS Training for Bathymetric Mapping Course. December 6 2005.

Gardner, J.V., UNH Law of the Sea mapping, given to the Hydrographic Services Review Panel, August, 2005.

Malik, M.A., ‘Study of fishing impacted areas on Jeffrey’s Ledge using multibeam sonar and videography.’ Presentation CINEMAR PI meeting 4 January 2005, UNH, Durham NH.

Malik, M.A. ‘Identification of bottom fishing impacted areas using multibeam sonar and videography.’ MS Thesis defense, 14 April 2005. CCOM, UNH, Durham NH.

Mayer, L.A., Mapping and Visualizing the Seafloor: Seeing Without Really Being There, Invited Presentation , Annual Meeting of the American Association of Advancement of Science, Washington D.C., Feb19, 2005

Mayer, L.A., New Directions in Seafloor Mapping and Visualization, Invited Presentation, Lamont Colloquium , Lamont Doherty Earth Observatory, N.Y., Feb. 25, 2005

Mayer, L.A., Mapping the Unseen: High Tech Imaging of the Seafloor, Invited Presentation, Sea Secrets Lecture Series of the University of Miami and The Ocean Research and Education Foundation, Miami, Fl., March 16, 2005

Mayer, L.A., New Directions in Seafloor Mapping and Data Visualization: Keynote Talk – RESON Multibeam Users Workshop – Tokyo Japan, April 20, 2005

Mayer, L.A., New Directions in Seafloor Mapping and Data Visualization: Invited Lecture – National Geospatial Intelligence Agency – Bethesda Md., July 13, 2005

Mayer, L.A., Mapping the Unseen: New Directions in Seafloor Mapping and Data Visualization – Bock Memorial Lecture, United States Naval Academy, October 18, 2005

Monahan, D., the Law of the Sea, Geomatics and Hydrography. Department of Geomatics Engineering, York University, Toronto, 2005.

Monahan, D., The seafloor, the Law of the Sea and Hydrography in the Arctic, Canadian Hydrographers Association, Burlington, Ontario, 2005.

Monahan, D., Hartoyo, D., Heredia, J.R., Bustamante, M., Yoshida, T., Bashir, M. and Lagonsin, A., Reaching out through the oceans: international education in mapping the seabed at the University of New Hampshire. *In* A public panel presented as part of International Education Week. Durham, NH. 15 November 2005.

Rzhanov, Y., "Practical Video Mosaicing", Workshop for NOAA Alaska Fisheries in Seattle, September 6-9, 2005.

Ware, C., and Arsenault, R., GeoZui3D for ROV and AUV visualization. NOAA Internal AUV workshop Silver Springs MD March 9.

Ware, C., Whale Behavior Analysis tools, ESME meeting Arlington. March 15.

Ware, C., R. Arsenault, and M. Plumlee, Interactively Visualizing Oceanographic Time-Varying Oceanographic Data, paper presented at Offshore Technology Conference, Houston, Texas, 2-5 May 2005.

Appendix D:

Meetings and Conferences Attended

Alexander, L. 11th Meeting of IEC TC80/WG 13 (Navigation Display), Sarasota, FL, 11-14 January 2005.

Alexander, L. OCS-NOAA Field Procedures Workshop, Norfolk, VA, 24-25 January 2005.

Alexander. L., MesoAmerican-Caribbean Sea Hydrographic Commission – Electronic Chart Working Group Meeting, Norfolk, VA, 26 January 2005.

Alexander, L., 9th Meeting of IHO WEND, International Hydrographic Bureau, Monaco 7-8 April 2005 (Rapporteur).

Alexander, L. , MesoAmerican-Caribbean Sea Hydrographic Commission – Electronic Chart Working Group Meeting, International Hydrographic Bureau, Monaco, 9 April 2005.

Alexander, L., 8th Meeting of IHO TSMAD, S-57 Edition 4.0 Sub-Working Group, CCOM-JHC, Univ. of NH, 25-29 April 2005 (Host)

Alexander, L., Meeting of the Florida Keys National Marine Sanctuary – Sanctuary Advisory Council – Coral Reef – MIO Project Working Group, Key Largo, FL, 3 May 2005.

Alexander, L., RNC, ENC, DNC Co-evaluation Project: Draft Report Presentation, Coast Guard C2CEN, Portsmouth, VA 5-6 May 2005 (Principle Investigator).

Alexander, L., North American – European Inland ENC Harmonization Group Meeting, St. Petersburg, FL 16-18 May 2005 (Technical Coordinator).

Alexander, L., 4th IEC TC80/WG7 (ECS), St. Petersburg, FL 19-20 May 2005

Alexander, L., 3rd Harmonization Group on MIO Working Group, IHB, Monaco, 27 June 2005 (Chair).

Alexander, L., IALA Aids-to-Navigation Information Service (ANIS) – MIO Workshop, IHB Monaco, 28-29 May 2005 (Chair).

Alexander, L., 12th Meeting of IEC TC80/WG13 (Navigation Display), Bonn, Germany, 17-22 July 2005.

Alexander, L., 17th Meeting of IHO Committee on Hydrographic Resource Information Systems (CHRIS), Rostock, Germany, 4-10 September 2005. (Rapporteur)

Alexander, L., 13th Meeting of IEC TC80/WG13 (Navigation Display), Linthicum Heights, MD, 28-30 September 2005.

Alexander, L., RTCM Special Committee 109 (Electronic Charting), Linthicum Heights, MD, 11-12 October 2005.

Alexander, L., North American – European Harmonization Group on Inland ENC, Rotterdam, The Netherlands, 23 & 26 October 2005.

Alexander, L., MesoAmerican – Caribbean Sea Hydrographic Commission Meeting, Veracruz, Mexico, 9-12 November 2005.

Alexander, L., Inland ENC Encoding Guide, Seminar presented at ECDIS Stakeholders Forum in conjunction with IHO CHRIS 17 Meeting, 6-7 September 2005

Alexander, L., Electronic Charting: Current Status and Future Expectations. Seminar presented at University of New Brunswick, Fredericton, NB, 2 November 2005.

Alexander, L., IHO Digital Data Standards: Present and Future. Presentation at Electronic Chart Seminar – Pre-MACHC Meeting, Veracruz, Mexico, 7 November 2005.

Carline, C, Vitronics-Soltec Lead Free Soldering seminar, Radisson Hotel, Marlborough, MA, 25, May, 2005.

Conrad, R., Schuyler, Chad K. 'Feedrate Optimization & Tool Condition Monitoring for Flat End Milling Operations Utilizing Spindle Motor Power" Morse Hall, 18 November 2005.

Conrad, R., Society of Women Engineers National Conference: Women Engineers Leading Global Diversity, Anaheim, California, 3-5 November 2005.

de Moustier, C., IEEE Panel of Editors Meeting, April 8-10, 2005 (Fri-Sun), New Orleans, LA.

de Moustier, C., IEEE Oceanic Engineering Society Constitution & Bylaws mtg., April 30, 2005 (Sat) Houston, TX.

de Moustier, C., IEEE Oceanic Engineering Society ExCom meeting, May 1, 2005, (Sun) Houston TX.

de Moustier, C., Acoustical Society of America, Spring meeting, Vancouver BC, May 16-20, 2005.

de Moustier, C., Makai Experiment Planning Meeting, Vancouver BC., May 18, 2005.

de Moustier, C., IEEE Oceanic Engineering Society Constitution & Bylaws mtg.,Oceans '06 Americas/ Boston planning mtg. June 6, 2005 (Sat-Sun), Boston MA.

de Moustier, C., IEEE Oceanic Engineering Society Administrative Committee mtg., June 20, 2005, Brest, France.

de Moustier, C., IEEE Oceans '05 Europe Conference, Brest, France, June 21-22, 2005.

de Moustier, C., IEEE Oceanic Engineering Society Administrative Committee mtg., September 18-19, 2005, Washington DC.

Gardner, J.V., Chesapeake Technologies, Inc. workshop Nov. 2-3, 2005

Glynn, J., Vitronics-Soltec Lead Free Soldering Seminar, Radisson Hotel, Marlborough, MA, 25, May, 2005.

Kraft, B. J., ONR SAX04 Workshop, APL-UW, Seattle, WA, 4-5 May, 2005.

Kraft, B. J., ONR Ripples DRI Review, Scripps, San Diego, CA, 12-13 September, 2005.

Malik, M.A. NOAA workshop on Non Fishing impacts, Mystic CT. 10-12 Jan 2005.

Malik, M.A. Workshop to develop guidelines and specifications for seabed mapping to support ecosystem characterization in National Marine sanctuaries. CCOM, UNH Durham NH, 23-24 May 2005.

Monahan, D., Extraordinary Hydrographic Conference, Monaco, April 11-15.

Monahan, D., International Maritime Organization (IMO) 94th session of Council in London on June 21st, 2005.

Monahan, D., Sub Committee on Digital Bathymetry, Aguascalientes, Mexico, 07/08-09/05.

Monahan, D., GEBCO Guiding Committee, Aguascalientes, Mexico, 07/10-12/05.

Sullivan, B., WebSolutions Meeting – Planning your website, Durham, NH, 30 November 2005.

Sullivan, B., Brown University-Visualization group, Providence, RI, 22 July 2005.

Appendix F: Appendix E: Other Funding

Name	Grantor	FY Award	Total Award	Length
Electronic Charting, Tech Advisor	IPA Agreement OCS-NOAA	50,000	50,000	1 year
Electronic Charting, Tech Advisor	OCS-NOAA	50,000	50,000	1 year
Inland Electronic Charting	IPA Agreement USDOD Army	25,000	25,000	1 year
CUBE Bathymetric Data Process	Science Applications International Corporation	3,445	3,445	1 year
CUBE Bathymetric Data Process	Science Applications International Corporation	1,009	1,009	1 year
Transducer Project	US DOC NOAA	24,631	24,631	1 year
Volume Search Sonar Processing	University of San Diego	-	30,000	3 years
Multibeam Swath Bathymetry	University of California at San Diego	18,068	18,068	1 year
Geocoder Acoustic Backscatter	Interactive Visualization System	15,300	15,300	1 year
WGOMICA	NOAA	-	13,603	2 year
WGOMICA subcontract	NOAA	-	46,500	2 year
Journal of Oceanic Engineering	IEEE	40,000	120,000	3 years
Score Deep Tow Data Processing	University of California at San Diego	29,000	29,000	1 year
GEBCO/Nippon Foundation	NIPPON FOUNDATION	534,842	1,580,961	Projected
Geo -Reference Video Mosaics	National Science Foundation	156,920	156,920	2 years
Collaborative High Resolution Mapping	US DOI, US Geological Survey	-	4,693,730	5 years
Geoclutter Program	ONR	-	450,478	4 years
Paleoceanographic Record from Alaska	National Science Foundation (NSF)	-	57,471	3 years
Test Long Range Side-Scan	NOAA	800,000	1,500,000	3 years
Ripples DRI	US DOD, Navy	-	153,577	2 years
Support of Benthic Habitat Mapping	US DOC NOAA	8,000	8,000	1 year
Video Mosaic Research	US DOI, US Geological Survey	10,000	10,000	1 year
Multi-Scale Interaction w/3D Data Environment	National Science Foundation (NSF)	-	499,152	5 years
TYCO Endowment interest from perpetuity	TYCO	8,573	8,573	Perpetuity
Practical Mosaicing Workshop	US DOC NOAA	4,073	4,073	1 month
GI2Vis Phase III	BBNT Solutions LLC	30,910	30,910	1 year
		1,809,771	**9,580,401**	

2005 Field Programs

Sumatra "Tsunami "cruise. 7 May – 25 May, 2005. MV Performer. Task: Provide visualization support to the project (Arsenault, Mayer, and Ware).

Whale Tagging Project "Whale Tracks'05" 25 June – 9 July. 2005 R/V Nancy Foster. Task: Provide visualization and data analysis support to the project. (Arsenault, Ware).

NWFSC Fisheries Advanced Technology Cruise, 15-30 October 2005, R/V Thomas Thompson, Provide 3D mission planning, monitoring and review for SeaBED AUV. (Arsenault).

NOAA Ship FAIRWEATHER, Cape Decision OPR-O167-FA, Leg 3. 23 May – 3 June 2005. Petersburg, AK to Seward, AK. (Calder and Fonseca).

R/V KILO MOANA, Gulf of Alaska LOTS Mapping 2005, 24 June – 28 July 2005. Honolulu to Kodiak, AK (Gardner).

R/V KILO MOANA, Gulf of Alaska LOTS Mapping 2005, 30 July – 1 September 2005. Kodiak, AK to Honolulu, HI (Calder, Malik, Mayer).

NOAA Ship RONALD H. BROWN, Virtual Cruise: Lost City 2005, 22-31 July 2005. Woods Hole, MA to the Azores (Arsenault, Calder, Case, Mayer and many others).

Summer Hydrographic Course, June 8, R/V Little Bay; Observed and participated in the Klein 5410 installation and operation procedures for future reference of Baby Tow Fish installation. (Conrad).

JHC/COM survey and analysis of Hampton Harbor, 2005, aboard R/V Little Bay in support of Hydrographic Field camp and a contract to the U.S. Army Corps of Engineers. (Dijkstra).

Alaskan Fjords R/V Fairweather, Calibration of Backscatter from Reson 8101, 8111 and 8160 Multibeam Sonars, Petersburg to Seward Alaska, May 21 – June 5 2005
Plan and conduct experiments to calibrate Reson Acoustic Backscatter. (Fonseca).

NAVO Vessel Pathfinder -- Complete the mapping of the U.S. Atlantic continental margin for Law of the Sea, April 22 - June 21, 2005 (Gardner).

Klein 5410 Calibration, 6 July, R/V Gulf Challenger, System 5000 K-Wing II Depressor Test (Huff, Glynn).

NOAA Support, five days January 2005, Seattle WA, Testing of fiber optic operability of Klein 5410 (Huff).

NOAA Support, 5410 plus K-Wing II stability testing, May 2005; Isles of Shoals on Gulf Challenger (Huff).

NOAA Support, two days in June 2005, Hampton Harbor NH, Setup and testing of Klein 5410 for the summer Hydro Field Program; R/V Little Bay. (Huff).

Hubbard Camera/ROV testing/demonstration, 1 day June 2005; Isles of Shoals on Gulf Challenger (Huff).

Summer Hydro, 22 May – 25 August, R/V Little Bay, Hampton Harbor, (Armstrong, Dijkstra, McLeod).

Optical water properties measurement cruise Portsmouth – Isle of SHOALS
November 8, 2005, UNH vessel Measuring in-situ optical properties of water (Pe'eri).

GPS RTK integration cruise JEL (Adams Point) September 30, 2005, Coastal Surveyor
Field test to the new GPS RTK integration (Pe'eri).

Atlantis II, AT11-27 leg, May 18 -- June 3, 2005, East Pacific Rise. (Rzhanov).

Appendix G: Visitors January 1 2005- December 31, 2005

Name	Date	From	Visiting	Purpose
T. Curley	1/13/2005	EPC	CCOM	MTS Meeting
B. Andrews	1/13/2005	Woods Hole Group	CCOM	MTS Meeting
P. Igo	1/13/2005	ESNE	CCOM	MTS Meeting
M. Newcombe	1/13/2005	RDI	CCOM	MTS Meeting
L. Gee	1/13/2005	IVS 3D	CCOM	MTS Meeting
T. Shyka	1/13/2005	GoMOOS	CCOM	MTS Meeting
L. Robidoux	1/13/2005	UNH/NOAA	CCOM	MTS Meeting
J. Izra	1/13/2005	Sygnus Technologies	CCOM	MTS Meeting
C. Kammerer	1/13/2005	UNH/NOAA	CCOM	MTS Meeting
A. Armstrong	1/13/2005	UNH/NOAA	CCOM	MTS Meeting
J. Case	1/13/2005	UNH/CCOM	CCOM	MTS Meeting
J. Rogers	2/5/2005		S. Dijkstra	PPK GPS of LiDAR Survey to be carried out in Wells, Maine
M. Brown	2/15/2005	CGTP	CCOM	Discussion on issues of uncertainty estimation and management in sparse and dense data for GeoDAS refurbishment
M. Cole	2/15/2005	NOS	CCOM	Discussion on issues of uncertainty estimation and management in sparse and dense data for GeoDAS refurbishment
R. McConnoughney	2/19-21/2005	NMFS	CCOM	Discussion of on going collaborative efforts with CCOM and NOAA
C. Yeung	2/19-21/2005	NMFS	CCOM	Discussion of on going collaborative efforts with CCOM and NOAA
X. Lurton	3/3/2005	IFREMER	CCOM	Discussion on various aspects of multibeam data processing
H. Bisquay	3/3/2005	IFREMER	CCOM	Discussion on various aspects of multibeam data processing
J. Sinquin	3/3/2005	IFREMER	CCOM	Discussion on various aspects of multibeam data processing
H. Floch	3/3/2005	IFREMER	CCOM	Discussion on various aspects of multibeam data processing
K. Johnson	3/8/2005	NWS	CCOM	NWS Visit to UNH
A. Wheeler	3/8/2005	NWS	CCOM	NWS Visit to UNH
D. St. Jean	3/8/2005	NWS	CCOM	NWS Visit to UNH

D. Vallee	3/8/2005	NWS	CCOM	NWS Visit to UNH
J. Barbera	3/17/2005	IEEE	C. De Moustier	Editorial Board Meeting
J. Lynch	3/17/2005	IEEE	C. De Moustier	Editorial Board Meeting
W. Carey	3/17/2005	IEEE	C. De Moustier	Editorial Board Meeting
P. Latham	3/18/2005	IEEE	C. De Moustier	Transponder Design Meeting
J. Canfield	3/18/2005	IEEE	C. De Moustier	Transponder Design Meeting
E. Chun Taite	3/22/2005	Marine Docents	CCOM	Information Session
P. de Beer	3/22/2005	Marine Docents	CCOM	Information Session
E. Powers	3/22/2005	Marine Docents	CCOM	Information Session
B. Corbett	3/22/2005	Marine Docents	CCOM	Information Session
D. Corbet	3/22/2005			
R. Morales	3/22/2005	Marine Docents	CCOM	Information Session
B. Newall	3/22/2005	Marine Docents	CCOM	Information Session
K. Fitzgerald	3/22/2005	Marine Docents	CCOM	Information Session
B. Moynihan	3/22/2005	Marine Docents	CCOM	Information Session
P. Crosby	3/22/2005	Marine Docents	CCOM	Information Session
I. Crosby	3/22/2005	Marine Docents	CCOM	Information Session
F. Beattel	3/22/2005	Marine Docents	CCOM	Information Session
M. Olsen	3/22/2005	Marine Docents	CCOM	Information Session
I. Lourie	3/22/2005	Marine Docents	CCOM	Information Session
P. Flynn	3/22/2005	Marine Docents	CCOM	Information Session
L. Flynn	3/22/2005	Marine Docents	CCOM	Information Session
B. Kath	3/22/2005	Marine Docents	CCOM	Information Session
J. Kath	3/22/2005	Marine Docents	CCOM	Information Session
C. Horrigan	3/22/2005	Marine Docents	CCOM	Information Session
J. Walker	3/22/2005	Marine Docents	CCOM	Information Session
J. Jervis	3/22/2005	Marine Docents	CCOM	Information Session
E. Nielon	3/22/2005	Marine Docents	CCOM	Information Session
H. Crosby	3/22/2005	Marine Docents	CCOM	Information Session
P. Kelera	3/22/2005	Marine Docents	CCOM	Information Session
D. Cacchione	3/30-4/2/2005	Coastal & Marine Environments	CCOM	Visiting CCOM
B. Altmeier	3/31-4/1/2005	Florida Keys National Marine Sanctuary	CCOM	Workshop on Practical Mosaicing
D. Coleman	3/31-4/1/2005	Institute for Exploration	CCOM	Workshop on Practical Mosaicing

J. Broadwater	3/31-4/1/2005	Monitor National Marine Sanctuary	CCOM	Workshop on Practical Mosaicing
P. Dartnell	3/31-4/1/2005	USGS	CCOM	Workshop on Practical Mosaicing
K. Gleason	3/31-4/1/2005	Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve	CCOM	Workshop on Practical Mosaicing
R. Green	3/31-4/1/2005	Thunder bay National Marine Sanctuary	CCOM	Workshop on Practical Mosaicing
M. Lawrence	3/31-4/1/2005	Stellwagen Marine Sanctuary	CCOM	Workshop on Practical Mosaicing
D. Marx	3/31-4/1/2005	Stellwagen Marine Sanctuary	CCOM	Workshop on Practical Mosaicing
R. Neyland	3/31-4/1/2005	US Naval Histroical Center	CCOM	Workshop on Practical Mosaicing
S. Schmidt	3/31-4/1/2005	US Naval Histroical Center	CCOM	Workshop on Practical Mosaicing
B. Schwemmer	3/31-4/1/2005	Channel Islands National Marine Sanctuary	CCOM	Workshop on Practical Mosaicing
B. Seymour	3/31-4/1/2005	National Park Service, Submerged Resource Center	CCOM	Workshop on Practical Mosaicing
B. Terrell,	3/31-4/1/2005	National Marine Sanctuary	CCOM	Workshop on Practical Mosaicing
J. Weirich	3/31-4/1/2005	NOAA Office of Ocean Exploration	CCOM	Workshop on Practical Mosaicing
C. Dundorff	4/1/2005	Klein Associates	CCOM	Delivery and assembly of engineering tank suspension system for Klein 5410
J. Rogers	4/4/2005		S. Dijkstra	PPK GPS of LiDAR Survey to be carried out in Wells, Maine
D. Barnes	4/13/2005	HarborView	CCOM	Lecture on Harborview and DNC
W. Holtgren	4/13/2005	HarborView	CCOM	Lecture on Harborview and DNC
R. McConnoughney	4/13-15/2005	NMFS	CCOM	Discussion of on going collaborative efforts with CCOM and NOAA
J. Rogers	4/18/2005		S. Dijkstra	PPK GPS of LiDAR Survey to be carried out in Wells, Maine

H. Astle	4/25-29/2005	CARIS	CCOM	8th TSMAD S-57 Sub-WG Meeting
P. Birkle	4/25-29/2005	Mitre Corp	CCOM	8th TSMAD S-57 Sub-WG Meeting
H. Bothiem	4/25-29/2005	SevenCs	CCOM	8th TSMAD S-57 Sub-WG Meeting
M. Brown	4/25-29/2005	OCS-NOAA	CCOM	8th TSMAD S-57 Sub-WG Meeting
O.A. Føre	4/25-29/2005	Norwegian Hydro Service	CCOM	8th TSMAD S-57 Sub-WG Meeting
S. Freeman	4/25-29/2005	Coast Guard C2CEN	CCOM	8th TSMAD S-57 Sub-WG Meeting
D.Gaulton	4/25-29/2005	Dept. of National Defense	CCOM	8th TSMAD S-57 Sub-WG Meeting
B. Greenslade	4/25-29/2005	UK Hydrographic Office	CCOM	8th TSMAD S-57 Sub-WG Meeting
E. Kuwalek	4/25-29/2005	IIC Technologies	CCOM	8th TSMAD S-57 Sub-WG Meeting
M. LeGleau	4/25-29/2005	SHOM (France HO)	CCOM	8th TSMAD S-57 Sub-WG Meeting
J. Melles	4/25-29/2005	BSH (German HO)	CCOM	8th TSMAD S-57 Sub-WG Meeting
E. Mong	4/25-29/2005	C-Map Norway	CCOM	8th TSMAD S-57 Sub-WG Meeting
J. Powell	4/25-29/2005	OCS-NOAA	CCOM	8th TSMAD S-57 Sub-WG Meeting
J. Radice	4/25-29/2005	Coast Guard NAVCEN	CCOM	8th TSMAD S-57 Sub-WG Meeting
K. J. Simmons	4/25-29/2005	NGA	NGA	8th TSMAD S-57 Sub-WG Meeting
D.Tallon	4/25-29/2005	CHS (Canadian HO)	CCOM	8th TSMAD S-57 Sub-WG Meeting
G. Uguen	4/25-29/2005	SHOM (French HO)	CCOM	8th TSMAD S-57 Sub-WG Meeting
D. Vachon	4/25-29/2005	CHS (Canadian HO)	CCOM	8th TSMAD S-57 Sub-WG Meeting
C. Roberts	4/25-29/2005	Australian HO	CCOM	8th TSMAD S-57 Sub-WG Meeting
T. Pharaoh	4/25-29/2005	IHB	CCOM	8th TSMAD S-57 Sub-WG Meeting
M.LeGleau	4/25-29/2005	SHOM (France HO)	CCOM	8th TSMAD S-57 Sub-WG Meeting
D. Gaulton	4/25-29/2005	Dept. of National Defense	CCOM	8th TSMAD S-57 Sub-WG Meeting
A. Pharoah	4/28/2005	International Hydrographic Bureau	CCOM	GEBCO project to use ENC data in bathymetry
D. House	5/5-6/29/2005	Visiting Scientist	CCOM	Optimal Data Visualization

C. Gostnell	5/9/2005	HSTP	CCOM	Discussion on test conditions for PMBS systems
R. Nairn	6/7/2005	Marine	CCOM	Briefing on CUBE, Navigation Surface, and the Open Navigation Surface
T. Weber	6/7/2005	University Park, PA	CCOM	Giving a seminar on Multibeam Sonar at Penn State
E. Mantz	6/8/2005	Greenline	L. Mayer, A. Armstrong	Reporting on UNH ocean oriented research
A. Freeman	6/8/2005	Greenline	L. Mayer, A. Armstrong	Reporting on UNH ocean oriented research
D. Brooks	6/8/2005	Greenline	L. Mayer, A. Armstrong	Reporting on UNH ocean oriented research
T. Hiller	6/20/2005	GeoAcoustics	CCOM	Discussion of test protocols for SAS
N. Gracias	7/15/2005	Miami University	CCOM	Visiting CCOM
G. Sentch	7/4-16/2005	Electronic Navigation Ltd.	CCOM	Sea trials of the Wide Angle Sonar Seafloor Profiler (WASSP)
H. Brohl	7/18-19/2005	Great Lakes Shipping Association	A. Armstrong	NOAA's Hydrographic Services Review Panel
J. Dasler	7/18-19/2005	David Evans Associates, Inc.	A. Armstrong	NOAA's Hydrographic Services Review Panel
E. Dickinson	7/18-19/2005	Boat Owners Association of the United States	A. Armstrong	NOAA's Hydrographic Services Review Panel
W. Gray	7/18-19/2005	Gray Maritime Company	A. Armstrong	NOAA's Hydrographic Services Review Panel
S. Hickman	7/18-19/2005	Houston Pilots Association	A. Armstrong	NOAA's Hydrographic Services Review Panel
L. Lapine	7/18-19/2005	South Carolina Geodetic Survey	A. Armstrong	NOAA's Hydrographic Services Review Panel
R. Larrabee	7/18-19/2005	The Port Authority of New York and New Jersey	A. Armstrong	NOAA's Hydrographic Services Review Panel
A. McBride	7/18-19/2005	Port Director, Lake Charles and Terminal District	A. Armstrong	NOAA's Hydrographic Services Review Panel
A. McGovern	7/18-19/2005	Sandy Hook Pilots Association	A. Armstrong	NOAA's Hydrographic Services Review Panel

M. Myrtidis	7/18-19/2005	Nowregian Cruise Line	A. Armstrong	NOAA's Hydrographic Services Review Panel
J. Oswald	7/18-19/2005	John Oswald and Associates, LLC	A. Armstrong	NOAA's Hydrographic Services Review Panel
S. Rainey	7/18-19/2005	American Pilots Association	A. Armstrong	NOAA's Hydrographic Services Review Panel
T. Skinner	7/18-19/2005	Durand & Anastas	A. Armstrong	NOAA's Hydrographic Services Review Panel
R. West	7/18-19/2005	Environmental Strategies, Inc.	A. Armstrong	NOAA's Hydrographic Services Review Panel
L. Whiting	7/18-19/2005	Terra Surveys LLC	A. Armstrong	NOAA's Hydrographic Services Review Panel
NOAA Sponsors	7/26/2005	NOAA	CCOM	Annual Presentations-Vislab Demos
Dartmouth Modelers	8/11/2005	Dartmouth University	CCOM	Vislab-looking at flow models
HSRP	8/19/2005	HSRP	CCOM	Vislab Demos and Presentation on Currents
L. Nash	8/22-23/2005	President of Measutronics	CCOM	delivery and installation of Trimble RTK GPS configuration
E. Paz Costa	8/25/2005	Comissao dos Espacos Maritimos, Republic of Angola	CCOM	Visiting CCOM
N. Grinelli	8/25/2005	C&C Technologies	CCOM	Visiting CCOM
A. Kleiner	8/25/2005	C&C Technologies	CCOM	Visiting CCOM
S. Tani	9/5/2005	Japan Coast Guard	CCOM	Review Nippon Foundation Project
P. Latham	10/10/2005	Orion Design Inc.	C. De Moustier	Transponder Design Meeting
J. Hall	10/12-15/2005	Geological Survey of Israel	CCOM	Visiting CCOM
P. Ellsworth	10/21/2005	University of Wyoming	CCOM	Visiting CCOM
J. Hall	10/21/2005	Geological Survey of Israel	CCOM	Visiting CCOM
S. Beaulieu	10/21-23/2005	NFS	Y. Rzhanov	Visiting CCOM
R. Macnab	10/24-28/2005	Canadian Geological Survey	CCOM	Visiting CCOM
N. Grinelli	10/25-28/2005	C&C Technologies	CCOM	Visiting CCOM

E. Paz Costa	10/25-28/2005	Comissao dos Espacos Maritimos, Republic of Angola	CCOM	Visiting CCOM
Center for Talented Youth	10/29/2005	Johns Hopkins	CCOM	Vislab Demos and Whale presentation
Marine Docents	11/1/2005	UNH	B. Calder	Presentation on the Lost City Expedition
B. Anderson	12/1/2005	SAIC	CCOM	GEBCO meetings
R. Falconer	12/1/2005	Institute of Geological and Nuclear Science	CCOM	GEBCO meetings
M. Fox	12/1/2005	Director of JGDV	CCOM	GEBCO meetings
J. Frias	12/1/2005	National Mapping Service of Mexico	CCOM	GEBCO meetings
C. Jacobs	12/1/2005	National Oceanography Centre	CCOM	GEBCO meetings
M. Loughridge	12/1/2005	retired from NGDC	CCOM	GEBCO meetings
H. Werner	12/1/2005	Alfred Wegner Institute	CCOM	GEBCO meetings
B. Whitmarsh	12/1/2005	National Oceanography Centre	CCOM	GEBCO meetings
H. Karl	12/2/2005	Mitre Corp	CCOM	Visiting CCOM
R. McConnaughey	12/7-8/2005	NMFS	CCOM	Discussion of on going collaborative efforts with CCOM and NOAA
C. Yeung	12/7-8/2005	NMFS	CCOM	Discussion of on going collaborative efforts with CCOM and NOAA
H. Woodsum	12/15/2005	Sonetech Corporation	C. De Moustier	Parametric Sonar Calibration