The NOAA/UNH Joint Hydrographic Center and the UNH Center for Coastal and Ocean Mapping: An Educational and Research Partnership of the Federal Government, the University of New Hampshire and Ocean Industry.

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Abstract

Ocean mapping technology is becoming an increasingly important tool in the full range of ocean-related enterprise. Moving well beyond its initial base in hydrographic surveying and nautical charting, ocean mapping has become a critical component of offshore oil exploration and development, submarine cable routing and installation, and geologic and essential fish habitat mapping. The technology of ocean mapping has blossomed rapidly in the past decade with the introduction of multibeam sonar, high-resolution side scan sonar, airborne lidar bathymeters, and laser line scan recorders. The next decade will likely see increased demand for ocean mapping data and continued demand for even more sophisticated ocean mapping technology. In response to this increased demand for ocean mapping data and the increasing complexity of ocean mapping technology, the National Oceanic and Atmospheric Administration (NOAA) and the University of New Hampshire (UNH) have established the complementary Joint Hydrographic Center (JHC) and Center for Coastal and Ocean Mapping (C-COM). The JHC is a NOAA/UNH partnership, and C-COM is a University organization with growing private sector participation.

To provide NOAA and other program sponsors with the technology needed to meet their hydrographic and ocean mapping responsibilities, JHC and C-COM have developed a multidisciplinary and interdisciplinary program of research. The research program of the Centers has begun with principal themes encompassing ocean and electrical engineering, computer science, and earth science. Research topics will focus on sonar system capabilities and limitations; data processing, visualization, and presentation; seafloor characterization; and other new applications of seafloor mapping technology and data.

Meeting the challenges of developing and deploying new ocean mapping tools will require not only extensive research and development activity, but also an increased cadre of hydrographers and ocean mapping professionals. For this reason, these new Centers will have the mission of hydrographic/ocean mapping education as well as research and development. Through these Centers, the University will offer masters and doctoral level ocean mapping degree programs in both Earth Sciences and in Ocean Engineering. Several of the new graduate level courses will be open to upper-level undergraduates. This could lead to the establishment of an undergraduate minor in ocean mapping, and will provide a mechanism to interest undergraduate engineers and earth scientist in hydrographic and ocean mapping careers or graduate school. To meet the needs of practicing professionals in the hydrographic and ocean mapping fields, the Centers will offer both basic and advanced short courses and seminars.

INTRODUCTION

The Importance of Ocean Mapping

The National Oceanic and Atmospheric Administration (NOAA) is charged with the responsibility of providing comprehensive and accurate nautical charts of United States waters. NOAA's mission includes both the acquisition of hydrographic survey data and the compilation and publication of traditional paper charts as well as raster and vector electronic nautical charts. The total area of NOAA's hydrographic survey and nautical charting responsibility is approximately 3.5 million square nautical miles. While much of this area is deep water, hundreds of thousands of square miles of this area are in the range of depths where accurate surveys and charts are an absolute necessity for safe navigation. Meeting this need for safe navigation has been the primary purpose of hydrographic surveying for centuries. This need has not diminished. More than ninety-five percent by weight of the United States' international trade moves through our ports and harbors. Fifty percent of these goods are hazardous materials. Waterborne commerce more than tripled in the last half of the 20th century and it is expected to triple again in the next three decades [1]. The increased volume of cargo and passenger traffic has led to ships of greater length, breadth, and draft. 1000-foot cargo ships and tankers now operate with drafts of 60 feet or more. Larger ships with deeper drafts mean smaller under-keel clearances and consequently greater demand for accurate depths and assurance that no submerged objects are left undetected. Our major ports and harbors are not the only areas where complete and accurate ocean mapping is required. In 1970, cruise ships carried about half a million passengers a year. In 1999, 6 million people cruised. This year the number is expected to increase by another full million [2]. Cruise ships of more than 1000 feet in length are being built to carry 3800 passengers

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and 1100 crewmembers. This increase in passenger capacity, and size and numbers of cruise ships means increased pressure for new cruising areas in waters that are less traveled and more remote. These rapidly expanding cruising areas are increasing the demand for accurate and up to date hydrographic data faster than NOAA can complete new surveys and compile new charts.

NOAA is also the federal agency responsible for marine fisheries management. In the 1996 Magnuson-Stevens Sustainable Fisheries Act, the U.S. Congress, in recognition of the critical role that habitat plays in sustaining our marine fisheries, mandated the identification of habitats essential to managed species and measures to conserve and enhance this habitat. Congress defined essential fish habitat as those waters and substrate necessary to fish (and other managed marine living resources) for spawning, breeding, feeding, or growth. Substrate was defined as including sediment, hard bottom, structures underlying the waters, and their associated biological communities. This mandate could very likely create a need for ocean mapping even larger than the traditional requirements of safe navigation. Not only are vast new areas in need of mapping, new types of ocean mapping data are required. In addition to bathymetry, information on bottom type and character is required. Related to fisheries management is NOAA's role in coastal zone management. NOAA, along with other federal agencies (EPA, U.S. Army Corps of Engineers) and regional coastal zone managers require coastal and ocean mapping data to review dredge spoil disposal plans and evaluate the impacts of ocean dumping and sewage outfalls.

NOAA is not alone in the need for ocean mapping data. For many years now, the offshore oil industry has employed ocean mapping tools in support of exploration, rig placement, and pipeline operations. The extension of oil development into deeper water and increased economic incentive for exploration and extraction will undoubtedly lead to increasing demands for seafloor mapping. The submarine fiber optic cable market is growing rapidly. Over the past three years, the market for installed systems has increased 91 percent. This year, the market size is estimated to be $6.5 billion, a 19 percent increase from 1999 [3]. Fiber optic cable installation is highly dependent on accurate maps of the seafloor. As in habitat mapping, both bathymetry and bottom character are essential. In fact, for cable routing and laying operations, the need for mapping of essential fish habitat often coincides with the ocean mapping requirements of installing the cable. As fiber optic cable come ashore, coastal and living marine resource managers are demanding that the routes are consistent with sustainable management of those resources. Cable companies must not only find suitable routes for the cable, they must avoid critical habitat. Other demands for ocean mapping data come from the oceanographic and marine geologic research community, the placer mining industry, and the military.

The Case for R&D

While the demands for ocean mapping data are burgeoning, so too is the technology of ocean mapping. In the last decade, shallow water multibeam sonar, high speed high resolution and interferometric side scan sonars, airborne lidar bathymeters, and laser line scan recorders have all become part of the ocean mapping toolkit. These systems are capable of producing complete (or near-complete) coverage of the seafloor in contrast to the sparsely spaced individual measurements typical of traditional echo sounders.

These new systems also offer a virtually untapped potential for nautical charting and other applications. Most important is the inherent data density produced by these systems, which combined with state-of-the-art data visualization techniques, can produce unprecedented images of the seafloor. These images provide a realistic view of the three-dimensional morphology of the seafloor in a manner that is instantly and intuitively interpretable. In addition, many of the new sonar systems have the ability to collect acoustic backscatter data (side-scan sonar-like imagery) at the same time that bathymetric data is being collected. The backscatter data is related, in a complex way, to the seafloor material type (sand, silt, clay, etc) as well as the surficial roughness of the seafloor, and thus provides yet another dimension to seafloor mapping – the ability to extract qualitative, and potentially quantitative information on the distribution of seafloor types and materials (seafloor classification).

The near full-bottom coverage offered by modern mapping systems, in concert with backscatter data and new analytical and visualization techniques, opens up a world of opportunities in terms of value-added products and services that can be derived from standard hydrographic surveys. We now have the potential for a full view of the seafloor much like that of the earth offered by satellite imagery. And just like the early days of satellite imagery we believe that we are poised to make the leap from data acquisition to information extraction, a leap that will benefit all those involved with the collection of hydrographic data.

While the advantages of these new mapping approaches are manifest, they come with a high price. These new systems are inevitably much more complex, much more costly, and have much steeper learning curves than traditional surveying techniques. The complexity of the systems, particularly with respect to the need to integrate the inputs of several independent sensor systems (e.g. motion sensors, sound speed sensors, positioning systems and the sonar) makes them particularly prone to artifacts that can seriously degrade the usefulness of the collected data. While many of these systems have been in use over the last few years, it is still rare that the full potential of the data (i.e., the specified capabilities of a given system) is achieved.

In addition to the problems associated with data quality, the massive volumes of data produced by these new systems present tremendous challenges to their operators. While data volumes will vary with water depth and system configuration, shallow water mapping systems can easily produce data at rates of more than 500 Mbytes/hr. If we are to take full advantage of the tremendous range of opportunities offered by these new mapping systems, we must have the means to manage, manipulate, visualize and verify the accuracy of these data in a timely manner.

Tools and technology alone are not enough, for if we are to use modern seafloor mapping data to its fullest extent, we must also ensure that we have a cadre of new-generation hydrographers and scientists who understand and fully appreciate both the complexities and potential of these new ocean mapping approaches.

THE CENTERS

It is with these issues in mind that the NOAA/UNH Joint Hydrographic Center was established. On June 4, 1999 the Administrator of NOAA and President of the University of New Hampshire (UNH) signed a cooperative agreement describing a Joint Hydrographic Center (JHC) at UNH. On July 1, 1999 a grant was awarded to UNH providing the initial funding for the establishment of the JHC. 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 center is focusing its activities on two major themes, a research theme aimed at developing and evaluating a wide range of state–of-the-art hydrographic and ocean mapping technologies and applications and 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 (C-COM) 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. Unlike many university-based centers of excellence, C-COM has not established a "one-size-fits-all" partnership program. Each partnership agreement is based upon the mutual interest of the university and the partnering entity. Some organizations may wish to provide grants and endowments to the program, some may offer equipment and/or software for use in research and educational programs, some may support graduate students working on projects of interest, some may collaborate on research of mutual interest, and some may simply enter into contracts for services. All of these models have been applied under a general partnership umbrella, and all offer the opportunity for advancing the technology of ocean mapping.

In establishing the Centers within a university setting our hope is to create an environment that will foster and promote the training of a new generation of hydrographers to meet the growing needs of both government agencies and the private sector (as well as train a new generation of academics). We are establishing a program that will provide students with the essential fundamentals of hydrographic surveying but at the same time expose them to state-of-the-art (and beyond) survey techniques and data processing methods. Our training program takes advantage of existing courses already being offered at UNH as well as new courses being created by Center personnel. While our initial focus is on graduate education, the long-term goal will be to establish both degree and certificate programs at both the graduate and undergraduate level. The Center will also sponsor continuing education and outreach programs designed to make advanced hydrographic and ocean mapping training available to a wide sector of the hydrographic and ocean mapping community.

THE RESEARCH PROGRAM

Research has begun on several major themes. In keeping with the collaborative approach to research at the Centers, these themes overlap and support one another. Our research will involve both University and NOAA personnel, and will also include our industrial partners.

Innovative sonar design and processing for enhanced resolution and target recognition

A fundamental goal of all hydrographic and ocean mapping surveys is to achieve the greatest resolution possible while maximizing the area covered. We will strive to achieve this goal through the combination of new hardware design and innovative processing algorithms. The hardware component will focus on the development of new approaches to both side scan and multibeam sonar design that are aimed at substantially increasing the resolution achievable with these systems. The software component of the project will involve both enhanced algorithms for bathymetry and the design of innovative and automated approaches for target or object detection. Finally, this research theme will also explore more efficient approaches to mosaicing side scan sonar (and other) data as well as ways to fuse and overlay multiple data sets.

New approaches to multibeam sonar data processing

Over the past few years, major advances in multibeam sonar processing have allowed the hydrographic and ocean mapping community to produce cleaned hydrographic data at a rate that is on the order of the time required to collect the data. While this ratio represents an improvement from that which was possible only a few years ago, significant decreases in the amount of time spent on processing are essential for truly efficient ocean mapping. We will use the collective statistical, visualization, and hydrographic expertise of the C-COM/JHC team to develop statistically robust techniques for the rapid cleaning of hydrographic data. Critical to this development will be our close association with NOAA and

private sector hydrographers to assure that techniques developed will be based on sound hydrographic practice.

New approaches to data visualization and presentation

With the rapid improvements in seafloor mapping techniques comes both tremendous opportunities and tremendous challenges in terms of data visualization and presentation. In particular, the great density of data provided by multibeam sonar allows the application of advanced scientific and 3-D visualization techniques that may provide for greatly enhanced insight into the data; at the same time the sheer quantity of data presents serious challenges in terms of manipulation, interaction and verification. We propose to take advantage of the expertise associated with our Data Visualization Laboratory and begin to define the "chart of the future". We envision this chart to be a digital, multi-layer product that can be interactively explored in 3-D and customized to the needs of a particular user or application. These applied projects will be combined with more theoretical studies of how people interact with 3-D virtual environments and with large screen displays. The results of these studies can then be combined with the applied work to help design optimal bridge displays that will allow the navigator to easily and intuitively integrate the disparate information sources necessary to assure safe passage of a vessel in all circumstances.

Seafloor Characterization

While historically, much of the focus of hydrographic activity has been on the accurate depiction of seafloor bathymetry, there is growing awareness of the tremendous potential for the quantitative extraction of seafloor properties from the same acoustic data used to derive bathymetry. The Center will address the issue of remote seafloor characterization from several fronts including vertical beam echo sounders, side scan sonar, multibeam sonar, and video imaging.

Data Mining, Blending and Fusion

The hydrographic agencies of the world are under increasing pressure to produce updated, accurate charts of their navigable waters. In the U.S. alone, NOAA estimates a 30 to 40 year backlog for surveys of regions deemed "critical". With the growing popularity of multibeam sonar mapping for purposes other than hydrography there will be a growing database of data that is potentially useful for hydrographic purposes but may not have been collected to the standards often required by hydrographers. This theme will explore ways of combining data sets collected by different organizations with different sets of standards in a robust way that may they then be used to address the needs of the hydrographic community.

THE EDUCATION PROGRAM

The goal of the educational program of the Center is to create an educational environment that will meet the growing needs of both the government and the private sector for a properly trained new generation of hydrographers who have an understanding and appreciation of both the complexities and full potential of modern ocean mapping systems. The program provides students with the essential fundamentals of hydrographic surveying and services as well as introducing them to state-of-the-art survey techniques and data processing methods. We believe that the best way to do this is to ensure that the training component is intimately connected (both physically and spiritually) with leading edge research programs. In this manner, students at all stages of their career are exposed to and involved with ongoing research, testing and demonstration activities. This approach fosters hands-on experience and creativity, and ensures that the curricula remain focused on state-of-the-art techniques and technologies. We hope to develop professionals not just to carry out surveys, but who will have the background and knowledge necessary to shape the course of hydrography and ocean mapping technology for the future.

The initial focus is on a graduate degree offered through either the Department of Earth Sciences or through the interdisciplinary Ocean Engineering Program, depending on the background of the students (physical scientists would enter through the Earth Sciences program, engineers through the Ocean Engineering program). This degree program has been implemented through the existing structure of the UNH graduate program. Both these degree options are thesis programs, in keeping with the emphasis on exposing students to state-of-the-art research and development.

The Department of Earth Sciences provides a core curriculum of oceanography courses that is combined with the ocean mapping-specific courses that will be required for an Ocean Mapping Option. An Ocean Mapping Option within the Ocean Engineering Program has been similarly implemented. In this path, engineering students seeking a M.S. in Ocean Mapping take the core courses required for Ocean Engineering and supplement these with ocean-mapping specific courses developed by Center staff. Ocean mapping specialization is also offered in Earth Sciences and Ocean Engineering at the Ph.D. level.

Following the implementation of the graduate program will also come the development of undergraduate, certificate, and distance education programs aimed at assuring a constant supply of well-trained entry-level hydrographers and ocean mapping professionals to the government and the private sector. These programs will not have to be built from scratch, as UNH has an extensive undergraduate program already offering many of the requirements of an undergraduate hydrographic concentration in Earth Science or Engineering. The basis for an Associate degree technician program also exists, starting with six courses in surveying and mapping

offered at the Thompson School of Applied Science located at UNH.

Recognizing the trend toward an increasingly large component of hydrographic surveys being carried out by the private sector, it is critical that the private sector is supplied with well-trained hydrographers. While the graduate and undergraduate programs to be offered through the Center will address some of this need, there will also be a growing need for continuing and distance education programs including short courses. UNH will endeavor, where appropriate, to supply some of its course content in a mode that can serve the portion of the community that cannot fit within a regular University schedule. The Centers will also host, every other year, the U.S./Canada Hydrographic Commission Multibeam Sonar Training Course.

In setting up this program, UNH has recognized not only the benefit of government and private sector partnerships, but also the great value of university to university partnerships. UNH is actively involved in creating cooperative programs in ocean mapping education with the University of Southern Mississippi, the University of New Brunswick, Old Dominion University, and is exploring a partnership with the University of Alaska Anchorage. These partnerships affirm the desire to provide students with the best possible combination of resources, and recognize the fact that an ideal combination of resources for some students may come from more than one university.

REFERENCES

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