

The Establishment of The Hydrographic Science Research Center at The University of Southern Mississippi

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Introduction

From the beginning of man's venture out on the open seas, hydrography has been of crucial importance in both marine navigation and safe passage. Because of their close relationship with the fundamental aspect of marine safety, hydrographers have tended to be conservative and have been cautious in embracing changes in the way hydrography is performed and the data used. However, today's demands for hydrographic information have been reoriented in directions of time and space that are far different than the traditional demands of three or even two decades ago. Moreover, these demands have outstripped the ability of their being serviced by traditional hydrography.

Recent technology advances offer a vast menu of tools and methods that can be made to meet these changed demands. The present day hydrographer is faced with the complex challenge of which of these ever changing technological advances will most expeditiously meet the new requirements.

To help meet present and future hydrography requirements, the University of Southern Mississippi has established The Hydrographic Science Research Center as well as a complementary Hydrographic Science Master's Program. This paper will describe the new center as well as its rationale.

A Revolution in Hydrographic Affairs

Traditionally, the science of hydrography has addressed issues of ocean and coastal navigation and has provided for these purposes accurate charts for the routing and operation of surface ships. To do this, hydrographers have concentrated their efforts on delineating features of the seabed covered by navigable waters and the characteristics of the sea that impact safe navigation. The rich centuries-old heritage of hydrographic accomplishment in the world's oceans is something hydrographers can be justly proud. With sextants and lead lines, they have performed remarkably well in charting the world's oceans and providing safe passage for the mariner.

In the last few decades, the science of hydrography has undergone a revolution with technology being the key driver. New positioning techniques, such as GPS and especially the various methods of improving GPS to sub-decimeter accuracies, have provided both new capabilities and challenges. On the one hand, these instantaneous and accurate positioning systems have enabled the hydrographer to conduct surveys with a fidelity and ease heretofore unrealized. On the other hand, since most mariners also have

these tools at their disposal, there is an urgent need to make charts with this navigational accuracy.

The lead line, with its two bytes of information (water depth and bottom composition), or the single beam fathometer, with its more rapid retrieval of a single depth value, are being replaced with side scan sonar and multi-beam sonar. The resulting ensonification of the bottom can provide 100% coverage ensuring all hazards to navigation are identified. However, the terabytes of data streaming from these sensors burden those tasked with quality control and overwhelm the data managers.

Advances in economical computing and data display have allowed mariners to depict both their positions and chart features in real time in electronic charting systems. The navigators' goal of knowing where they are rather than where they were is now attainable. But the advent of "black box" navigation brings to question how the fidelity of the hydrographic data is assured and the utility of the display system assessed.

To further signal the revolution in hydrography, the science is now used for far more than safety of navigation. Pipeline and cable route surveys extending into the ocean's depths employ many people who once focused on fixing the channel boundaries on a harbor approach chart. The U.N. Convention on the Law of the Sea has placed economic priority rather than scientific interest in delineating the extent of a nation's continental shelf. The economic development of the coastal regions and the protection of sensitive habitat require the hydrographer to establish one of the fundamental boundary conditions.

Faced with this revolution in mission, technology, and customer orientation, hydrographic organizations must form new partnerships that embrace innovation in dealing with change. To this end the U.S. Naval Oceanographic Office (NAVOCEANO) has partnered with The University of Southern Mississippi (USM) to prepare their workforce for the future and to assimilate technological advances into their operational survey.

A Complex and Demanding Mission

The U.S. Naval Oceanographic Office (NAVOCEANO) is tasked by the Department of Defense to collect and process hydrographic data outside the territorial waters and Exclusive Economic Zone of the United States.

Only a few years ago NAVOCEANO devoted the majority of its resources to understanding and charting the depths of the open ocean in support of the Cold War "Maritime Strategy." Now, the U.S. Navy, when called upon to protect our national security interests, finds itself increasingly responding to contingencies in the littoral regions of the world. The safe and effective execution of the current naval strategies, "Forward...from the Sea" and "Operational Maneuver From the Sea," requires an accurate and timely understanding of this dynamic near shore environment. NAVOCEANO now focuses its resources, nearly exclusively, on the measurement, analysis, modeling and prediction of the littoral waters around the world.

The resources available to NAVOCEANO are quite impressive. Eight multi-purpose survey ships are among the newest and most capable in the world. These ships are employed continuously overseas in the littoral areas within which the Navy may be called upon to operate. The survey equipment employed by these ships and the survey launches, remotely operated vehicles and autonomously operated vehicles they deploy

includes virtually any hydrographic and oceanographic measurement system. Additionally, NAVOCEANO uses aircraft for wide-area assessment of ocean conditions and for LIDAR shallow water bathymetry. The data flow from these sensors is expansive and complex.

To assist in data quality control and processing, NAVOCEANO uses hundreds of workstations and one of the largest supercomputers in the world. To process the data and produce the end products, NAVOCEANO uses several commercially available and in-house developed software packages. The end product itself is dynamic. Much of the data displayed is time varying and the depiction of the data changes with the customer or its intended use.

The final metric of success of all of this is that the operational naval commander has a timely, accurate, clear picture of the battlespace in which he is engaged.

Embracing New Technology

An educated workforce is essential to accommodating the change that technology causes. Additionally, a research program, keyed to the technical issues of its operational customer, can develop innovative solutions for these issues and provide effective implementations of new technology as they become available. For over fifteen years, The University of Southern Mississippi (USM) has provided responsive service to the graduate education needs of the professional workforce at NAVOCEANO. Three PhD and eight M.S. programs are available on site through a consortium of USM, University of New Orleans and Mississippi State University. Education and its associated research programs will be an important aspect of how NAVOCEANO capitalizes on recent technological advances and optimizes its collection and production processes.

The Hydrographic Science Master's Program: In September 1999, USM instituted an academic program to provide graduate level education in hydrography and FIG/IHO Category A certification. The initial goal was to provide the necessary education and training for the naval officers and civilian workforce at the U.S. Naval Oceanographic Office (NAVOCEANO). Ten students graduated from the first class in August 2000 and thirteen students currently enrolled are progressing toward graduation in August 2001. To date, inquiries concerning the program indicate that the enrollment could nearly double for the 2001-2002 academic year.

As presently structured, the Hydrographic Science Master's Program is an intense one-year, non-thesis program. Students enter the program in the Fall Semester and complete 15 hours of classroom and laboratory-based studies. Instruction continues with another 15-hour series of lecture- and laboratory-based course work in the Spring Semester. During the summer, there is a combination of lecture-based instruction and comprehensive "hands-on" practical course work, culminating in the completion of an individually conducted hydrographic field study. Each student is required to write a detailed report of the field study similar to one required of a working hydrographer. The completion of the degree program over a one-year period is not a requirement, and those students wishing to carry on their studies over a longer time frame may do so.

Further information regarding the USM Hydrographic Science Masters Program is available at <http://www.marine.usm.edu/hydro>.

In addition to the core group of students from NAVOCEANO, potential students include employees of other U.S. government agencies, international attendees and recent

college graduates in the marine, geomatic and computer sciences looking to begin a career in hydrography. Although the curriculum and class structure was tailored to meet the needs of NAVOCEANO, it is clear that the course appeals to a much broader audience.

The Hydrographic Science Research Center: As a complement to its graduate academic program, USM established The Hydrographic Science Research Center (HSRC) in October 2000 whose long-term goal is to provide an innovative research environment for the faculty and graduate students.

Collocated with NAVOCEANO, at the Stennis Space Center (SSC) in Mississippi the HSRC has an excellent opportunity to assess and address the research and development needs of one of the premier hydrographic organizations in the world. The HSRC is well positioned to transition new capabilities and improved methodologies to NAVOCEANO's operational fleet. Additionally, the HSRC will provide the opportunity for basic research in the underlying sciences associated with hydrography. This is a critical element in the NAVOCEANO / USM partnership since NAVOCEANO is not funded for internal R&D.

Establishing the Work Program: The HSRC's first order of business was to determine its work program. With the many pressing needs of the hydrographic community, an effective HSRC required a well-structured work program and set of policies to govern its future direction.

For this purpose, USM convened a workshop from October 30 through November 1, 2000 with thirty experts in various aspects of hydrography. The attendees represented government, academia and industry from the U.S. and Canada. Presentations from Navy, National Oceanic and Atmospheric Administration, National Imagery and Mapping Agency, U.S. Army Corps of Engineers and The University of New Hampshire provided the background information for the workshop deliberations. Ensuing discussions centered on:

- policy,
- operational needs and
- technology opportunities.

The following discusses the deliberations that resulted from these meetings as an indication of the direction that HSRC will be taking in the immediate future.

HSRC Policy: The discussions regarding policy involved determining the customer, program focus, governance and external interactions/partnerships.

Customers. It was the common consensus of the attendees that the HSRC must assess and understand who its customers are to be. The driving force, of course, will be the source of funding. In the near term, the major source of potential funding will be the Navy through the Oceanographer of the Navy (CNO N096). This leads to two distinct Navy markets.

The first, NAVOCEANO, as the organization within the Navy executing the mission of collecting, analyzing, disseminating and generating hydrographic data products, is a customer with well-defined research and development needs.

The second is that part of the Navy the workshop called "the Warfighter."

The Warfighter is not concerned with how the data was collected or processed, only that the data be displayed in a timely, accurate and useful manner pertinent to the operational needs.

These are the two main users of the HSRC in the short term and most probably the long term as well. However, the attendees also indicated that in the long-term perspective, other very vital users (NIMA, NOAA, USACE, Industry, IHO, etc.) may join the Navy become major customers of the HSRC.

Focus. Again, funding dictates the focus of the HSRC. Since the Navy will be the major immediate source of funding, the research program should focus on the development and demonstration of hydrographic capabilities that directly benefit NAVOCEANO and/or the Warfighter. The research program should produce deliverables in the near-term that improve existing capabilities or implement new capabilities.

The HSRC should also develop funding sources that would support exploratory development and basic research in addition to a strong, applied research program. The HSRC must be constantly aware of the changing missions of hydrography and the developing tools and methodologies that may be applied to these missions. In addition, it must recognize where there are gaps between these changing missions and the available tools and work to overcome these deficiencies.

Governance. All of the participants believed the HSRC must have a strong Advisory Board. While a proposal for the board to be composed of NAVOCEANO and USM leaders was put forth, many participants felt that the membership of the board should include a more diverse membership than initially proposed.

Interaction. The HSRC must maintain a highly interactive relationship with its customers and others in the hydrographic community. Its success and growth requires that it nurture close and continuing ties with organizations such as the University of New Hampshire (UNH), the University of New Brunswick (UNB), NOAA, NIMA, foreign Hydrographic Offices, International Hydrographic Organization (IHO) and industry.

Operational Needs and Technology Opportunities: Since the policy discussions indicated the HSRC should focus on the U.S. Navy and specifically NAVOCEANO as its most-likely, near-term customer, the operational needs and the technology opportunities of NAVOCEANO were investigated. The following items were identified as applicable opportunities for technical assistance:

NAVOCEANO Survey Operations Center. NAVOCEANO is establishing a Survey Operations Center (SOC) that will, in real-time, monitor, receive and quality control data from its deployed fleet of survey ships. The HSRC should evaluate the SOC operations, recommending improvements to the coordination, monitoring, and processing initiatives.

NAVOCEANO – NIMA Co-Production. NAVOCEANO and the National Imagery and Mapping Agency (NIMA) have entered into a co-production agreement that will increase NAVOCEANO's role in the final compilation of

Digital Nautical Charts (DNC®), Littoral Warfare Data (LWD), Additional Military Layers (AML) and, in some circumstances, Electronic Nautical Charts (ENC). This transition to digital data products will require technical assistance.

NAVOCEANO Airborne LIDAR Bathymetry System (ALBS).

NAVOCEANO plans to procure an ALBS. A partnership with U.S. Army Corps of Engineers (USACE) has provided experience with an ALB; however, additional technical assistance will be required to enhance in-house survey planning, data processing and data fusion capabilities.

Autonomous Underwater Vehicles (AUV). NAVOCEANO has recently taken delivery of a large, highly capable AUV. As with the ALBS technical assistance is needed to enhance the in-house survey planning, data processing and data fusion capabilities. Additionally, AUVs present challenging issues with regard to navigation. An R&D effort focused on improving navigation of AUVs to meet both the needs of the naval warfighter and the specifications of the IHO is needed.

NRL / NAVOCEANO Transition. There is a perceivable gap between Naval Research Laboratory's (NRL) charter to take research from conception to proof-of-concept stage and NAVOCEANO operational implementation of this concept. The transition of each concept involves at a minimum the management of change and the introduction of training. The HSRC could play an active role in helping bridge this gap.

Qualified NAVOCEANO Hydrographic Personnel As more and more complex technology becomes available to address NAVOCEANO needs, the requirement for both graduate-level and technician level training is increasing.

Research Thrusts: From these introductory presentations and discussions, the workshop formulated six potential research thrusts for the HSRC to undertake in the near term.

Production Enhancement: The program of record for NAVOCEANO contains several new collection initiatives in addition to an already sophisticated suite of capabilities. Effective use of these capabilities, the ability to process large volumes of hydrographic data and the need for timely products derived from these data require that the entire production process be reassessed.

Working closely with NRL's "Production Enhancements" project in analyzing NAVOCEANO post-production pipeline, the HSRC will expand this study to include the end-to-end process from survey planning to end product generation. In addition to computer processing optimization, the study should include the automation of processes, the applicability of artificial intelligence and new industrial engineering approaches to the production process.

With the prospect that large volumes of data will be sent continuously from the various collection platforms to the Survey Operations Center, data basing (formats, structure, validation and reattribution) and data management

(distribution, dissemination, data thinning, compression, archiving and storage)
warrant immediate investigation

The HSRC should establish a prototype processing facility and a test bed data set to test the accuracy and efficiency of new ideas and methods as they become available. The HSRC can also serve as an Off The Shelf Commercial Technology clearing house, reviewing new technology for its efficacy and cost/benefit ratio to the NAVOCEANO process.

Tides and Water Levels: The collection, processing and integration of tidal data are critical to the final accuracies of hydrographic surveys. However, procedures currently used create an unacceptable bottleneck in achieving a prompt throughput of the data from collection to finished product.

There are two related thrusts in dealing with tides and water levels. One involves the overall improvement in the collection, processing, correction, and zoning of tides and other water level variations. This includes the use of kinematic carrier phase differential GPS for vertical positioning as well as using the WGS84 ellipsoid as a simple and stable vertical reference surface. This would establish “Separation Models” between WGS84 and existing Chart Datum sites.

The ultimate goal is to conduct hydrographic surveys using real-time kinematic GPS that do not rely on a tidal prediction or separate measurement. The net result of adopting such a methodology is substantial as it permits land measurements to be used in a common reference with those taken at sea – in essence a seamless battlespace. In such a scenario, the tide gauge and local tidal prediction, a frequent source of error and delay, are demoted from primary data source to a GPS quality checking role and remote sensing platforms are more easily employed.

A second thrust involves a better understanding and predictive capability for tides, water levels and currents that are operationally important to the Warfighter. In this regard, improved tide models and new data sources should be investigated. With improved tide models, these data should be incorporated as additional military layers into DNC®/ENCs. As these improved methods are transitioned to operations, appropriate training for NAVOCEANO and the Warfighter should be developed.

Error Analysis: To properly assess the accuracy of hydrographic data, a complete knowledge of the uncertainties involved in each phase of the data’s collection and analysis should be made. In addition, a comprehensive study of the propagation of errors through the system should be initiated and maintained as the system evolves.

The HSRC should conduct an assessment, attribution, cataloging and propagation of uncertainties of the disparate data sources available to NAVOCEANO. The accuracy of the survey system and the algorithms for errors in surveying should be evaluated and refined. Of particular importance is the adoption of accurate automated hazard detection and outlier discrimination.

The ultimate goal of this effort is to simplify the determination of uncertainties of each product and effectively communicate these uncertainties to the Warfighter and other end users.

Electronic Chart Technology Center: An end product for hydrographic data and services is something that can be used onboard ships for both navigational safety and the ability to engage in combat operations. However, at this time electronic chart systems cannot be used without digital data being available in a suitable format to be used in presently installed systems. The goal of Navy-fleet wide implementation of ECDIS-N by 2007 requires a full range of data and services be made available to support a paper-less bridge.

The HSRC should develop the necessary data compilation, data processing, data management, product generation and product distribution techniques to enable NAVOCEANO to service the electronic chart needs of the Navy and its international cooperative program (HYCOOP) partners. This includes the ability to generate DNC@s, ENCs and AMLs. Of particular value would be the development of a common product specification that would facilitate harmonization between the various formats.

Bridging the Gap in the NRL to NAVOCEANO Pipeline: As mentioned above, there is often a gap between "proof of concept" of an R&D application and actual implementation in an operational survey or Navy fleet use. The operational users often do not have the resources to investigate and answer all the issues of actually implementing the new technology; therefore much new technology does not get implemented across the user community.

The HSRC must lead the way to bridge this gap by testing the efficacy of new technologies, integrating them with existing systems, developing deployment plans for fleet introduction, and delivering necessary training. This philosophy should be part of all the specific initiatives undertaken by the center - i.e., the R&D projects that are undertaken should include transition, (which may well include specific training) to the NAVOCEANO and Navy users.

Sediment Classification: In addition to bottom depth, seabed characteristics are also an important hydrographic parameter. NAVOCEANO collects terabytes of backscatter data daily using multi-beam and side-scan systems but obtains primarily hydrographic soundings and qualitative descriptions of the seafloor. Quantitative measurements such as sediment properties and seafloor roughness could be extracted; however, data are not being collected, processed, or used on a routine bases for these applications. Similarly, LIDAR data may also provide quantitative descriptions of the seafloor. Standard Operating Procedures for system calibration as well as algorithms and models for parameter extraction must be developed to realize quantitative measurements from these data.

HSRC Staff: To accomplish the program of work, the HSRC is recruiting a staff tailored to the research thrusts. Under the direction of a Director and Research Director, a principal investigator will focus on each thrust. Research assistants, either full-time

employees or graduate students in the academic program, will augment the principal investigator. In total, the research staff will be assembled to provide expertise across various technical matters to include computer science, industrial engineering and the classical hydrographic specialties of geodesy, acoustics and remote sensing.

HSRC Facilities: USM now occupies modern administrative and classroom facilities at SSC and The State of Mississippi has funded the construction of new laboratory facilities. The HSRC will have the necessary computer and survey equipment for its research and has access to an extensive array of survey platforms, survey equipment, computer hardware and computer software through its partnership with NAVOCEANO. Specific laboratories will include an Electronic Chart Display Information System (ECDIS) Lab and a Data Processing Prototyping Lab. The ECDIS Lab will enable investigators to develop and evaluate both the hardware and software suite used for chart display systems. Additionally, the ECDIS Lab will provide facilities to develop a Common Product Specification Framework to harmonize product content and facilitate exchange amongst the various international digital data standards. The Data Processing Prototyping Lab will provide an environment where innovative processing techniques can be developed and tested prior to implementation in the operational systems.

National Center of Excellence in Hydrography

NAVOCEANO and USM's Hydrographic Science Masters Program and HSRC are located on the Stennis Space Center (SSC) near Bay St Louis, MS.

SSC is a federal reservation administered by NASA. Originally devoted to the testing of the propulsion units of the Mercury, Gemini, Apollo and Shuttle mission, NASA has also sited its commercialization of remote sensing activities at SSC. With over thirty activities currently residing at SSC, NASA has encouraged the location of public and private activities that contribute to or benefit from the sensing and analysis of the environment.

Activities residing at SSC specifically dealing with hydrography include NAVOCEANO, NRL, USM, and NOAA (National Data Buoy Center and National Coastal Data Development Center) and several industry leaders. This amalgamation of expertise provides a unique opportunity to solve the issues created by the technology explosion in hydrography and its data management challenges. This partnership of activities forms "The National Center of Excellence in Hydrography (NCOEH)." The University of Southern Mississippi (USM) is proud to step forward and take a leadership role establishing the NCOEH.

Conclusion

The applications requiring hydrographic data and the techniques used to collect and process these data have undergone a dynamic revolution within the last decade. It is obvious that we are in the middle of that revolution and those fundamental changes will still be occurring within the next decade. We must be prepared to both meet the present day requirements of these revolutionary changes and be prepared to implement others that arise in the near future.

The effective assimilation of these revolutionary technologies into day-to-day operations and the generation of hydrographic products that are responsive to the end user's requirements pose significant challenges. The University of Southern Mississippi, through its Hydrographic Science Research Center and complementary Hydrographic Science Master's Program, is assisting in preparing the hydrographic community to meet these challenges.