A Modular Approach to Hydrographic Expertise Development

Guy NOLL, United States, Michael BRISSETTE, Canada

SUMMARY

The IHO has long promulgated the certification requirements for hydrographers through categorical ratings that rely upon proving the knowledge inherent in the discipline through testing based upon formal education and experience. In the rapidly evolving technological field of hydrographic surveying, the need for continuous learning is increasingly evident. The tools used for hydrography have evolved in parallel to the available computational power, and thus have changed the role of the hydrographer in data review and production from verification of every measurement to statistical review of the results of algorithmic applications. Further changes as data and applications migrate to "clouds" of servers separated from the hydrographer will further alter the skillsets needed to create accurate and precise nautical charts and other survey products, and emphasize the requirements for visualization, network bandwidth, and creative problem-solving. It is generally understood that training in advanced software programs used in hydrography is difficult to digest without prior experience with field operations. Therefore, a training program has several critical path elements, including familiarity with expensive hardware, computer technologies, and equipment integration on boats or ships that challenge the development of a traditional step-wise curriculum. In turn, the high technology threshold barring entry to training prevents rapid assimilation of new, talented, potential hydrographers into the discipline. An alternative modular solution to the challenge of creating hydrographic expertise is needed for the practical surveyor while fulfilling the IHO Schemes definition 4.1.

Key words: education, training, hydrography, technology, curriculum, expertise

1. Background

The nature of hydrographic surveying has been a scientific craft for hundreds of years. A surveyor from circa 1500 had as his goal the measurement of depth, the appropriate correction of the raw measurement for water level and other factors to the best of his knowledge, and the positioning of the depth relative to nearby navigationally-significant features. The technologies employed by the hydrographer fundamentally did not change until the introduction of the echosounder in the early 20th century and the rise of electronic positioning methods to free the surveyor from shore in the mid-20th century. Since 1960, however, increasingly rapid changes in technologies and resultant measurement data volume have created a challenge for education. The modern practicing hydrographer uses advanced technologies to bring to bear his or her keen awareness of the curvature of the seas along with the associated corrections to increasingly complex measurements.

If two hydrographers from 1500 and 1960 were to meet, despite existing four centuries apart, they would likely equally understand the terms and work to be performed. However, how would the hydrographer of today begin to explain the state of the art technology to these hydrographers, and what fundamentally has not changed? This problem may seem to be a fantasy, but it is a reality for many of today's educated hydrographers at the beginning of their careers, and others who have not been exposed to the revolution of the last decade and a half. In short, the context of modern hydrography, if separated from tradition, becomes a video game. The International Hydrographic Organization (Standards of Competence for Hydrographic Surveyors Publication S-5, 2011) categorizes the fundamental and practical knowledge to reflect the traditional approach to the science. This latest edition recognizes that hydrographers do need to know the foundations of their practice, and also often need to be familiar with the latest technology to be employable.

As the pace of change in accuracy and resolution in measurements increases, and the interrelationship of these measurements become more complex, the knowledge required to manage potential errors efficiently also grows. As most errors begin at the point of measurement, practice with the hardware and software involved is critical to understanding source characteristics, defining control mechanisms to minimize or mitigate the errors' effects on the final product, and describing those that cannot be eliminated from the final product to the client.

Adapting traditional measurement and management approaches to the current state of hydrography has been successful as seasoned hydrographers used their past experience to migrate best practices to the new technologies. However, with the rapid state of change in these technologies, as seen in Table 1 below, and the decreased investment in Hydrographic Offices and other sources of talent, will this evolutionary approach continue to work, or will the next generation be at a disadvantage from lack of depth of knowledge of the software and equipment used in the field?

Measurement Type	Pre-1920 (A. Theberge, 2006)	Pre-1995 (Mayer, 2003)	Current Era
Time	Mechanical Chronometer Stopwatch	Electronic Chronometer	GPS/GNSS
Depth	Pole/Leadline/Wire	Echosounder (E/S)	Multibeam E/S
Water Column	N/A	Nansen/Niskin/SeaBird	SeaBird/AML/MVP
Tide/Water level	Staff measurements	Bubbler/Stilling Well	Acoustic/KGPS
Position	Sextant(s)	Electronic Ranging	KGPS/DGPS/WAAS
Vessel offsets	N/A	N/A, maybe heading	KGPS-assisted attitude
Notional Accuracy in 4D (H x V x T)	20m x 2m x 1 min	5m x 0.5m x 6 sec	0.5m x 0.1m x 0.1 sec

Table 1 Hydrographic measurement changes over time

Stepwise correction and transformation of a measurement is a long-standing tradition in surveying, used both to mitigate the compounding of measurement errors and to avoid fallacy of assumptions that lead to erroneously believing a measurement is robust. The ability to understand the measurements and avoid the fallacy needs to be grounded in the reality of actual measurement. Surveyor training programs are thus a balance between academic studies and performing actual survey tasks. An educational format in the following chronological format is typical:

- Fundamental education sometimes in a related subject such as engineering
- Internship and exposure to the survey discipline
- Basic practice of skills in an On-the-Job-Training (OJT) setting
- Additional formal education focused on hydrography-related subjects
- More advanced practice under guidance of a qualified surveyor
- Formal credentialing through jurisdictional certification
- Expert practice as a qualified hydrographer-for-hire
- Maybe additional (continual) learning to maintain technology knowledge?

The rapid changes in technology from 1995-2005 created an "OJT" experience for nearly every hydrographer (Gardner, Glang, Jacobs, Riley, & Noll, 1999). Now that a fairly stable suite of measurement technologies is in common usage, we must assess, restructure, and formalize a best practice in the training of the next generation of hydrographers so that they are prepared to adapt to their clients' needs for future deliverables. For example, this quote from a past conference paper highlights the foundation knowledge and opportunities that await a well-trained surveyor capable of informing the world of scientific measurements in the future:

"The hydrographic surveyor of the past was much more knowledgeable on oceanographic matters as it affected their survey methods greatly. In recent years the hydrographic surveyor has been focused heavily on positioning accuracies and bathymetric accuracies. By taking the burden

of processing off the human interaction and onto the computers and enabling the processing of other types of deliverable, today's hydrographic surveyor will once again be able to become much more knowledgeable about the whole oceanographic process." (Mallace & Gee, 2005)

The traditional hydrographer training progression, measured primarily by progress in a certified academic program, has not adapted to the need for relevant problem-solving using the new technologies that have evolved since 1995.

2. Scope and Price of Current Problem

2.1 Cost of post-secondary education and equipment

There has been a general lack of cost control in the United States' post-secondary scholastic institutions in the last thirty years (Ehrenberg, 2000), thereby impacting how students choose academic majors, post-academic employment, and eventual careers in order to pay off their student loan debt. Hydrographic surveys are fairly personnel and equipment intensive operations, and paying more salary expense to attract and retain top talent is a trade-off for investing in new technologies that may make that talent more effective and continue to attract new work as well as improve employee value. A four-year science degree, generally required for entrance to an IHO-certified Master's level hydrographic program, has more than doubled in constant dollars from 1980 to 2010 (National Center for Education Statistics, 2011). It should also be noted that 2-year or community college is the minimum requirement for fully-qualified Hydrographic Survey Technician work, and that technician salaries (US Department of Labor, Bureau of Labor Statistics, 2010) are about half of what is earned by cartographers or photogrammetrists who have a full 4-year degree.

Costs of the infrastructure needed for acquiring and processing hydrographic data are highly dependent upon the location of the survey and office, as well as the type and variety of work undertaken. It is recognized that the actual survey services and products have changed over time and that hydrographic firms have had to invest in improved systems to meet client desires. Fully autonomous survey systems are not yet operational, so at least one skilled hydrographer and a boat operator are still required for data acquisition. A third person is a luxury, and although this extra set of eyes can bring value and safety to the survey operations, a seat and opportunity to use new software and equipment requires time and space on the boat that is often not available.

2.2 Field experience cannot be attained through avatars, or can it?

The increasing potency of computing coinciding with the advances in multibeam echosounder technology has created a race between data quantity and data management. Internet computing is making possible serious remote processing separated from the field unit (Hare, Peyton, & Conyon, 2011). As these techniques for data processing become more robust and extend to ships at sea, there are large efficiencies to be gained by segregating the tasks such that the processing shifts ashore thereby reducing the number of requisite shipboard personnel. Other staff-reducing factors may include new automated processing routines, and remotely operated or autonomous vessels acquiring data robotically.

In this near future, the newly graduated hydrographer may have a steep challenge to attain field experience. The requirement to manage field hydrography, analyze data and recognize error patterns is the first (post formal education) step in the development of expertise. Can this occur while in an office reviewing data, or does it require physical presence in the field? The measurement of heave in a boat or ship surfing with the sea, and the pounding of equipment into a head sea, are both difficult to imagine sitting in an office. More importantly, it may be difficult to estimate from afar the impact on data quality of changes in the wind, the position of the incoming tide line, and the amount of sunshine warming the ocean surface layer, and yet these create tremendous variability in the periodicity of oceanographic measurements to ensure the accuracy of echosounder readings. Recognizing the pattern and adapting to the actual environment are the hallmark of responsible hydrography. Similar to the academic field season, rotations from field to office and back again are currently in use in government and industry.

3. Potential Solutions to Current Problem

Today, hydrographers are called upon to manage a wide variety of disparate processes, including advanced positioning, data file management, physical oceanography, vessel staffing, metadata creation, and technical equipment maintenance. A lead hydrographer may be seen by junior technicians, or even a lesser hydrographer, as a "Master of All Trades" or a "Wizard", with great organizational value. Two questions become relevant:

- Will the skills of today's lead hydrographer be relevant in the next decade?
- How will the industry make or find these lead hydrographers in the future?

In the past, a hydrographer was identified from ship's personnel roster or as a result of formal training programs, and acclimated by mentors and provided hands-on experience with the equipment and the processes of the time. Certification of hydrographers in fleet operations was, and generally is mandatory due to safety concerns of vessel operations, and includes balancing desired mission outcomes with vessel husbandry. However, technical expertise requirements in both the maritime and hydrographic sectors invite focus of knowledge on effective usage of the expensive hydrographic tools by the surveyors, and similar compartmentalization of expertise in ship operational management. Cross-training at a junior level, when it does occur, cannot cover either subject matter to the desired depth.

3.1 Evolving Technology and "Fighting the Last War"

Within hydrographic organizations, the separation of training by focus areas results in local experts (lead hydrographers) with the responsibility, authority, and knowledge to ensure that requisite survey controls are in place. Ideally, this results in a fully-documented organizational standard (recipe) that the field hydrographers follow in detail without adaptation; any changes necessary revert back to the lead hydrographer for resolution and a new standard. Technology implementation often forces review of a test and evaluation cycle before becoming part of an updated standard. However in haste to use a newly acquired piece of equipment or software, hydrographers may succumb to improper assumptions regarding the measurements. Software and hardware associated with Side Scan Sonar, Multibeam Sonar, GPS-aided inertial measurement, and Kinematic GPS have all had "fits and starts" in industry adoption due in part to this rush to use in the field.

It takes an experienced hydrographer to properly assess and implement new technologies and techniques when they are truly ready. The lead hydrographer, well-seasoned by prior technology implementations "at the bleeding edge", has a "weather eye" for marketing materials. Creating a new piece of kit that "is 10 times better than the one you have now" may sound critically important to the success of the task at hand, yet an analysis of errors associated with the targeted measurement may show that the investment is wildly out-of-proportion to the expected gain, or that there may be no overall gain in accuracy because this particular measurement is "buried" by errors associated with, for example, water levels or dynamic draft of the survey vessel. When properly analyzed, the errors are not only placed in the context of the survey, but also linked back to the user of the survey product, whether a navigator on a ship, a dredge operator, a pipeline/cable layer, or a habitat manager.

Field operational safety can also be compromised due to reduced oversight of a lead hydrographer or the lack of context in which the survey "recipe" is applied. Products created by the system in place can also be compromised by inattention to local detail. Worse, lack of hydrographic expertise amongst vessel operators compounds the already dire lack of expertise in operational oceanography and resulting products, such as electronic charts. Operator-based errors have been linked to many recent grounding incidents such as M/V Rena (Garrett-Walker, 2012), M/V Costa Concordia, HMCS Corner Brook (Green, 2012), and USS Port Royal (Cole, 2009) due to ignorance of hydrographic science-based risks. Maritime industry questions were raised as well, in the Rena case (The Maritime Executive, 2012) for example, such as the implications of management interest in schedule over safety.

3.1.1 Designing Training To Build A Strong Foundation

The current training model is based on a strong academic focus and adhering to the strict certification requirements of IHO S-5 based on academic syllabus approval and field experience, often augmented by testing and evaluation by other hydrographers. The hydrographer must make it through this current system with a reasonably broad experience to become a Wizard that can make magic happen, even if the client doesn't need magic. The question then is how to justify the costs of developing and maintaining the wizardry. Can the advantages of the creation of these highly adaptable hydrographers prepared for further change in the industry be incentivized through client support as an additional cost (unlikely), government policy (who pays?), or international mandate (IHO/IMO regulation change, or insurer interest) to bring hydrographic expertise to the general and broad maritime industry? Academic nautical programs, such as the new postgraduate hydrography curriculum at the Australian Maritime College (2012), need to be designed to meet this broader interest in hydrographic sciences, not just a week or less of 'exposure' to the subjects in maritime training, and thus place value in the Wizard.

3.1.2 Remote Processing And Effects On Field Experience

Many large survey organizations use a model of identifying field personnel at the technician level who are interested in attaining professional certification. This model could be formalized through application for apprenticeship after an initial period of introductory hydrographic tasks, with those accepted beginning a rotational program of office and field posts. Adapting the IHO Category B certification to this level of work would be similar to the Journeyman's license pattern in skilled trade practices (Hydro-International, 2012). Master's level work would be predicated on a number of proven accomplishments in applying hydrographic discipline. This implementation is coherent with government or military rotations, but may be difficult to sustain in a resource restricted organization. The primary disadvantages are industry-independent, however, as they include a long training period from beginning to end, the resulting likelihood of "burnout" amongst junior personnel before they reach fully-qualified status, and creation of "bubbles" or gaps in knowledge as technologies change more rapidly than personnel who are trained in these technologies can accede to more senior hydrographic positions. In addition to the IHO Category A certification, the primary advantage to this model is a well-established career track with firm expectations of how a candidate will become a lead hydrographer. Given the still-unknown impacts of remote processing, the long-term viability of this option is doubtful.

3.1.3 Inspired Approach – Filling The Gaps With On-Demand Education

Modular training is an increasingly widespread approach, using appropriate technology and available time, in technical fields as diverse as surgery and computer network analysis. It's also the premise behind the Khan Academy (Financial Times, 2011). Corresponding hands-on practice with technology is not widely available, though most manufacturers offer some form of User Meeting with a short practicum period available. Further training may be obtained through nautical training centers and other means, such as short-term equipment leases, as well as by leveraging existing field resources in government, industry, and academia. The exciting announcement of the new Hydrographic Academy associated with Plymouth University, Fugro, and the Royal Navy may (hopefully) follow this implementation pattern.

4. The Future Impact on Small Hydrographic Organizations

The changing nature of developing the lead hydrographer of the future may leave smaller hydrographic organizations and independent companies unable to participate. Their limited financial resources and restricted number of personnel will make anything but the Inspired Approach in Section 3.1.3 above unrealistic. What then is the solution for small start-ups, financially constrained non-profits, and governmental organizations?

One excellent candidate that can address the challenges faced by small offices is the major price advantage to using a “just-in-time” expertise delivery model. The primary benefit is that a client pays for the expertise only when needed, and can reduce hotel costs at sea by bringing such expertise via telepresence or on port calls. The “Rent-a-Wizard” method, bringing a senior hydrographic consultant to the worksite, is not only a way to use focused time with a subject matter expert on a particular software or hardware platform, but can also be a way to review a proposed new workflow, system performance verification, change in software, or shift into a new survey market.

Generally speaking, these “Wizards” may also bring substantial additional value to the staff training plans by spending an extra day or two to provide an independent assessment of expertise, and to raise awareness of the missing pieces in a firm’s survey knowledge. By combining the hands-on professional presence of a senior mentor with virtual access to streaming information on the web, when available, the hydrographic team can adapt itself to the present environment and document the changes it has experienced, thus preparing for additional future change.

5. Conclusion:

The hydrographer of the next decade remains unafraid to try new things, with especially quick adaptation time due to his/her comfort level with new technologies in data storage, positioning, and perhaps acoustics. Continuing acceleration in change of computing resource availability will drive information analysis past manual methodologies into semi-automated and then automated processes that are guided by senior hydrographer expertise. Major impacts will occur in bandwidth of data analyses, multi-dimensional position measurement, and increasingly refined sonar solutions. Using all of the information will require controlled experiments to manage propagated error through empirical tests, combinatorial techniques to identify sensitivity of variables, and tracking solutions that trend towards repeatable results. Accepting performance based on past results will not be good enough for the new technologies that can potentially measure an order of magnitude more accurately than those of a decade earlier.

The future hydrographers’ adaptability will require collaboration with subject matter expertise both at sea and ashore, and outside of the traditional hydrographic community to include physical and biological oceanographers, for example. Transitioning from a position of “Wizard” that has been required with the implementation of new paradigms in KGPS, multibeam sonar, and semi-automated processing tools, the hydrographer will now be asked to quickly convey critical knowledge of field practice to specialists ashore who can use the measurements to identify trends and analyze subcomponent errors for rapid resolution as well as identify potential value of a specific measurement in real-time. The “Master of All Things” approach to training hydrographers rightly requires a lifetime of skills both at sea and ashore across a wide variety of responsible positions. Many hydrographers will not reach the level of expertise required to manage the entire operation, nor is that required in a task-based designed workflow that can manage production through appropriate controls. Hydrographic practice, even at sub-certification levels, will require sensitivity to other ocean science domains and ability to communicate effectively with leaders in these areas.

Tomorrow’s lead hydrographer is the product of today’s student learning in a new training environment where technology makes data collection more voluminous yet more accurate and more efficient. Further, these ever-evolving technologies make data processing easier, faster but increasingly more remote from the survey vessel. These technological benefits are remarkable and should be embraced; yet they threaten to compartmentalize each survey process within the job-description of one type of specialist, thus eliminating the traditional learning path of today’s most senior hydrographers. New training models can adapt to this imminent compartmentalization while still cultivating those who seek to move beyond a single job description and become a “Master of All Trades”. Formal post-secondary education will remain the cornerstone in the formation of tomorrow’s lead hydrographer, however more inspired on-demand training courses will be required as the hydrographer progresses in his/her craft and seeks to gain much-needed yet harder-to-find sea time.

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BIOGRAPHICAL NOTES

Mr. Noll leads a matrixed group of project managers, marketing, and technical specialists focused on GIS implementation across the maritime and ocean science realm for Esri. With more than 24 years' experience in hydrographic survey, nautical charting and science vessel operational management with the US National Oceanic and Atmospheric Administration, Mr. Noll brings breadth of expertise and senior leadership to Esri's oceanic science and mapping practice. He is a 2009 graduate of Harvard Kennedy School of Government Executive Education programme, Senior Managers in Government, and has degrees in Civil Engineering from Columbia University and Mathematics-Physics from Whitman College.

Mr. Mike Brissette is the president of MosaicHydro, a company specializing in hydrographic training and service delivery. Prior to forming MosaicHydro in 2004, Mr. Brissette retired from a 20 year career in the Canadian Navy having been in charge of hydrography for Canada's west coast Navy for his last 7 years. He has a Bachelor of Computer Science degree from College Militaire Royal de St. Jean and a Master of Survey Engineering degree from the University of New Brunswick.

CONTACTS

Guy Noll
Esri
380 New York Street
Redlands, California
USA 92373
(909) 793-2853 x3393
Gnoll@esri.com
Esri Ocean GIS http://www.esri.com/industries/natural-resources/oceans/index.html

Mike Brissette
Mosaic Hydrographic Services (Canada) Ltd
2239 Meadowvale Drive
Victoria, British Columbia
CANADA V9B 6J2
(250) 727-7853
mike@mosaichydro.com
MosaicHydro http://www.mosaichydro.com/index.html

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