

# Quality Assurance Initiatives in the Hydrography Department of the U.S. Naval Oceanographic Office

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## Abstract

The recently re-formed Hydrography Department of the U.S. Naval Oceanographic Office (NAVOCEANO) has undertaken aggressive initiatives to formalize its quality assurance systems. Quality assurance (QA) is of the utmost importance to the leadership at NAVOCEANO, since the reputation of “Leading the World in Operational Oceanography” and stewardship of public funds are taken very seriously. Through systematic improvements to the processes, QA will achieve such results as superior data and products. By-products of using QA include task accountability, process improvement, performance metrics, training direction, process tracking, corporate knowledge retention, waste reduction, and increased data value. These are compelling reasons to implement a formal QA process. The QA process in hydrography starts with the customer defining quality standards, or the allowable error at the onset. Personnel are trained to achieve and analyze the quality standards to be met and adhere to best practices in the collection and validation of field data, in-house data, and product appraisal. All these processes are subject to a formal documentation and sign-off process, thereby beginning to comply with industry QA standards and ISO 9001:2000 methodology. Common hydrographic problems such as process and data validation tracking, the need for standardized instructions, feedback to the survey crews, and data quality attribution are starting to unravel in discussions by the international community. This paper details both the immediate actions taken to fill holes in the current processes and to document the data flow processes culminating in the implementation workflow tracking software. It also describes the parallel efforts to build a solid foundation to ensure the viability and longevity of QA by fostering workforce ownership, providing management support, and developing professional practices within the hydrographic community.

## Introduction

“Quality is free—It is not a gift, but it is free. What costs money are the unquality things—all the actions that involve not doing things right the first time. Quality is not only free, it is an honest-to-everything—profit maker.”— Phil Crosby, quality guru.

In the past, Hydrographic Offices (HOs) could attain much more accurate data than was available to the mariner, which provided some insulation from quality issues. By using more superior equipment than the mariner and controlling the chart scale, the HO could control the magnitude of chart errors. This has all changed with the availability of reliably accurate instrumentation and the electronic chart. The user can now view hydrographic data at any scale desired [1]. The Naval Oceanographic Office (NAVOCEANO) has been aware of this higher demand on hydrographic data and product quality and has answered the call at the level of strategic planning. In the 2000 Strategic Plan [2], NAVOCEANO set goals for improving the quality of nautical products through managing the entire hydrographic process, streamlining the data collection, processing, and production processes, and increasing the technical expertise in hydrographic science.

Giants in the field of quality, such as Crosby, Edward Deming, and Joseph Juran, laid a philosophical framework for quality, whose principals have matured into international standards. Successful organizations now realize that total quality principles are essential to effective management practice and form a sound approach for business success. Quality may be defined in many ways, such as lack of defects, superiority, or excellence, or can be related to product features. The American Society for Quality defines quality as “the totality of features and characteristics of a product that bears on its ability to satisfy given needs.” *Meeting or exceeding customer expectations* has become a popular definition for quality, which directs focus to the customer, whether internal or external. For the purposes of QA efforts in the Hydrography Department of NAVOCEANO, a well-written text by Evans and Dean [3] says total

quality (TQ) “denotes a comprehensive effort involving everyone in the organization to meet customer needs and continuously improve products and services.” Given this definition, the remainder of the paper will not just refer to quality, but rather TQ, which encompasses a huge arena from good relations and feedback from customers to strategic planning, workforce participation, process improvement, and much more. This paper is written to bring the basic concepts of TQ to the workforce and management of NAVOCEANO by summarizing the latest approach in literature to quality management and in addition point out what NAVOCEANO and other HOs are doing in this regard.

## Why Formalize a Quality Management System?

For HOs around the world, the digital revolution has invaded nearly every aspect of the production cycle, from planning the survey to producing the chart. Manual hard-copy production methods, where every step in the process is visible and procedures at all stages are known, have been replaced by soft methods. These soft methods often have discreet sets of instructions or manuals, but how they are to be used together as a process is usually unclear. The NAVOCEANO workforce has learned the new soft methods at a pace somewhat behind the development of technology, causing frustration for them. Little attention is paid to documenting new procedures, which seem to be ever-changing and are viewed as overwhelming documentation attempts. A series of “cheat sheets” can be found that are usually very specific to a certain set of circumstances. If the conditions change, the cheat sheets are no longer valid. Consequently, newer, less experienced staff suffers from process-anxiety, never quite knowing if they are handling their part of the cycle properly. Pleas for training in the correct procedures are heard across the Office. The call is being answered in part by more training being provided, but this is a quick fix that helps only those individuals available at the time. The longer term answer lies in formalizing the functional activities by a huge process improvement effort, which includes documenting and controlling the processes. Motivating factors to define our processes and flow of work are:

- Improved efficiency, leading to lower costs or higher workload capacity.
- Improved control, resulting from the standardization of procedures.
- Improved ability to manage process: Performance problems are made explicit and understood [4].

Also gained from a formal QA system are task accountability, process improvement, performance metrics, training direction, process tracking, corporate knowledge retention, waste reduction, and increase data value. As discussed below, many staff members from various departments across NAVOCEANO have a role in collecting and field processing the hydrographic data. Without a record of who does what to the data up- and downstream (lack of accountability), it is difficult to determine where personnel weaknesses lie. Identifying weaknesses in the workforce gives a direction for the training plan and shows where the most benefit can come from training dollars.

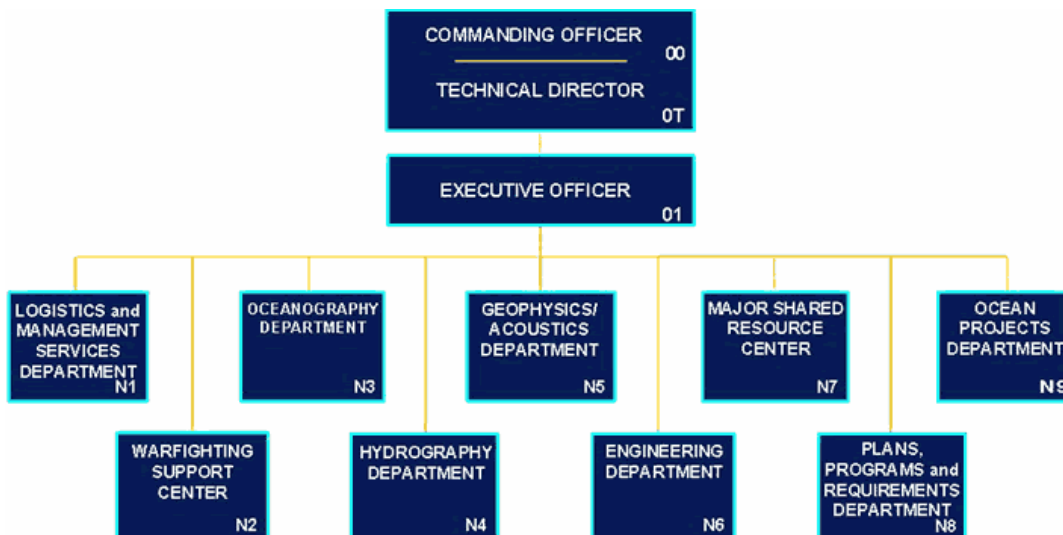


Figure 1. NAVOCEANO organizational chart following the 2000 realignment.

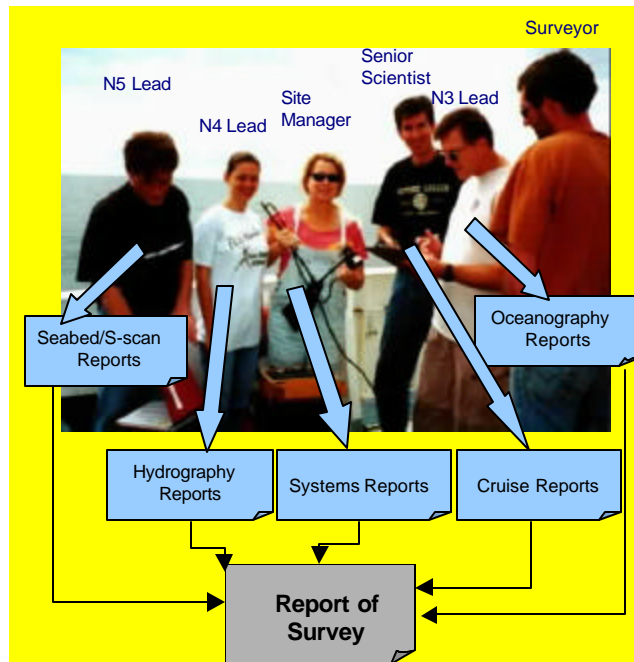
As in many organizations around the world, downsizing can be quite a shock when the folks who know the best practices suddenly retire without their coworkers ever having captured their knowledge in black and white. And with so many advances in technology, usually only a few people learn a new technique, and before they can spread the knowledge, are called away. Their absence then becomes a point of failure. People sometimes become tied to one area or process simply because their knowledge has not been captured and they are viewed as irreplaceable. Capturing corporate knowledge has tremendous value for the present as well as the future.

The more that is known about a dataset, the more valuable the data becomes. When the quality of data, or associated uncertainties are known, this information could become vital in choosing a dataset. Some applications require a high level of accuracy and at other times, less accurate data will suffice. A standard for describing data quality is discussed later. Formal QA tracking adds value for data queries and also provides a vehicle for capturing performance and quality measures.

**Data Quality Challenges**

NAVOCEANO operates seven multi-operational survey platforms and mans them with personnel from five departments (N2, N3, N4, N5, and N9). The NAVOCEANO organizational chart can be seen in Figure 1. The data “owner” is the in-house division within a department that validates the sensor data as they come in from the field, provides the data in a final form to the product line, and archives the data. It is often the case that the data owners do not collect the data. The field crews rotate every other month, and ship manning has to come from a wide pool of staff with varying areas of expertise. For this reason, it is especially important that good documentation of the instructions is provided.

To address the expertise gap at sea, NAVOCEANO has implemented a manning schema that requires a department lead staff member from each of the departments that own the data, since few people have the necessary know-how to collect and evaluate all data types. The Oceanography Department lead is accountable for the tide, tidal stream, sound speed, water clarity, and other ancillary data. The Hydrography Department lead oversees the geodetic work and bathymetric data collection and processing, sounding accuracy, navigational aids, wrecks and obstructions, and sounding data. The Geophysics and Acoustics Department is responsible for seabed sampling, seabed texture, gravity, and mine warfare side-scan operations. The Hydrography Department dictates side-scan operations relative to target detection for hazards to navigation. The site manager, generally the most experienced field staff member, manages the data and systems and works with the senior scientist to ensure that the data are collected and processed according to technical specifications. Each lead contributes to the Report of Survey and Cruise Report for one of the most important aspects of the survey—documentation. Perhaps the single most important factor to assure quality, next to data redundancy, is documentation. A single Report of Survey is built from multiple survey operations (SURVOPS) reports for a final distillation of the project. Figure 2 shows a typical field survey crew, which is almost never the exact same combination of personnel on any survey.



**Figure 2. Typical NAVOCEANO survey crew composition with their reporting responsibilities.**

**Feedback to Survey Crews**

One of the first priorities in the hydrographic QA effort is to document and track the validation of hydrographic data as they arrive from the ships. The data owners have developed Quality Review (QR)

checklists and fill them out for each dataset. This is an initial attempt to attack one of the glaring holes in the current system—feedback to the survey crews. Feedback has one of the most significant impacts on improving data. QR and trip reports are reviewed, and feedback is given in a debrief setting. If there are significant problems, feedback is carried out through field crew participation in correcting errors. Eliminating rework is, of course, a foremost goal. Data owners are simply not manned to do rework. Hydrography Department management has directed that the survey crew be given the opportunity to complete the job in-house under the guidance of the data owners, if needed. This is intended to be a positive learning experience. It can be extremely beneficial to recall survey crews to rework datasets in-house, which should empower them to become a stronger field collection and validation force in the future.

### ***Increasing Technical Expertise***

Another focus for the Hydrography Department is to support training by providing expertise and trainees. This has been a huge focus for NAVOCEANO (again, right out of the 2000 Strategic Plan) and has resulted in the coordinated development of a Category “A” Hydrography Program with the University of Southern Mississippi (USM). A Center for Excellence in Hydrography was also established in the USM building at Stennis Space Center. A recent Command directive has prompted the development of a concentrated (3-month) Category “B” program for NAVOCEANO employees in addition to the existing 6-month Category “B” program for foreign officers. There are about 33 Category “A” and 33 Category “B” graduates so far, and all department personnel are encouraged to attend either training over the next few years.

### ***QA Branch Mission***

The Hydrography Department has put quality as a primary goal and formed a Quality Assurance Branch (the smallest organizational unit) whose mission is, in part, to:

- Ensure all platform data collection and processing are done right the first time.
- Provide the Department with guidance on quality system issues.
- Ensure the quality standards (allowable error) are defined and adhered to.
- Provide guidance in training personnel to analyze whether those quality standards were met.
- Ensure field and in-house personnel follow the best practices.
- Guide branches in documenting and implementing in-house quality-appraisal procedures.
- Provide a formal tracking process for data, from requirements through the end product.

To answer the challenge of building formal QA within the department, much research and networking has been done. Fortunately, some needed resources have appeared. Papers dealing with QA in industry and, more importantly, hydrography have materialized. A free conference on performance excellence was recently held in New Orleans and was very educational in quality concepts. There is also a local organization called the New Orleans Federal Performance Excellence Network ([www.nofpen.org](http://www.nofpen.org)), which is a forum of Federal employees from the New Orleans and Mississippi Gulf Coast areas who share benchmarking and performance improvement information. At the national level, the American Society for Quality is also a resource for networking and learning how QA concepts are implemented in different organizations. Also, an extremely knowledgeable and energetic industrial engineering graduate student, Megan Olson, has headed up the workflow management system at NAVOCEANO (discussed later). She is invaluable in training the scientists how to map their processes. The hydrographic community is ripe for comparing notes in these efforts, and several HOs are setting precedence. (See the later discussion on the International Discussion Group for QA in Hydrography.)

### ***U.S. Legislation for Quality***

There are external as well as internal reasons for wanting to formalize QA at NAVOCEANO. Federal legislation was enacted in 1993 (the Government Performance Act [5]) whose purpose is to improve the accountability and performance of Federal agencies by requiring that they implement and establish performance measurements. The focus of the Act is twofold, strategic planning and performance

measurement [6]. More recently, President Bush is very serious about the management of agencies and presented his strategy in the FY02 President's Management Agenda [7], which ties budget to performance. Federal agencies must provide evidence of program performance, since funding would be allocated based not just on perceived need, but rather on the basis of what is actually accomplished.

The "quality revolution" of the 1980s, brought about by the airing of a white paper entitled "If the Japanese Can ... Why Can't We?" [3] eventually prompted legislation by President Reagan's administration for a national quality award in 1987. The Malcolm Baldrige Award has since become a powerful catalyst to stimulate American companies and is discussed in more detail later. NAVOCEANO was no less affected by this trend and provided an environment for extensive Total Quality Management (TQM) training and working groups made up of the full spectrum of employees in the early 1990s. Although changes were prescribed and even implemented as a result of these working groups, the explicit efforts of TQM faded over time, as lack of management and workforce support and two major office-wide realignments slowed the momentum. Even still, the effort was valuable in introducing the TQ principals and getting the workforce thinking in terms of how they affect the quality of products and what they might do to influence positive change. It is suggested that failure could be rooted in the organizational approach [8]. This paper describes the current effort at TQ within the Hydrography Department, where matured quality principals, industry guidelines, management support, and a focus on implementation will build on the TQM ideas from the past and achieve ongoing success in the area of TQ. Widely accepted ideas as to the issues and methods of achieving quality are becoming even more pertinent today, as we spend a large amount of public funds and have also declared ourselves to be "Leading the World in Operational Oceanography" [9]. We are determined that a fresh approach, along with management support, will encourage those who always knew TQM was a good idea to present a logical way to conduct our daily activities and eventually bring everyone, top to bottom, to the conclusion of "Why do it any other way?"

## **Basic Elements of TQ**

Regardless of whose quality philosophy, criteria, or standards are sought, there are some basic elements common to all. The basic elements of TQ can be condensed to (1) customer focus, (2) strategic planning and leadership, (3) continuous improvement and learning, and (4) empowerment and teamwork. The first, customer focus, recognizes that the customer is the ultimate judge of quality.

The initial efforts at quality in the Hydrography Department focus on the customer requirements to create digital nautical charts smooth sheets and field sheets in response to requirements generated by the U.S. Navy Fleet, the National Imagery and Mapping Agency (NIMA), and host countries. External requirement starts the flow of work, but it should be recognized that customers could also be internal. Instead of putting the customer outside the enterprise, TQ views everyone as both a customer AND a supplier, whether external or internal. Internally, one functional unit (the supplier) hands off to the next node (the customer), who then becomes the supplier. Customer focus extends beyond the obvious to the community as well. To be an exemplary corporate citizen is to be concerned with applying some amount of resources toward national, industry trade, and community activities. NAVOCEANO participates heavily in the community through mentorship programs, student and teacher educational development programs, scientific conference support, and many other community support activities.

Top managers must give quality priority or else long-standing practices detrimental to quality may never be overcome. Management must make a long-term commitment, set direction, set the customer focus, contribute to the development of the workforce, and encourage participation, learning, innovation, and creativity. Otherwise, the quality effort is doomed to fail. The top managers can do much through their perspective and vision, but even if that doesn't happen, strong middle management leadership and involvement of the workforce can still foster improved quality. The company strategy must reflect commitment to changes. In traditional management, financial and marketing issues drive the strategic plan. In TQ, quality goals become a cornerstone of business strategy.

Continuous improvement, the third basic element of TQ, refers to both incremental as well as breakthrough improvement. Improvement can consist of enhanced value to the customer through an improved product, new business opportunities, reduced error and rework, improved cycle time, and improved productivity and effectiveness in the use of resources. Adaptation, or learning, by the workforce brings out new goals or approaches. Learning and continuous improvement should be embedded in the daily work and should seek to eliminate problems at their source. An advantage to applying industry

standard methodology is that adherence to documented processes, which is enforced by auditing, leads to continuous improvement. This is facilitated at the beginning by involving the workforce in the process mapping effort and has allowed a certain level of pride and ownership to emerge. This is a huge asset for implementing new methods.

In traditional management, individuals work by themselves against performance measures and rarely see how they fit into the whole process. Under TQ, workers form team structures such as self-directed work teams or steering committees. Work across departments is optimized, and even adversarial relations are traded for partnerships, particularly in the areas of education, training, and employee involvement in process improvement. Workers empowered to make decisions increase their creativity and drive toward quality. Opportunities to learn and put new skills into practice is bolstered through teamwork and should bring all employees to a common understanding of goals and a means to attain them. Training must be a continuous effort that ensures everyone wins [3].

## Quality Standards and Criteria

Philosophies by Deming and others provide fundamental principals on which to base TQ but do not show how to implement or assess TQ in relation to peers or other companies. For this reason, award criteria and standards have been found extremely useful as tools to achieving excellence.

### ISO 9000

The International Organization for Standardization (ISO), founded in 1946, has adopted a series of quality standards to

define written quality system standards that guide a company's performance of certain requirements in the areas of design and development, production, installation, and service. The original ISO 9000 standard, devised in 1987 and revised in 1994, called for process documentation and auditing as a means to foster compliance. The standard was again revised at the end of 2000 and is known as ISO 9001:2000. The revised standard is much less prescriptive and emphasizes a "documented quality system" over a "system of documentation." For those organizations yet to implement a Quality Management System, the new ISO 9001:2000 suggests a process approach as follows:

- Identify the processes necessary for the effective implementation of the quality management system (e.g., Our six major functional nodes, discussed later.)
- Understand the interactions between these processes.
- Document the processes to the extent necessary to assure their effective operation and control. (It may be appropriate to document the processes using process maps. It is emphasized, however, that documented process maps are *not* a requirement of ISO 9001:2000.) [10]

The goal is to generate confidence by documenting conformance to established requirements. At NAVOCEANO, our objective is to get way from written verification at only the final inspection and move toward verifying processes at all stages of production. To do this, a great starting point for an organization with no formal TQ in place is to employ the methods needed to conform to ISO 9000 standards [3]. Table 1 shows, in part, the ISO 9000 family of standards and guidelines. Note that the first, ISO 9000:2000, is the starting point and defines terms; the second is the ISO 9001:2000, which assesses your ability to meet requirements and is the only standard where third-party certification may be acquired. At this time it is not our intention to apply for certification (i.e., hiring a contractor consultant to help with conformance efforts and the ultimate certification) but rather to implement efforts to create a quality system that follows the ISO 9000 guidelines. This is a jumping-off point for formal TQ initiatives within the Hydrography Department.

Table 1. ISO 9000 family of standards and guidelines.

Standards and guidelines	Purpose
ISO 9000:2000, <i>Quality management systems - Fundamentals and vocabulary</i>	Establishes a starting point for understanding the standards and defines the fundamental terms and definitions used in the ISO 9000 family which you need to avoid misunderstandings in their use.
ISO 9001:2000, <i>Quality management systems - Requirements</i>	This is the requirement standard you use to assess your ability to meet customer and applicable regulatory requirements and thereby address customer satisfaction. It is now the only standard in the ISO 9000 family against which third-party certification can be carried.
ISO 9004:2000, <i>Quality management systems - Guidelines for performance improvements</i>	This guideline standard provides guidance for continual improvement of your quality management system to benefit all parties through sustained customer satisfaction.

Reviewing work done by the Canadian and United Kingdom HOs and others has been invaluable. Both offices have attained ISO 9000 certification and have truly led the way for formalizing TQ in the hydrographic community. Many other HOs are not far behind and even use ISO-certified contractors for their QA. (See the discussion on the International Discussion Group in the last section.)

### **Malcolm Baldrige Quality Award**

Many national and state quality programs are used by hundreds of industries to stay abreast of competition and improve performance. The Baldrige National Quality Program has been adapted to many of these local programs and is becoming a standard for quality criteria. The criteria can help align resources; improve communications, productivity, and effectiveness; and achieve strategic goals. The Baldrige Criteria (Table 2) are the bases for organizational self-assessment and, at first glance, appear to require a huge undertaking to implement. The core values and concepts focus on results and creating value is embedded in the beliefs and behaviors of high-performing organizations. The insert to the right elucidates the seven award criteria. The award does not exist merely for the purpose of "winning." Its purpose is to improve quality and productivity, recognize the achievements of selected companies, and establish guidelines and criteria that businesses can use to evaluate their own efforts [3]. It provides specific guidance on how to manage for high quality through sharing the experiences of the winners and providing detailed feedback to applicants. The application process itself will culminate in invaluable feedback for your organization, whether or not you ever develop to the point of being competitive. It was suggested that one of the best ways to learn about this award is to become trained as an examiner (free training sessions are offered periodically).

### **ISO 19000**

How the quality information is attached to a dataset in a way that it can be retrieved and easily understood is a topic that merits focus. The evolving ISO 19000 standard addressed in this section is providing the hydrographic community with guidance now being incorporated into the newest revision of the International Hydrographic Organization (IHO) standard for the exchange of digital hydrographic data, S-57. The IHO has declared that further developments of S-57 must be in conformance with ISO 19000 series of standards. The IHO Web site has the following quote:

... S-57 is intended to support all types of hydrographic data. In order to meet this requirement, S-57 needs expanding... S-57 Edition 4.0, which will support these new requirements, will be based to the greatest extent

**Table 2. Malcolm Baldrige Award Criteria**

#### **1) Leadership**

According to the 1997 Award Criteria, leadership is examined through the "senior leaders' personal leadership and involvement in creating and sustaining values, company directions, performance expectations, customer focus, and a leadership system that promotes performance excellence. Also examined is how the values and expectations are integrated into the company's leadership system, including how the company continuously learns and improves, and addresses its societal responsibilities and community involvement."

#### **2) Strategic Planning**

The Strategic Planning category evaluates a company's strategic directions and how key action plans are determined. The plans are also examined to see how they are translated into the management system.

#### **3) Customer and Market Focus**

The Customer and Market Focus category involves the customer focus along with the market focus. Also involved is the company's involvement with the customer relationship and their satisfaction.

#### **4) Information and Analysis**

The Information and Analysis category examines the management and effectiveness of the use of data and information to support key company processes and the company's performance management system. (1997 Criteria)

#### **5) Human Resource Development and Management**

This category is important because it shows how the workforce has developed and utilized its full potential while implementing the company's objectives. Also, the company's efforts to create and maintain performance excellence, full participation, and growth are examined.

#### **6) Process Management**

Examined is 'the key aspects of process management, including customer-focused design, product and service delivery processes, support processes, and supplier and partnering processes involving all work units. The Category examines how key processes are designed, effectively managed, and improved to achieve better performance.'

#### **7) Business Results**

This category is examined by investigating key business areas: customer satisfaction, financial and marketplace performance, human resource, supplier and partner performance, and operational performance. One cannot investigate this area without also looking at the performance levels of the competitors. This facilitates process modifications and plan changes and allows agreement on performance metrics.

#### **Conclusion**

The Malcolm Baldrige Award is not just necessary for each company to read and understand, it is necessary for each company to follow its guidelines to be successful in today's competitive environment.

#### **Links used for information**

<http://www.quality.nist.gov> [12]

possible on the geospatial data standards produced by, or under development by, the International Standards Organization (ISO)...[13]

Since 1994 an international standard for geographic information has been developed through the work of ISO/TC 211. The scope of this effort is standardization for objects or phenomena associated with a relative or absolute position on the Earth's surface. The standards address geographic information standards, access technology, content, organization, and education [14].

Of particular interest are the ISO 19113 (Quality Principals), ISO 19114 (Quality Evaluation Procedures) and ISO 19115 (Metadata). As geographic datasets are increasingly shared and used for purposes other than originally intended, quality becomes a necessary attribute. Complete descriptions of the dataset quality allow potential users to match applications with how well the dataset meets the criteria set out in the project specification. The ISO 19113 standard provides principals for describing the quality of geographic data, and ISO 19114 provides a framework for evaluating and reporting the quality results as part of either data quality metadata or as a quality evaluation report.

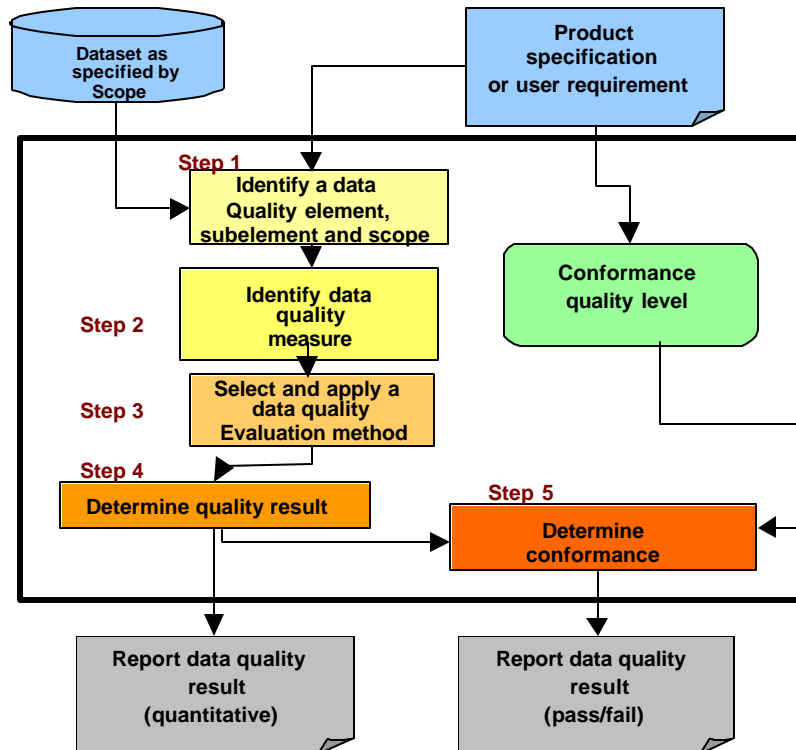


Figure 3. ISO 19114 Process for evaluation and reporting of data quality results.

The process for evaluating and reporting data quality is pictured in Figure 3, taken from the ISO 19114 document [15]. Step 1 determines the dataset quality scope and data quality elements and subelements, which describe the extent or characteristics for which the quality information is being reported. In Step 2, the data quality measure, data quality value type, and unit are identified. Step 3 selects and applies a data quality evaluation method, the data quality result is determined in Step 4, and conformance is determined in Step 5. Quality evaluation methods can be direct or indirect. Direct methods use a comparison to some internal or external information. Indirect is to infer or estimate data quality based on information such as source or age. The results can then be reported either quantitatively or pass/fail. The ISO 19114 and 19115 standards describe how the quality information should be evaluated and what should be recorded.

Table 3 is a table of data quality components (as specified in ISO 19114 ) and sample information about a dataset redundancy check, where two survey lines cross the same area of the seafloor. This standard is useful for hydrographic data quality retention. As previously mentioned, the quality component of the data can be extremely valuable for decisions on applying the data. It is becoming increasingly important that data quality be easy to access and presented in a way that's easy to understand. Elements that address spatial data quality include lineage, positional and attribute accuracy, completeness, logical consistency, semantic accuracy (the meaning conveyed) and timeliness, or currency, all of which are portrayed in the ISO 19114 standard.

**Table 3. Data quality components from the ISO 19114 standard. The rightmost column is an example of quality information that can be captured for hydrographic data.**

Data Quality Components		Short Name	Sample
Data Quality Scope		DQ_Scope	Multibeam Crosscheck Analysis
Data Quality Element		DQ_Element	Depth Comparisons
Data Quality Subelement		DQ_Subelement	Residual Depth Differences
Data Quality Measure		DQ_Measure	RMS95
Data Quality Measure Description		DQ_MeasureDesc	Normalized Std at 2 sigma
Data Quality I. D. Code		DQ_MeasureID	RMS95
Data Quality Evaluation Method		DQ_EvalMethod	Compare depth differences in gridded MB data at crossings
Data Quality Evaluation Method Type		DQ_EvalMethodType	automated statistical evaluation
Data Quality Evaluation Method Description		DQ_EvalMethodDesc	All crossings
Data Quality Result		DQ_QualityResult	
Data Quality Value Type		DQ_ValueType	number
Data Quality Value		DQ_ValueType	1.5
Data Quality Value Unit		DQ_Value	meters
Data Quality Date		DQ_Date	3/24/2003
Data Quality Conformance Quality Level		DQ_ConformanceLevel	IHO Specification

## Process Improvement at NAVOCEANO

How quality management principles are applied depends on the nature and needs of the organization. With 450 people across 5 departments manning the survey platforms, the need for consistency, or systematically defining what is required to achieve the desired result, is a very high priority. To improve, processes must first be defined, and to keep up with the extreme pace of information technology evolution, continual process improvement is needed just to stay in place. Fundamental to QA is the simple philosophy of "Say what you do, do what you say, and prove that you did it." Documentation allows a QA system that ensures processes were followed. As Sean Hinds of the Canadian Hydrographic Service (CHS) points out his paper "First Steps on a Quality Journey," "the lack of documentation ... resulted in greater reliance on end-of-line inspection." [16] We want to rely instead, on documentation of the processes done on the data and also be able to focus resources on improving our processes that are lacking, as evidenced by quality reviews.

### Documentation Schema

Qualities Review (QR) forms, simply checklists, are used as the third part to a three-tiered documentation effort. Patterned after UK Hydrographic Office schema, the highest tier is the Quality Procedure (QP), which lays out the company best practices. The QP tells the scope (where and when to use

the procedure), and the second tier is the Quality Working Practices (QWP—the how to). The QWP points to standard operating procedures (SOPs) such as operator manuals or internal instructional guides. These SOPs are delivered on CD-ROM with the documentation and are ever-changing. The third tier is the QR, or rather checklists, which show where the different parts of the process are executed. Checklists are filled out quickly and help catch deficiencies before the data go any farther downstream.

The starting point of documentation in the Hydrography Department is at the QR level. This may seem backward, but documenting criteria for dataset validity helps address some immediate problems (don't-miss steps, giving feedback to the collectors and validators, providing metrics) and also starts the tracking of proof of processes prior to delivery. The new ISO 9001:2000 standard is more focused on proving effectiveness rather than documenting processes, and fully mapping the processes first helps iron out the logical flow and can help reduce the time spent on written documentation.

### Starting Off With a Key Process: Bathymetric Data Validation

The process identified as the highest priority for TQ in the Hydrography Department is that of collecting and validating the bathymetric data. Bathymetric data validation and depicting uncertainty or quality are a series of involved processes, which are very well-addressed in several papers [15, 17, 18]. The intention here is not to detail the validation process and issues, but rather show the approach to putting a quality system in place. Using the aforementioned ISO 9000 process approach and ideas gleaned from a workshop and papers written by the CHS and others, Quality Assurance Branch personnel initiated a series of work sessions with the process owners. As mentioned, the overall strategy is to map processes and, once the processes are sorted out diagrammatically, delve into the written documentation effort. Each of the major functional nodes pictured in Figure 4 are captured first. Facilitating the process owners to define their processes rather than doing it for them has proven to be one of the best ways to get the workforce involved and excited about the TQ effort.

The entire flow from requirements through data validation to the final product comprises the *backbone*, or high-level process. Figure 4 is a diagram of the hydrographic data flow using six major functional nodes. This flow depicts process ownership that extends beyond the Hydrography Department since the Requirements and Data Ingest nodes are functions of other departments. The Data Collection functional node (as previously mentioned) controls some data types that will require the involvement of other departments to provide collection specifications and validation methods. All personnel who man the survey platforms undergo in-house training (a vital component of TQ), which necessitates further involvement of other departments. Involving other departments in hydrographic processes requires work as interdepartmental teams, and fortunately for the data types most important to depth corrections, the sound speed and tide data, full cooperation has been provided. Figure 4 shows in red what gets handed off from

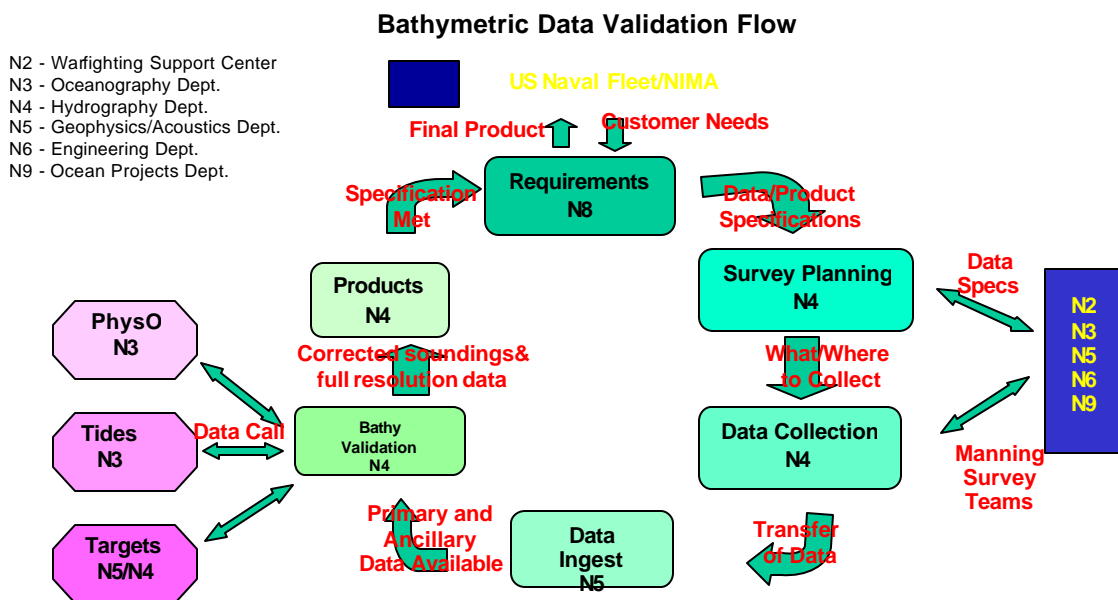
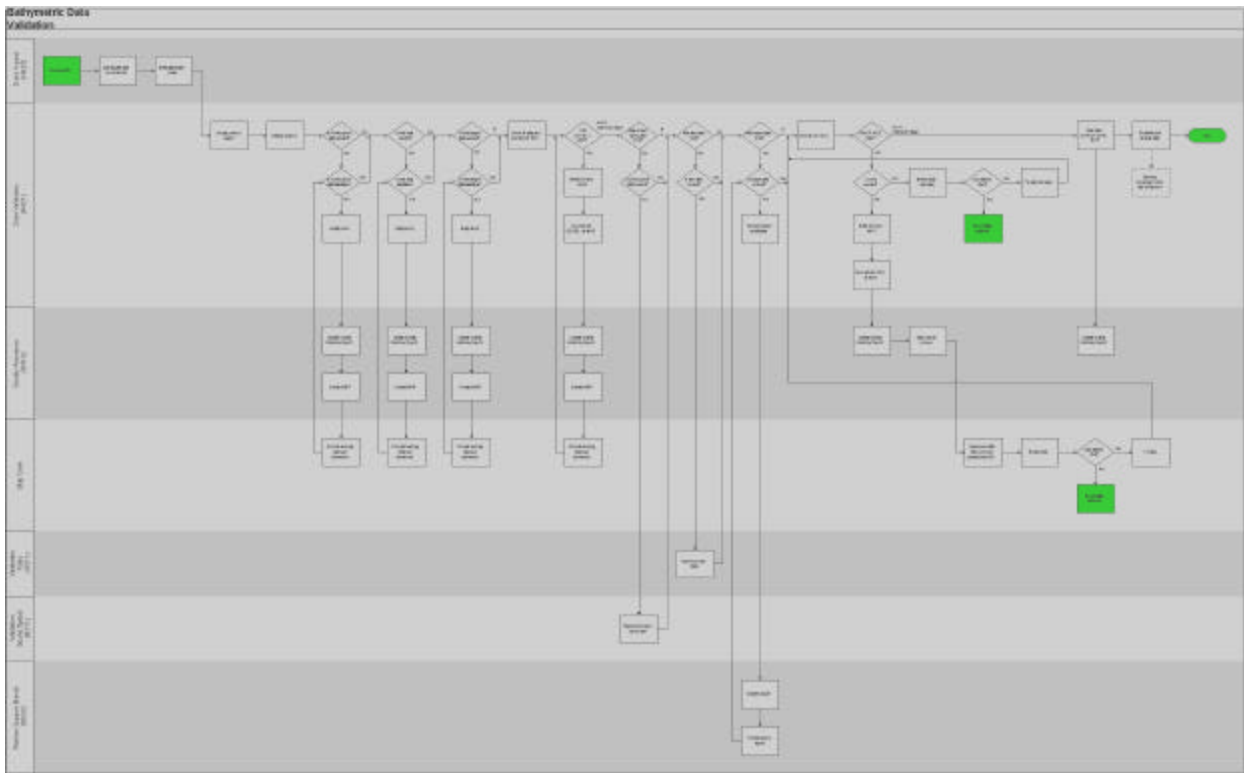


Figure 4. Hydrography Department bathymetric data validation flow. Interdepartment cooperation is vital to this flow.



**Figure 5. Swim-lane-style process map of bathymetric data validation. Each swim lane represents a functional unit and nicely portrays the role of each.**

one functional node to the next. It is at these handoffs where the most value can be gained from process improvement. Figure 5 shows a swim-lane-style process map for the bathymetric validation process. Each swim lane is a functional unit that has a task to perform. The green boxes depict the start and finish points. This type of process map shows the players, the work, and the interaction between them.

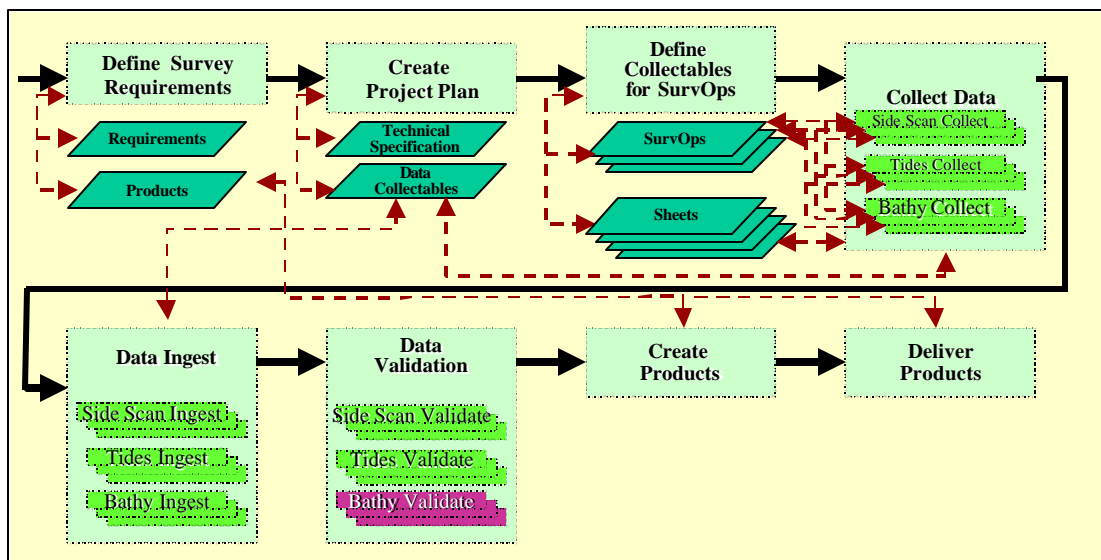
### ***The Organization as a System View***

Since each functional node is already managed competently, the process gains the most benefit when senior management manages the white space, or the functional node interfaces. Rummler and Brache assert that “the greatest opportunities for performance improvement often lie in the functional interfaces—those points at which the baton (for example, “production specs”) is passed from one department to another.” A typical organizational chart (Figure 1) doesn’t depict the customers, suppliers, and products, nor can any type of workflow be perceived. The traditional vertical view works fine when an organization is small and everyone knows each other and understands the each other’s functions. As the organization becomes more complex, each separate unit is managed independently and has individualistic goals. Communications between functional nodes become just activity reports. This “silo” view perceives other departments competitively, and this prevents issues from being resolved at lower levels. At this point, higher level management is resolving low-level issues and some things even “fall through the cracks” completely.

A different perspective is presented as a horizontal, or systems view, rather than the vertical view of the organization. This would show the three missing ingredients: the customer, the product, and the flow of work. Notice that in Figure 4, interdepartment cooperation is vital. To have the depicted process flow smoothly, WORK, not just input, is required from the other departments outside Hydrography. QA efforts are actually breaking down some of the interdepartment barriers to accomplish working together toward a common goal—providing the best data possible. A department head brief was presented early on to bring awareness to senior department management that the Hydrography Department will have some interdepartment tasking. That can be a sticky wicket, but so far the essential players have been willing and available. As the TQ principals and workflow management saturates the Office in the future, enhanced views of the organizational chart should emerge that depict the connectivity between departments (give peace a chance...).

## Workflow Management Software

A parallel development in the Hydrography Department should actually *enable* this interdepartment flow of work for bathymetric validation even more—an automated workflow system. A workflow system is computer-based support for business process logic that provides a *process control backbone* to mediate the flow of responsibility from person to person and from task to task. A workflow system defines each process, keeps track of the state of each instance of the process as it progresses through its defined task stages, and pushes the process along to the next task that needs to be performed. To develop software to track bathymetric data validation and workflow at this time may seem premature since the documentation effort has just started. But circumstances were such that outside department funds slated for



**Figure 6. Backbone process for the Hydrography Department implemented in the first delivery of workflow software [19].**

workflow developments in the Hydrography Department were available, as streamlining the processes fall in line with the Strategic Plan. The initial implementation of the workflow system creates the backbone process—six major functional nodes. These nodes, Requirements, Survey Plans, Data Collection, Data Ingest, Data Validation, and Products are treated at a skeletal level on the first delivery. Figure 6 shows the backbone process for the Hydrography Department as implemented in the workflow software. The only detailed workflow drills down into the process for bathymetric data validation shown in pink in Figure 6. Arrows show one to many (one technical specification for several survey operations), many to many (many data types collected for several sheets), and one to many (a survey operation fulfilling different requirements) relationships. These relationships are complex and have been appropriately implemented so far in the software delivered.

Process capturing became driven by what was needed to feed the contractor who was configuring the workflow software based on the process maps supplied. Doing the process maps internally creates better process maps due to internal familiarity with the processes and owners, and a tremendous amount of billable contractor time is saved. TNG Unicenter Service Desk software is used as the workflow engine. This turns out to be an economical software solution with regards to licensing. An added benefit is that this is the same software used by the NAVOCEANO Survey Operations Center. The intention is that if the Hydrography Department is successful with the workflow software, then ultimately, the workflow effort could extend to other departments. Signs of success in the Hydrography Department will be if:

- Department (and some interdepartment) personnel adapt to the system for tracking their daily tasks and discover it enhances their ability to work.
- Useful performance metrics are obtained.
- Data validation tracking becomes a key to added data value.

- Processes stay current—configuration of software is easily understood and lends easily to updating processes as needed.
- Processes are easily controlled and managed.
- Handoffs between functional nodes is smooth, and tasks don't get between nodes.
- Consensus views the software as money well spent.

## International Discussion Group for QA in Hydrography

Table 4 itemizes QA components that are important to hydrography in the digital age. The component of interest here is that of developing professional practices, where the various HOs "apply approximately the same QC tools at approximately the same intensity at all levels." [1] In the spirit of "the various HOs marching forward together in the digital age," an International Discussion Group was formed. The purpose of having such a group is to meet at opportune times (hydrographic conferences) to provide a forum of exchanging information on QA issues. This allows each HO a chance to network with other like professionals struggling with some of the same issues.

The first discussion was held during the CHC2002 conference in Toronto (May 2002) and was the perfect opportunity to kick off such a discussion group. The following excerpt from the meeting minutes reveals some of what is happening on the international scene for QA in hydrography.

A roundtable discussion followed with members of various national survey agencies sharing their particular survey practices. The first part of the discussion focused on the survey staffing and feedback methods. At the U.K. Hydrographic Office (UKHO) the surveys are conducted by the military or by contractors, the charts are produced on the civilian side. The chart production side is unable to get close to the data because another agency performs the collection. The data reviewers fill out an appraisal, which is provided to the field crews and contractors.

New Zealand contracts everything out: geodesy, topography, etc. Their QA process is part of the contract. Independent evaluators QA the data and the chart production is also contracted.

The Canadian Hydrographic Service (CHS) performs the entire survey -to-chart process in house. They have achieved ISO9000 certification and have just had their first external audit.

The Royal Australian Navy conducts the surveys for the Australian Hydrographic Service. AHS QCs and produces the charts. All ships have SOPs and all crews have standard procedures. QC is performed aboard ship. Rendered data is then forwarded to the office, accompanied by a certification signed by the captain that the data has been thoroughly checked. The data is QC'd again in house. The hydrographic data is formatted with 30 attributes. The metadata file containing the attributes is linked to and accompanies the data until it is put into a chart. Storage of the metadata is a problem. Much data comes in from other sources. The QA varies from source to source. The AHS is methodically evaluating old charts by area. A Zone of Confidence (ZOC) is assigned subsequent to the evaluation.

The U.S. National Oceanographic and Atmospheric Administration (NOAA) provides feedback to its own crews. Its processing centers are in daily contact with the vessels. A copy of the Report of Survey accompanies data forever, and another copy goes back to the ship. Feedback to contractors takes longer but a report does go back to the contractors. Standards exist for manual processing but there is none for auto processing.

**Table 4. QA Components in Hydrography, as determined by Monahan and Monahan [1]**

- **Education and Training** - This is the most important corporate tool at our disposal. This includes formal and on-the-job training.
- **Planning and Decisionmaking** - The level of accuracy expected could depend on the planning and decisions made. Certain processes and standards adopted will have implications throughout the production cycle.
- **Survey Design or Data Gathering Strategy** - Survey design plays a large role in QC and determines the amount of data redundancy used for data checks as well as placement of mission essential equipment (gages).
- **Standards** - International standards exist for products and their usage that the national standards can support.
- **Manuals** - These can be a set of instructions that codifies the organization expectations about the quality of the products and describes how that quality is to be achieved. Manuals can form the basis of in-house training.
- **Retroactive Quality Evaluation** - When all data are kept and considered until replaced or disproved by newer data sets, incorporating older data, collected at different standards, will require some form of QC.
- **ISO** - ISO is an approach to managing how quality goals are met and specifies how and when existing standards are applied. Existing standards should conform and respond to customer requirements.
- **Professional Practices** - This dictates that all HOs operate in approximately the same way, i.e., that they apply QC tools at about the same intensity at all levels.
- **Inspection** - Inspection or assessment of the product at various stages can include peer review or checking procedures by a specialist for some items. [1]

The UKHO provides appraisal in the form of checklists to the Royal Navy and to contractors. These are the only guidelines provided as the contractors have their own standards and procedures for how to meet the specifications. The surveyors (military or civilian) report and state whether and how standards were met.

The U.K. has amassed years of reports. They achieved ISO9000 certification within the last 5 years and their reports and procedures are standardized.

The QC evaluations at AHS are subjective, as the evaluator knows the personnel.

In Sweden, at the Swedish Maritime Administration, the home office is in daily contact with the ships. The survey crew performs the QA on board and receives feedback from the office at least every two weeks.

The French hydrographic service (SHOM) derives attributes for their own data from their own specifications. They map to each sounding a measure of accuracy. Each sounding is archived with this attribute. This is not the case with the data received from contractors. There is no control of quality from contractors. SHOM cannot attribute or use that data in chart production. Externally derived data is only used for planning.

The question was posed whether international QC standards should be instituted and whether S-44 is sufficient direction. It was observed that S-44 was purposely vague about procedure in order not to restrict national survey organizations to one specific method for meeting IHO standards. A UKHO rep contributed that it is permissible to use standards less than S-44's for data capturing for non-navigational areas. He asked if S-44 is appropriate for non-SOLAS areas.

The ISO certification process was the expedient means for CHS to embrace the modern quality standards. They were surprised at how the process gave the CHS staff a sense of ownership, confidence and satisfaction in their jobs. The UKHO is also ISO-certified and France is also committed to being certified by the end of 2003. The UKHO can track performance as the data moves through the processing pipeline. They tend to contract with other ISO companies and were pleased with the results of having organized their practices along ISO guidelines.

Since this discussion in May, the NAVOCEANO Hydrography Department has pushed forward with added confidence. It appears that many HO's around the world are indeed addressing similar issues, and the approaches to QA are fairly consistent. Whether or not a hydrographic agency decides to pursue ISO 9000 certification, the concept is becoming part of the way to do business in many organizations. The next discussion will be held during the Hydro2003 Conference in March 2003 in Biloxi, MS.

## Summary

The Institute of Quality Assurance states, "Quality is essential to the success of business. To make a difference, good quality practice must be embraced by senior management and instilled within an organization's culture. Quality is not just about implementing a system or working towards a set standard. It is an attitude, a way of working, which not only improves businesses but the way people work and live." [20]

The NAVOCEANO Hydrography Department has been on a discovery mission for the past year to find out how to achieve QA in hydrographic products. There is good news on the quality front! Irrespective of the type of industry, there does exist a logical approach to QA that has been adapted and propagated by quality organizations. Quality philosophies have matured into a set of international standards and award criteria that are simply a common-sense approach to business, where the customer ultimately determines quality, and along with strategic planning, management, and the workforce, this approach is an integral part of a total quality system.

Using the methodology laid out in the standards, through process documentation and control, it is surmised that customer expectations can be met through a well-managed and implemented quality system. Simple compliance to documented processes does not guarantee quality, however. Only consistency can be expected from such an approach. However, reducing variance and increasing accuracy in the processes is a desired goal for the Hydrography Department, especially given the rotation of survey crews who collect and field process the data. Using data owners as the experts, best practices are documented, and then quality reviews are used to ensure the processes are followed as instructed. A software solution is also being configured to control the flow of work needed for bathymetric data validation tracking.

Process control is just a piece of the total quality picture. Also vital is support of management to set vision and customer focus and provide resources for process improvement, and the workforce itself must be empowered and hopeful about their ability to affect the system and overcome the status quo.

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