Future of Nautical Charting at NOAA
(Nautical Chart System II)

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Abstract

As Hydrographic Offices face greater workloads of producing both Paper and Electronic Navigational Charts without an increase in resources, they are looking for new ways to streamline the production process. This streamlining needs to be efficient and deliver high quality and consistent products to the mariner in order to promote safe navigation. This requires new and improved ways of organizing data and workflows in making products, and taking into consideration multiple sources and formats. In order to accomplish this goal some Hydrographic Offices have chosen a central database solution from which all products can be extracted.

The National Oceanic and Atmospheric Administration (NOAA) embarked on a multiyear effort to streamline its nautical chart production. NOAA has contracted with McDonald Bradley, Inc. using ESRI Production Line Tool Set (PLTS) Nautical Solution to create a centralized nautical database. The Nautical Chart System II will not only be able to receive data from differing sources, but will have enough versatility to build those products needed by the maritime community and establish connections with the national geospatial database infrastructure and other agencies to exchange data in a seamless way.

This paper describes how NOAA is implementing such a system, the challenges faced and key outcomes once it is operational.

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Introduction

The Marine Chart Division (MCD) of the Office of Coast Survey, National Ocean Service (NOS), National Oceanic & Atmospheric Administration (NOAA), a bureau of the U.S. Department of Commerce, maintains a Nautical Chart System (NCS I) that underpins production of NOAA nautical charts, which are tools for safe, efficient and environmentally sound navigation in U.S. waters. MCD currently maintains two production systems – raster and vector – to maintain and generate nautical chart products. The NCS allows NOAA to maintain a current suite of products: traditional lithographic charts, Raster Navigational Charts (RNC), Electronic Navigational Charts (ENC), and Print-on-Demand (POD) charts. NOAA provides a weekly update service with critical correction changes to RNC, ENC, and POD charts in order for the mariner to receive timely and accurate information.

Updated nautical charts generated from the Nautical Chart System serve commercial and recreational mariners, coastal resources managers, the scientific community, other NOAA programs and U.S. Government agencies, including the Coast Guard, Navy, National Geospatial Intelligence Agency, and non-governmental organizations, including the American Pilots Association and US Power Squadron. The mariner is the beneficiary of a strong maritime transportation system that moves over two thirds of all consumer goods purchased in the United States.

Background

In the current configuration, NCS I supports two production lines. One production system maintains the RNC and derived products and services, and the other maintains the ENC. Each production line must apply source data to each product separately. Source data is the information that MCD receives on a daily basis which is analyzed and applied to the charting products. Source data providers are diverse and data is received in multiple and varied formats. During the analysis of source data, applications that are critical are identified for time-sensitive release to the mariner. In the current system (Figure 1), this is shown by MCD maintaining a maintenance copy for long term transactions and a weekly updates copy that reflects the time sensitive nature of critical corrections.

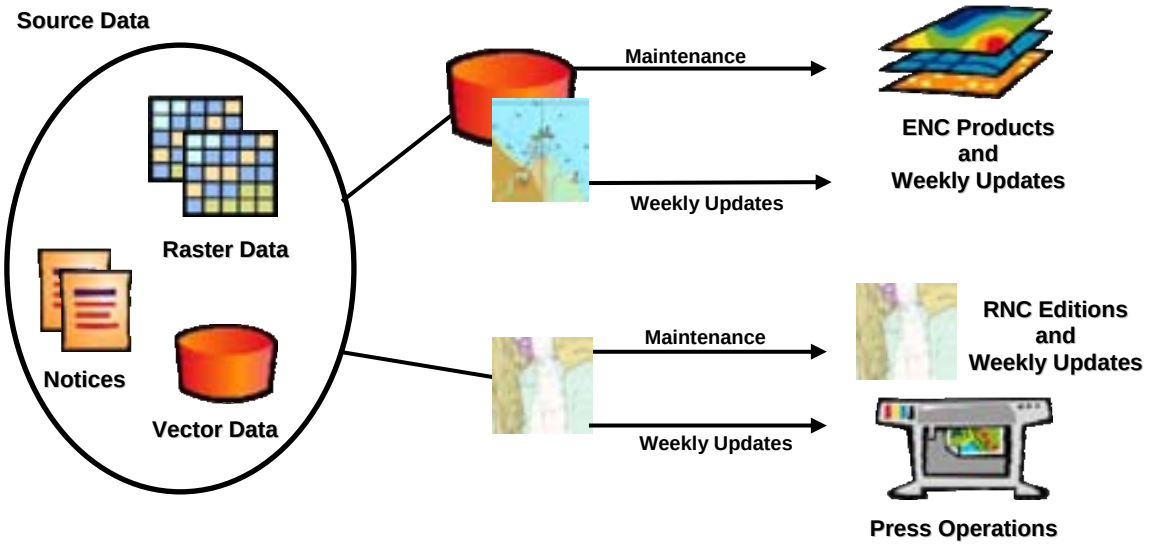

Figure 1: NCS I production lines

The maintenance of two production systems and four separate versions a product can cause product inconsistencies and an inefficient method of providing the maritime community with up-to-date products. As the ENC product suite continues to grow, MCD will not have the resources to maintain the two production lines with dual source application.

In recognition of this, MCD embarked upon a project in 2004 to leverage technology to improve efficiencies by applying source data only once into a central database from which to derive the multiple products and services. In addition to creating a more efficient workflow, the single production system will enable MCD to synchronize release of products to provide the mariner with timely, consistent, and up-to-date products. Figure 2 shows a simplified example of NCS II.

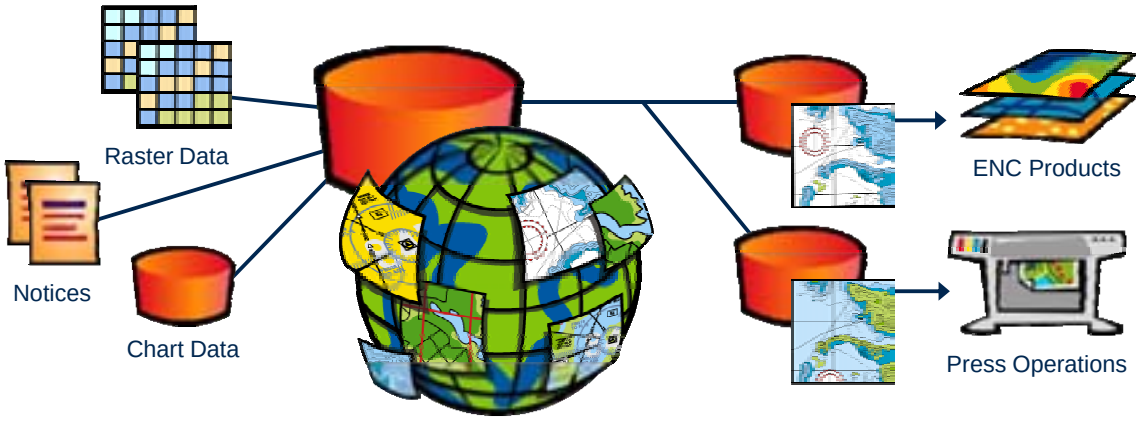

Figure 2: NCS II Production Design with a central database at the core of the system

In late 2004, MCD awarded a five year contract to McDonald Bradley Inc (MBI), to acquire and integrate a commercial off the shelf (COTS) software solution. The COTS solution must be able to produce both ENC and RNC/Paper products from a single vector based database. The system integration includes the provision of interfaces from the new COTS system to legacy database management systems. This system is known as the Nautical Chart System II (NCS II). In order to manage this project, it was broken into four phases:

Phase 1: Requirements Analysis
Phase 2: Trade Study and System Test
Phase 3: System Integration
Phase 4: System Transition

Phase 1: Requirements Analysis

In order to objectively choose a COTS solution MCD needed to perform a robust requirements analysis. This analysis documented the NCS I production system and formulated 443 discrete requirements spanning the general, functional, interface, operational, performance and quality aspects of the system. These sets of requirements are used as a baseline for the entire project.

Phase 2: Trade Study and System Test

In order to objectively select the COTS portion of the system MCD conducted a market survey. Invitations to vendors were issued to demonstrate their system capabilities against the requirements that were established in phase 1 of the project. Each vendor was invited to demonstrate their proposed solution over a two week period. The first week was spent demonstrating the functionality of the solution against the requirements, and the second week was spent demonstrating compliance with test scenarios that were developed by the combined MCD and MBI team. The market survey revealed that there was no COTS solution ready to integrate within the constraint defined for meeting 60% of system requirements “off the shelf.” The ESRI PLTS Nautical Solution offered the most extensible solution to achieve the required database driven functionality. MBI selected the ESRI Production Lline Tool Set (PLTS) Nautical Solution as the corner stone of the Nautical Chart System II (NCS II) solution.

ESRI PLTS Nautical Solution

The PLTS Nautical Solution is an extension to ESRI’s ArcGIS software, and leverages many components available in ArcGIS. The Nautical Solution includes an S-57 based data model, a variety of specialized tools for navigation data management and editing, quality control to IHO specifications, nautical product generation management, and workflow management. (Figure 3)

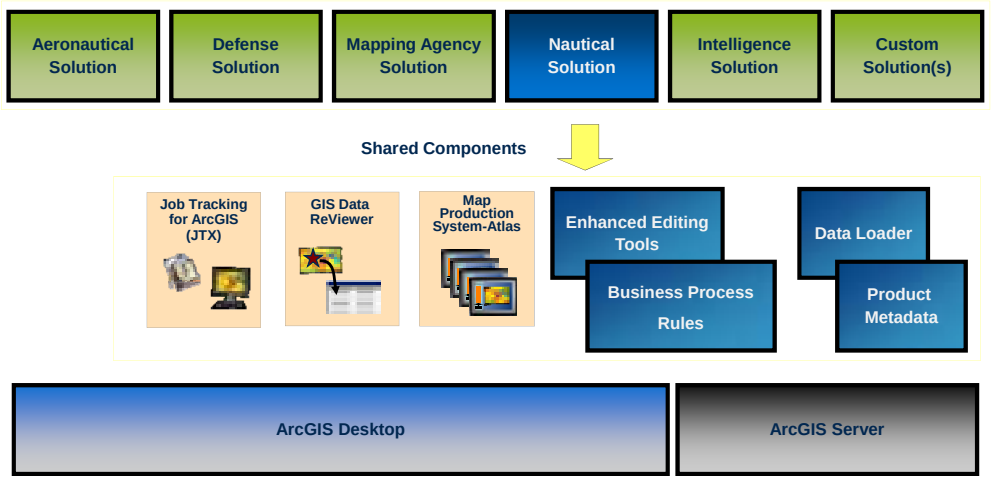

Figure 3: The ESRI Production Line Tool Set Solutions and ArcGIS

Product Neutral Central Database:

NOAA's data will be centrally managed and edited in a product independent database, referred to as the Nautical Information System (NIS) database. Since data is not attached to any specific product or standard (i.e. S-57), the hydrographic spatial information is stored as feature data in the geodatabase allowing the user to enter data into it from a variety of different source formats using standard GIS functionality.

The geodatabase is ESRI's native data format and is product neutral. A geodatabase is a container that is used to keep a collection of datasets; it stores the geographic data maintaining both spatial and non spatial data, such as object and feature classes, relationship classes, topologies, networks, terrains, raster datasets and raster catalogs. This data model is the core of the database and all products are derived from it.

The NIS database can be configured in various ways and adapted to a particular organization's size and needs. For MCD, existing vector data, such as ENC cells will be loaded into the central database. All feature, or real-world object, editing, such as creation of new features or maintenance of existing features, will be done in the central database. MCD has configured the NIS to store data on 22 different scales in order to support both the ENC and paper/RNC products. MCD made the conscious decision that data will be stored in the NIS database where there are products. Therefore compilation on the database will only occur at those scales where there is a product. However, MCD is also leveraging the use of a central database and is only storing Aids to Navigation once.

Multi-User Editing

NOAA's policies and business needs require the system to support a multi-user editing environment that is open to authorized users. The ESRI geodatabase supports a multi-user editing environment. This aspect of the geodatabase is called versioning, and is leveraged by the PLTS Nautical Solution. Versioning allows multiple users to edit the database in the same area

of interest at the same time, without locking or duplicating data. Each user is editing features in their version, also referred to as the child version. In the NOAA workflow, changes made to a child version will be posted back to the parent, once the changes have been approved through the QC process. (Figure 4)

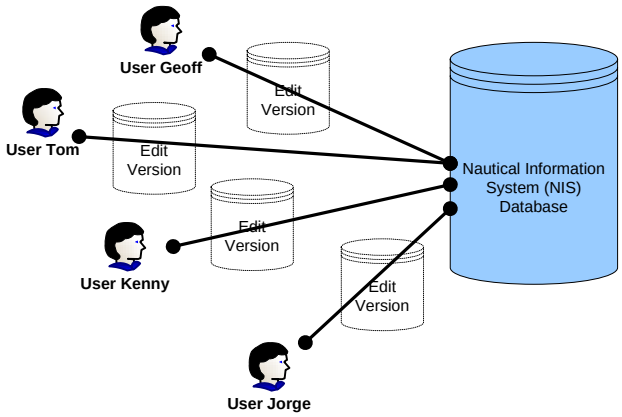

Figure 4: Editing in a Versioned Geodatabase

The ability to assign tasks to multiple cartographers working on the same area or even in the same feature at the same time will result in more versatility, efficiency and productivity.

Quality Control

In support of data production, the Nautical Solution has a quality control component, called the GIS Data ReViewer. It allows users to run automated attribute and spatial checks, as well as visually inspect the data. The results of the quality control checks are stored in a table in the database to serve as a historical record of what was identified during the QC cycle. Quality control will be implemented both on the central database and the products that are derived. When the reviewed area is exported to an S-57 ENC the resulting ENC is compliant with IHO standards. The GIS Data ReViewer will be integrated into the overall production workflow at NOAA.

Generating Products

The PLTS Nautical Solution generates ENC and raster chart products from the central database. Each product is its own geodatabase that is created, and maintained using ESRI's replication technology. A replica is a copy of all or part of an existing database. In the Nautical Solution, each product is a replica from the NIS based on its product's extent. Updates from the central database are synchronized to the affected product databases, when the product needs to be exported and published as either a new edition or a revision. At the product level the only editing allowed will be for chart beautification. All data editing is limited to the NIS database. For the NOAA implementation, product databases will also be versioned in order to support NOAA's business needs for continual maintenance changes and critical changes, as well as multi-user editing. (Figure 5)

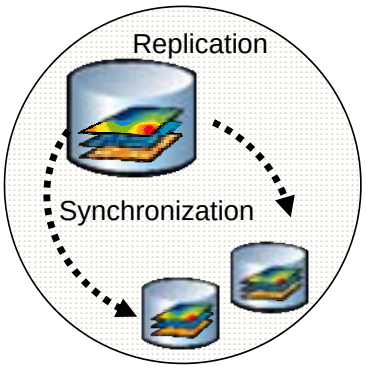

Figure 5: Creation and update of products through ESRI Replication technology

Managing Workflows

Integrated to the PLTS Nautical Solution is the Job Tracking Extension (JTX). JTX is an enterprise workflow management application that allows users from different roles and responsibilities in the organization to have guidance and control of their tasks and assign and supervise progress of other people's jobs included in the production workflows. Job actions are saved and archived as historic information, allowing managers to see step by step how the project is progressing; this information can be supplemented with comments and notes that make the documentation as detailed as needed. These workflows can be designed and configured according to the organization's needs.

Phase 3: System Integration

MBI is responsible for integration of all hardware and software to ensure that the NCS II system produces all products and services produced by the existing systems. The requirements for the single production system are based on the October 1, 2004 capabilities of the existing chart production systems in use by MCD personnel. The integration effort will be considered complete when the new system is able to create the products being created by current MCD systems within a single Coast Guard District. System acceptance is scheduled for completion January 29, 2009.

The NCS II Integration encompasses testing of the ESRI solution to validate the functional requirements, workflow development, interface development, system end to end test and acceptance test.

MBI developed an iterative approach to developing the workflow and interfaces for acquiring and applying continual maintenance and critical correction source, creating and managing product repositories, propagating changes to ENC and Raster products, and publishing ENC and Raster Products.

The NCS I system is comprised of several COTS and custom applications. The NCS II system is utilizing some of the existing custom applications. As a result, interface development is required to interact with the existing applications and in some cases customizing external applications is required. MBI analysis identified these areas of development and integration. The interface

development is primarily associated with acquiring source and managing source application and products. MBI continues efforts to complete development and integration by the end of summer 2008.

The evolution of the NCS II solution has been supported by several milestone builds of COTS development to gradually fulfill all system requirements. As of early 2008, there are two additional builds planned focused on resolution of priority technical challenges.

As the integration effort nears completion, testing and development are now focused on the primary capabilities required to complete workflow and interface development in preparation of the system end to end test. MCD users will exercise test scenarios designed to holistically test requirement, workflow and interfaces in a "near to" production mode, and will lay the foundation for acceptance testing to validate the capability to enter into a production capacity. The initial rollout is planned within a single Coast Guard District (CGD) with plans to gradually scale and add additional CGD coverage.

System deployment and scaling will be defined as part of transition planning. The plan will be derived to prudently phase-out the use of NCS I and transition products to NCS II.

As part of system integration, workflows will be established and tested for efficiency.

Phase 4: System Transition

Once the system has been accepted by NOAA the actual task of transitioning data and products to NCSII begins. However, NOAA realizes that transition does not happen overnight and has begun to plan for transition post system acceptance. Transition activities include data migration, customer focus, training, and organizational structure.

Data Migration

MCD has roughly 60 percent of their paper/RNC products in ENC and format available to the public. The remaining 40 percent has been collected, but needs validation, repair and to be updated to the most current source. One issue that arose in this project is that the ENC product specification is not geared towards producing paper charts. A comparative analysis between the ENC suite and the paper suite showed that there are many data gaps that need to be filled to support paper/RNC products in the new production system.

In addition, the same ENC data was initially collected directly off the raster charts causing many data inconsistencies that need to be corrected. For example, features between ENC cells may not match if they were collected from various products. Another issue is some features were not collected for the ENC, such as roads, topographic contours, and other land features, but are needed to support the paper/RNC product. All of these issues need to be addressed prior to loading the data into the NIS. MCD plans to prepare the data by systematically moving from one Coast Guard district to another.. Full ENC production will be established first, while paper chart and RNC production will be transferred to NCS II as paper chart templates are built.

Other data migration issues that MCD is facing is the re-scheming of the NOAA ENC suite, complying to the IHO SCAMIN recommendations published in November 2007 and building paper chart templates.

Customer Focus

MCD is using this transition as an opportunity to make product improvements. The Office of Coast Survey's Navigational Services Division is gathering product requirements in an effort to improve the product being delivered to the mariner. Data is being collected on what mariners place the most importance on when it comes to charting products, such as LORAN, land features, tabulation information, and channel information.

Training

Prior to the transition phase, MCD will have to provide training before shifting resources to NCSII. New skills will be required for digital compilation and validation. Training will be needed for learning the new tools provided by the PLTS Nautical Solution along with new NCSII workflows.

Organizational Structure

MCD is also using this effort to examine its organizational structure. It is essential that MCD aligns its organizational structure to leverage the capabilities of NCSII, rather than mold NCSII against the current production processes.

Conclusion

The goal of this project is to increase the efficiency of the production system by producing multiple products from a single vector database. The NIS is a central, product independent database that will allow MCD to receive data from multiple sources, to create and maintain a neutral format database which can be shared across multiple organizations, and from which multiple products and editions can be created and maintained.

Once the system is implemented, the following areas should see gains in efficiency: source loading, evaluation, and application. The system can accommodate a variety of formats, thus reducing datapreprocessing time. Compilation will be a one-time occurrence for all products, reducing time and increasing consistency across products. The use of a single user interface and production tool set will enable the workforce to be cross trained on multiple products, versus product specialization.

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Author Biographies

Julia Powell
Ms. Powell graduated from Cornell University with a degree in geology and holds a Masters in Computer Systems Management. She has worked at NOAA for 11+ years and is currently the NCSII Integration Manager and ensures that the government requirements are met during the integration phase of the project.

Jorge Arias
Mr. Arias is the NCSII System Integration Lead. He has over 17 years IT experience implementing Information Systems. As the MBI Technical Lead, he has worked closely with stakeholders' Technical and Management personnel to manage: system requirements, test cases, project deliverables, system architecture, process workflows, and system interfaces.

Paul Michael Lewis
Mr. Lewis has 25 years of experience in analysis, design, development, configuration management, integration, installation, operations and maintenance. As the MBI project manager, Mr. Lewis is leading a team of 11 IT professionals on NOAA programs to execute the integration of the next generation Nautical Charting System.

Travis Newman
Mr. Newman graduated in 1992 from the University of Wisconsin-Madison with a degree in cartography. He has worked at NOAA for 14 years and is currently the ENC production manager. Mr. Newman is also serving as the Transition Manager for the Nautical Chart System II.

Rafael Ponce
Mr. Ponce graduated from the Mexican Naval Academy as Naval Sciences Engineer and holds a Masters in Hydrographic Science (Category A Hydrographer) from USM. Mr. Ponce worked in the Mexican Navy HO for 10+ years and is currently working at ESRI as Deputy Program Manager in the Global Navigation Team.

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Ms. VanEsch graduated from Northern Illinois University, Bachelors of Science in Geography. She has worked at ESRI for 13+ years in Professional Services on various data production and software development projects. She is currently a Project Manager on the Global Navigation team.