

# Validation of the NOAA Electronic Navigational Chart

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## Abstract

The future of the National Oceanic and Atmospheric Administration's (NOAA) nautical charting program is vested in the production of NOAA's Electronic Navigation Charts (ENC<sup>®</sup>). These charts are compiled to support coastal management and marine navigation by supplying the marine community with highly accurate data portrayal. Most of the original collection of the NOAA ENC was accomplished using a rasterized chart base. Although this strategy proved an early ramp up to production, it introduced the inherent positional error of the legacy charts into the ENC. NOAA's customers are using positioning technologies that have eclipsed the traditional cartographic methods. They are expecting pinpoint accuracy from NOAA's ENCs.

A project has been identified for ENC validation. The project crosscuts NOAA's Office of Coast Survey (OCS) and the National Geodetic Survey (NGS). The goal of the project is to focus on the vital port infrastructure of the 40 major U.S. port areas. NGS' Remote Sensing Division (RSD) purchases high-resolution commercial satellite imagery with a spatial resolution of 1 meter or better and performs an analysis of changes and discrepancies between the ENC and imagery using GIS overlay techniques.

Analysis results are logged in the Chart Evaluation File (CEF). Upon completion of the analysis, the imagery may also be used to capture new or changed features impacting marine navigation in a new compiled vector shoreline data. This new vector shoreline is forwarded to OCS' Marine Chart Division (MCD) to be used to update the ENC. Data conflicts and hard-to-determine edits need to be resolved and reconciled in the field. The newly compiled shoreline, along with the CEF and source imagery, is sent to OCS' Navigation Services Division (NSD) for field verification.

NSD's regional Navigation Manager or Navigation Response Teams (NRT) resolve the issues or questions posed by RSD in the CEF and recommend edits to the vector shoreline data. While in the port area they also give the ENC a quick check to ensure that no critical feature has been overlooked in this process. Shoreline updates are returned to RSD to be incorporated in with the original vector shoreline. These changes are forwarded to MCD to enhance the ENC accuracy of these critical commercial areas.

## **NOAA ENC<sup>®</sup> Validation and Change Analysis**

The NOAA ENC validation and update process will cut across two separate Program Offices of the National Ocean Service (NOS), the Office of Coast Survey (OCS) and the National Geodetic Survey (NGS). The process will begin within the Remote Sensing Division (RSD) of NGS. RSD is responsible for surveying and mapping the coastline of the U.S. and its territories, and is the principal source of shoreline data for NOAA's nautical chart suite and the NOAA ENCs. RSD conducts its mission using both airborne and spaceborne imagery platforms. The Coastal Shoreline Change Analysis Program (CSCAP) is a relatively recent initiative to enable RSD personnel to analyze shoreline changes by comparing recent high resolution commercial satellite imagery with existing NOAA raster nautical charts and ENCs. By digitally overlaying the satellite imagery with the chart data, positional inaccuracies and changes in the shoreline and alongshore features (piers, jetties, etc.) can be easily detected, and the corrections and updates can be quickly compiled and submitted for rapid update of NOAA charts and ENCs.

Project planning personnel within the Requirements Branch (RB) of RSD will reacquire new satellite imagery covering major U.S. port areas every two, three, and four years according to ENC production priorities. The imagery purchased for use in CSCAP analysis has a very high spatial resolution (1 meter or better), is non-orthorectified, and comes from the vendor with a relatively low positional accuracy, estimated from 15 meters to 23 meters circular error at the 90% confidence level (Space Imaging, Inc., 2004; Digital Globe, Inc., 2005).

Using commercial off-the-shelf (COTS) Geographic Information System (GIS) software, the satellite imagery is georeferenced to the ENC and change analysis is performed. Discrepancies between the imagery and ENC are recorded in a Chart Evaluation File (CEF) utilizing the openly published (nonproprietary) ESRI<sup>®</sup> shapefile format. The shapefile is a de facto standard GIS data exchange format, enhancing the potential for interoperability between the different organizations which rely on the CEF. The GIS approach also enables users to digitally overlay the CEF onto a wide range of reference data of their own choosing, including raster charts, ENCs, and satellite imagery, both in the office and in the field.

Once CSCAP analysis has been completed, recommendations for resolving differences between the imagery and ENC are issued, if necessary. Recommendations may include compiling minor changes or corrections from the satellite imagery, recompiling the entire port infrastructure from the satellite imagery, or initiating a full scale photogrammetric survey of the port.

If recommendations include compiling features from the satellite imagery, the entire project is then forwarded to the Applications Branch (AB) of RSD and the number and distribution of Ground Control Points (GCPs) needed to yield high accuracy feature data is determined. RSD will then partner with field personnel and a Global Positioning System (GPS) survey will be conducted in order to obtain the precise coordinates of each

GCP. AB then uses the surveyed GCPs to re-georeference the satellite imagery to a much higher absolute accuracy. Typical accuracies range from 3 to 5 meters circular error at the 95% confidence level (Vidal, S., Graham, D., and Sault, M., 2001).

The instances of changes and inaccuracies logged in the CEF are then compiled directly from the satellite image. Due to inability to coordinate spaceborne imagery platforms with the tides, compilation from satellite imagery will be generally limited to man-made port infrastructure. The GIS workflow also allows AB cartographers the flexibility to add further items to the CEF for field verification as they work with the ENC and imagery. Once the compilation has been completed, a compact disc (CD) will be delivered to OCS containing the satellite imagery, CEF, ENC used in analysis, newly compiled shoreline data, and other pertinent documentation.

## **ENC Production Analysis**

Within OCS, the CD is registered as source information in the Marine Chart Division (MCD) using the Digital Registry (DREG). Once the ENC production manager assigns work to be compiled, the ENC production cartographer accesses the data from DREG. The CEF is loaded into the ENC production platform (LAMPS) by converting the RSD shapefile using the TRANSLATE utility. Once loaded, the ENC cartographer is able to edit attributes of the affected feature or create a new feature object.

CEF MARKUP, a LAMPS enhancement, was developed by the vendor to allow this in-line production modification of the CEF. Using CEF MARKUP, the ENC cartographer can address questions from the original RSD compilation, pose additional questions regarding the feature, or identify new features (not previously identified in the CEF) requiring field verification. The ENC cartographer populates the ENC\_NOTE field with comments to the field units to investigate those items whose charting action remains unclear. After comments to RSD's original CEF work are noted by the ENC cartographer, the revised CEF is stored in MCD holdings and awaits NRT deployment.

## **Field Verification**

A Navigation Response Team (NRT) from the Navigation Services Division (NSD) of OCS is provided with a CD containing the CEF and supplementary data issued by RSD, including source imagery. This data is to be used in the field to validate the shoreline compiled by RSD and provide feedback on hard-to-determine chart edits and data conflicts identified by RSD and MCD cartographers. The CEF and compiled shoreline are both provided in ESRI shapefile format with attribution.

Prior to embarking for the port being charted, the NRT converts the shapefiles into MapInfo® TAB format for evaluation and editing. The compiled digital shoreline is also converted to an AutoCAD® DXF format for display in HYPACK® hydrographic survey software. In addition, the CEF is used to create a HYPACK target file to precisely display the locations of specific questions presented to the NRT for validation or clarification.

The digital shoreline data is preferably viewed by the NRT from a water view while transiting along the shoreline in a survey launch. Using HYPACK software, the digital shoreline and CEF target file can be overlaid on a raster chart, ENC, or GeoTIFF image along with a display of the current position of the vessel. The shoreline compilation supplied by RSD is characteristically very accurate and requires few corrections or adjustments, whether originating from photogrammetry or satellite imagery.

While validating the digital shoreline, several different scenarios may arise. Although each scenario involves separate but distinct tasks, these would take place concurrently during field verification.

In the first scenario, shoreline or alongshore items in question or chart discrepancies identified by the RSD and MCD cartographers are addressed. This is the most common scenario and reflects the primary purpose for field verification. Usually these items are positioned accurately but are difficult to identify in the source imagery. Commonly the feature attribution may require clarification or correction.

In another possible scenario, misattributed point or line features may be discovered through field verification. In this scenario, corrective action would be initiated by the NRT hydrographer. In these cases, comments regarding field findings and recommendations for correction of the attribution are entered into the CEF. Generally the item in question is photographed to supplement the CEF for clarification purposes.

In the last scenario, field personnel may find critical features which either have inaccurate positions within the vector shoreline file or were overlooked entirely during compilation. To support a revision of the compiled digital shoreline, these features are positioned in the field using a Trimble Differential Global Positioning System (DGPS) backpack. New positions are acquired as a time series of differentially corrected GPS coordinates with standard sub-meter accuracy. Again the item is photographed and a notation is made to the charting recommendation of the item.

After the field verification is completed, the field notes and geographic positions are transferred from the acquisition device to MapInfo formatted files on a desktop computer. In the GIS environment, the CEF, shoreline, and newly acquired positions are displayed and the CEF is edited. The CEF attribute table has two columns specifically for NRT or field unit comments and charting recommendations. Field notes are entered in these columns, including references to supporting photographs. Any necessary edits are made to the vector shoreline data.

Three GIS layers are then returned to RSD in order to update their compilation of the vector shoreline. Besides the CEF, one layer contains the adjusted point features and another contains the adjusted line features.

## Application of Field Verification Data to ENC's

RSD will receive the field-edited CEF directly from NRT personnel. If field verification results in recommendations to refine or correct the previously compiled shoreline feature data, all necessary edits will be made to the master NGS shoreline database. Once editing has been completed, OCS will be notified through a web distribution mechanism known as the Shoreline Update Notice (SUN) that the data updates may be accessed. The NGS shoreline database would then be expected to reflect the current state of port infrastructure along with consistent relative positioning of features throughout the project area. The updated digital data would be available for application to the ENC and other OCS chart products.

The new GIS-based workflow (see Figure 1) is expected to benefit NOAA ENC users in at least two key ways. First, the ENC update process occurs far more rapidly than traditional nautical chart production workflows. Second, the shoreline data applied to the ENC's is field verified, giving users the greatest confidence in the correctness, accuracy, and currency of the data.

## Life Cycle of the Chart Evaluation File

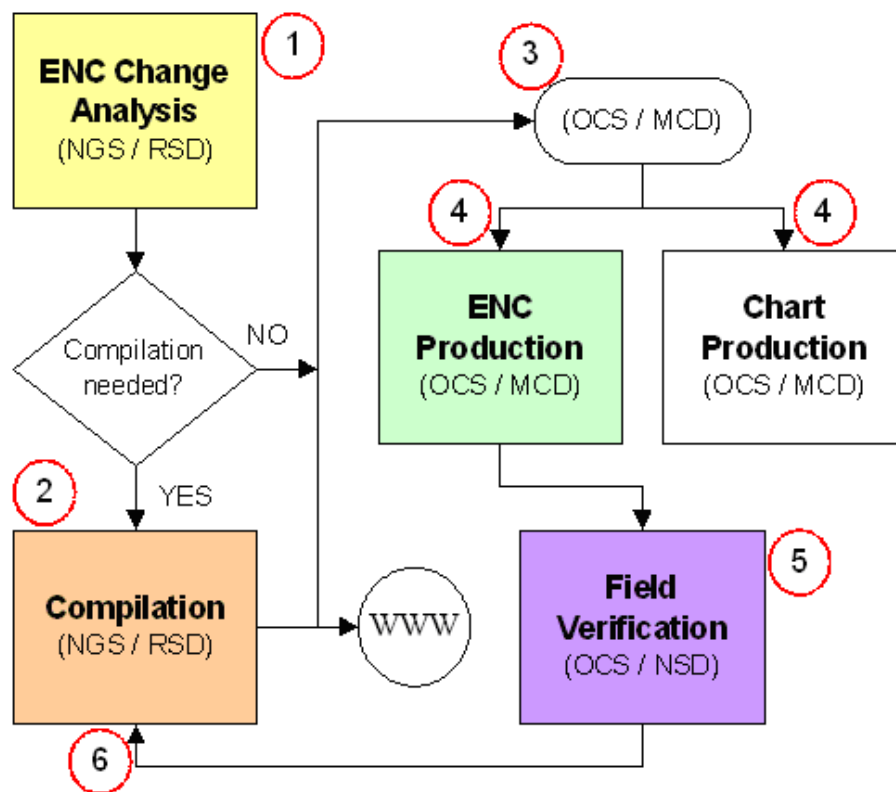


Figure 1 – Flowchart of the cooperative ENC Validation workflow.

## **Implementation Concerns**

Although the process described relies on proven GIS concepts and methodologies, as with any new production workflow there are concerns about possible obstacles to successful implementation. Below are listed some of the main concerns of the production groups involved in the ENC validation process.

1. Although most GIS and mapping software packages recognize the ESRI shapefile format, entrenched users of other software products (MapInfo, LAMPS, etc.) could misuse the shapefiles. The integrity of the CEF and other GIS layers must be maintained or the field verification process will yield little or no useful data to NGS. If this occurs, ambiguities in the NGS shoreline database will be inherited by the NOAA ENC. Possible solutions include offering training, encouraging communication between CEF creators in NGS and users in OCS, and increased adoption of COTS software recognizing widely used GIS data formats.
2. With the lengthy data flow across multiple distinct production offices, there is a concern that GIS data issued by NGS might not be successfully deployed in the field. An emphasis on regular coordination between key personnel within NGS and OCS would greatly reduce the chances of this occurring.
3. A third concern would be the need to rely on staff who may be unfamiliar with GIS procedures and data formats. Solutions would include GIS training and close communication between headquarters staff and those working at remote locations.

## **Conclusion**

Continued testing is planned as the different organizational components of the ENC validation initiative continue to be integrated toward their common purpose. As of the writing of this paper, a demonstration of the new workflow is planned for the port of Savannah, Georgia.

While many of the individual pieces of the new ENC validation and update workflow, including isolated production processes and limited program coordination, have proven their effectiveness, thus far an end-to-end project has yet to be carried out. Though coordination between the participating organizations continues to be refined, the reliance of the initiative on standard GIS methods and data formats is expected to yield an effective and cohesive workflow toward the goal of achieving the highest quality within NOAA's next generation of navigational data, the ENC.

## References

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