Using Commercial Satellite Imagery and GIS to Update NOAA ENCs

Michael Espey, Remote Sensing Division, NGS, NOS, NOAA

Abstract

Traditionally, coastal mapping at NOAA's National Geodetic Survey (NGS) and its predecessor agencies has been a meticulous labor intensive process whose end results were among the highest accuracy national coastal shoreline data available in the world. For many years limited programmatic resources have impeded providing new shoreline delineations in a timely manner. Now with the introduction of GIS for data generation and quality control plus the availability of high resolution commercial satellite imagery, rapid updates to shoreline data are finally possible for NOAA's traditional hardcopy nautical charts as well as the new NOAA Electronic Navigational Chart (NOAA ENC®) suite. This paper outlines a new workflow for validation and update of ENC shoreline and coastal features which crosscuts NOAA's Office of Coast Survey (OCS) and NGS.

Introduction

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 (NOAA ENC®). These charts are compiled to support coastal management and marine navigation by supplying the marine community with highly accurate data portrayal. The establishment of most of the original suite of NOAA ENCs was accomplished using a rasterized chart base. Although this strategy served as an effective early ramp-up to production, it introduced the inherent positional error of the legacy charts into the ENC.

Many of NOAA's customers are now using positioning technologies that have eclipsed the traditional cartographic methods, and these users expect pinpoint accuracy from NOAA's chart data. In response, the ENC validation initiative is under way to implement a workflow (Figure 1) which incorporates high resolution commercial satellite imagery and GIS methodologies into the chart production process in order to rapidly assess and update the entire suite of NOAA ENCs. This initiative is expected to bring the ENCs up to the high level of accuracy NOAA's customers require in a relatively brief time span.

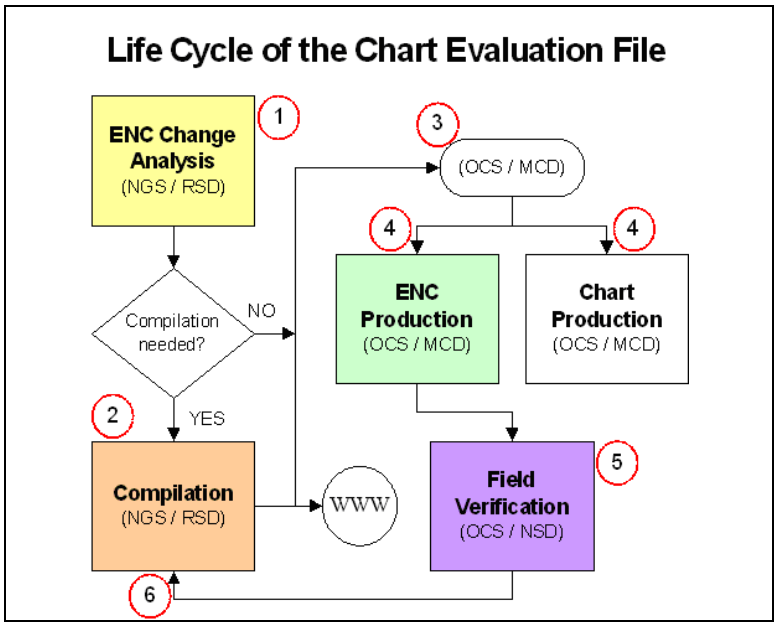

Figure 1 – Flowchart of the cooperative ENC Validation workflow. Various organizations (shaded) share responsibility for adding data to the Chart Evaluation File.

NOAA ENC® Validation and Change Analysis

The NOAA ENC validation and update process cuts across two separate Program Offices of NOAA's National Ocean Service (NOS), the Office of Coast Survey (OCS) and the National Geodetic Survey (NGS). The process begins 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 Coast and 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. Typically the lowest-cost basic products available from imagery vendors are purchased for use in CSCAP analysis. The imagery characteristically has a very high spatial resolution ($\leq$ 1 meter), is non-orthorectified, and comes from the vendor with a relatively low positional accuracy (Figure 2), estimated from 15 meters to 23 meters circular error at the 90% confidence level (Space Imaging, Inc., 2004; Digital Globe, Inc., 2005).

Using the georeferencing tools in ESRI®'s ArcGIS® software, the satellite imagery is spatially adjusted to line up visually with the ENC and change analysis is performed (Figure 3). Discrepancies between the imagery and ENC are recorded in a Chart Evaluation File (CEF) utilizing the openly published (nonproprietary) shapefile format developed by ESRI®. 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.

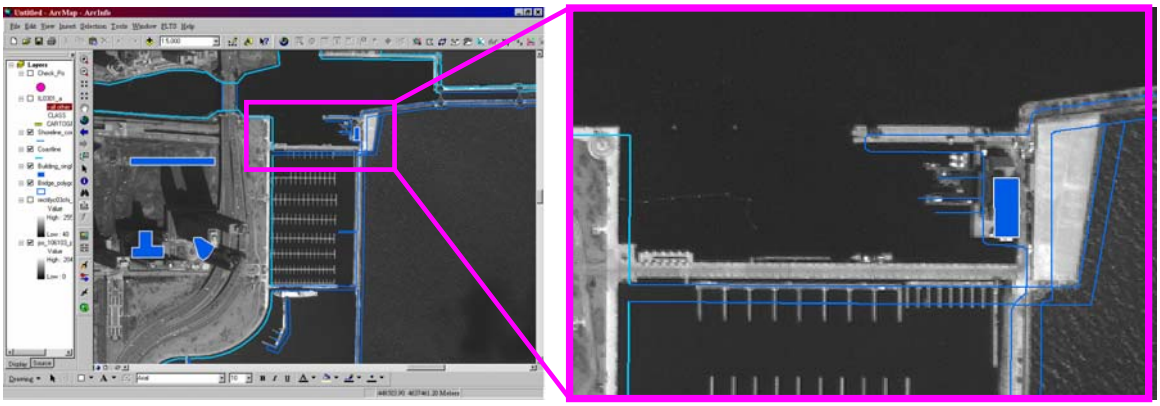

Figure 2 - Raw satellite imagery comes with a relatively low positional accuracy.

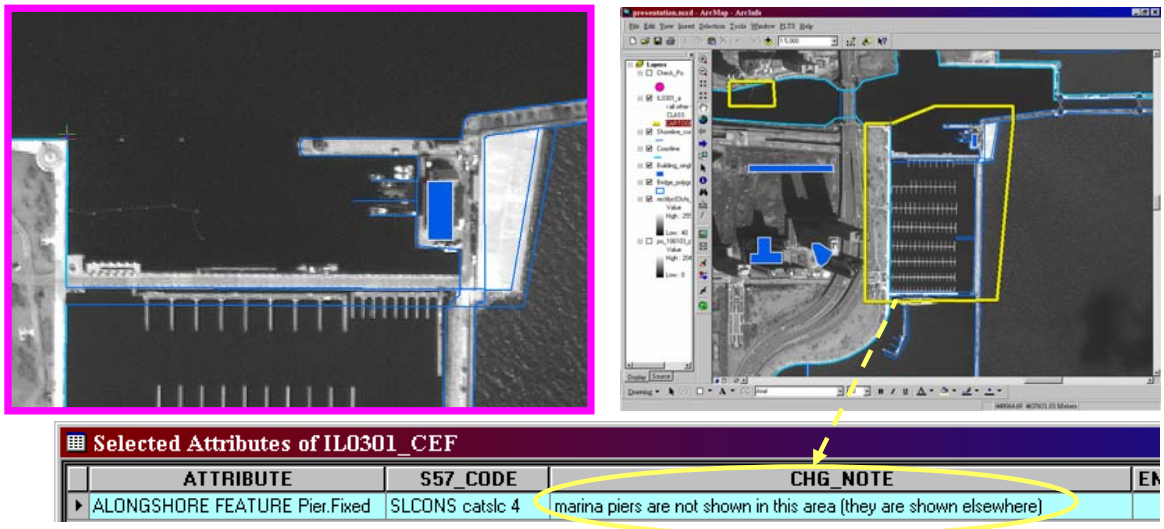

Figure 3 - Imagery is georeferenced to line up with the ENC, and discrepancies are logged in the Chart Evaluation File.

Once CSCAP analysis has been completed, recommendations for resolving differences between the imagery and ENC are issued, if necessary. Recommendations may include compilation of isolated minor changes or corrections from the satellite imagery, extensive recompilation of vast portions of the commercial port area from the satellite imagery, or initiation of a full scale photogrammetric survey of the entire port.

Vector Compilation of Changes

If recommendations include compilation of features from the satellite imagery, the whole project is then forwarded to the Applications Branch (AB) of RSD, where preparations are made to refine the geopositioning of the imagery to support feature collection which meets the rigorous chart accuracy requirements. Existing shoreline data which has been digitally compiled by RSD is the most convenient source of control suitable for attaining the necessary accuracy in the georeferenced imagery. If this source is unavailable however, then steps must be taken to obtain accurately measured Ground Control Points (GCPs) from a field survey.

After the number and distribution of GCPs needed to yield high accuracy feature data is determined (Figure 4), RSD then partners with field personnel and a Global Positioning System (GPS) survey is 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 using the GCP Tool in Erdas IMAGINE™ software. Currently IMAGINE is the preferred software for this task due to the capability of showing separate error statistics for X and Y. Typical accuracies resulting from this process range from 3 to 5 meters circular error at the 95% confidence level (Vidal, S., Graham, D., and Sault, M., 2001).

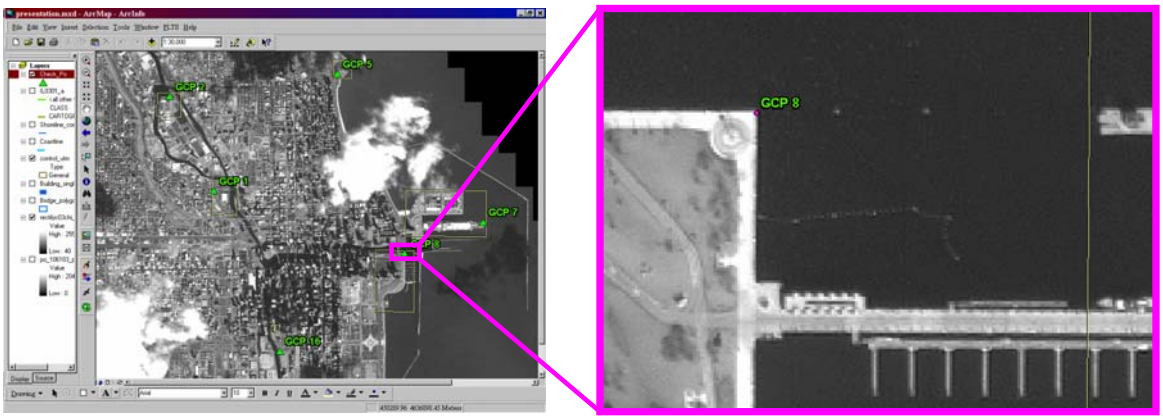

Figure 4 - Locations where GCPs would be most helpful are identified in the office prior to the field survey.

The instances of changes and inaccuracies logged in the CEF are then compiled directly from the satellite image (Figure 5). Feature data is collected in shapefile format using ArcGIS. Due to inability to coordinate spaceborne imagery platforms with the tides, compilation from satellite imagery is 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.

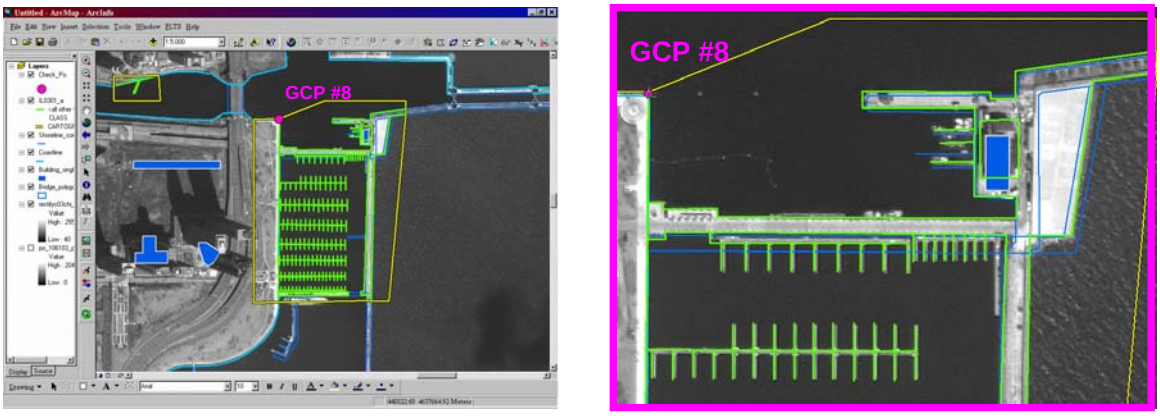

Figure 5 - Updates to the ENC are screen-digitized from the satellite imagery using ArcGIS.

Nautical Chart and ENC Production

Within OCS, the CD is registered as source information in the Marine Chart Division (MCD), which includes separate production segments for traditional hardcopy nautical charts, or raster production, and ENCs, or vector production. The nautical chart production cartographers apply the newly compiled feature data to update the existing chart base, using the CEF as a means of addressing features on the chart whose geographic position requires revision or whose existence has either been questioned or disproved by RSD using the satellite imagery.

The ENC production cartographers likewise access the GIS data from RSD, loading the newly compiled feature data and the CEF into the ENC digital production platform (LAMPS) using a data translation utility to convert the shapefiles to the necessary proprietary vector format. The ENC is then updated with RSD's feature data. Laser-Scan, the developer of LAMPS, has also developed a tool which allows for in-line editing of the CEF within LAMPS. Using this tool, ENC cartographers can either further address questions in the CEF posed by RSD or pose new comments or questions concerning features in the ENC requiring field verification which were not previously identified in the CEF. After comments to RSD's original CEF are noted by the ENC cartographer, the revised CEF is stored by MCD until deployment for field verification can take place.

ENC Field Verification

The field verification of new and existing feature data is an important step in ensuring the correctness of NOAA ENCs. Precisely identifying and attributing shoreline features and potential hazards to navigation within satellite imagery can be challenging, even for those with much image interpretation experience. Therefore the capability of deploying survey personnel equipped with mobile GIS technology to ports to verify ENC feature data greatly increases the level of confidence users can have in NOAA's final products.

Once a Navigation Response Team (NRT) from the Navigation Services Division (NSD) of OCS is assigned to visit the port being charted, NSD receives the GIS data from MCD, including RSD's shoreline feature data, the revised CEF, and satellite imagery. Vector GIS data is carried aboard the survey launch (Figure 6) on a laptop computer outfitted with MapInfo® software for data editing, and both vector data and imagery are loaded onto the onboard navigation computer for orientation and mission planning purposes.

Figure 6 – NOAA's Navigation Response Teams in action.

Field work can be broadly divided into two categories, investigation of specific issues delineated in the CEF and comprehensive verification of ENC shoreline. First, the NRT addresses specific shoreline or alongshore items in question or chart discrepancies identified by the RSD and MCD cartographers in the CEF. This is the primary purpose for field verification. Commonly the feature attribution may require clarification or correction, or charted features may no longer appear in the imagery. In the latter case, sonar data would be required to insure the absence of underwater hazards.

During the course of their field work NRT hydrographers continuously evaluate the RSD-compiled GIS data and NOAA ENC as they navigate the port, looking for misattributed or missing features. If problems are found, either new polygon features are delineated in the CEF or the alignment of missing or otherwise erroneous features are captured in a separate MapInfo TAB file for submission to RSD. Geographic coordinates may be collected using either a Trimble Differential Global Positioning System (DGPS) backpack (Figure 6)or the boat's guidance system in order to support data capture in the ENC. All GIS data captured or edited in the field are then returned to RSD in order to update their compilation of the vector shoreline.

Application of Field Verification Data to ENCs

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 ENCs is field verified, giving users the greatest confidence in the correctness, accuracy, and currency of the data.

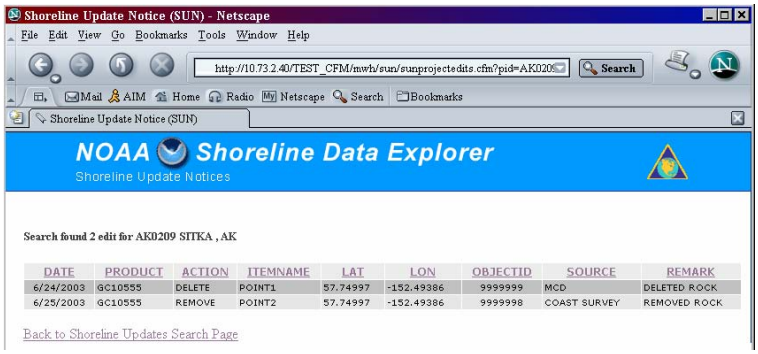

Figure 7 - The Shoreline Update Notice allows ENC production to receive only updates to the existing ENC feature data.

Conclusion

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. Continued testing is planned as the different organizational components of the ENC validation initiative continue to be integrated toward their common purpose.

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

Digital Globe, Inc., 2005. Basic imagery specifications.
URL: http://www.digitalglobe.com/product/basic_imagery.shtml (last date accessed: February 7, 2005).

Space Imaging, Inc., 2004. Imagery products, categorized by positional accuracy.
URL: http://www.spaceimaging.com/products/imagery.htm (last date accessed: February 7, 2005).

Vidal, S., Graham, D., and Sault, M., 2001. CSCAP: Coast and Shoreline Change Analysis Program; Using High-Resolution Satellite Imagery for Shoreline Change Evaluation Within Ports. *Proceedings of the U.S. Hydrographic Conference, Norfolk, Virginia, May 22-24, 2001*. URL: http://www.thsoa.org/hy01/5_2.pdf (last date accessed: February 7, 2005).

Author Information

Michael Espey
Lead cartographer, National Coastal Mapping Program
Remote Sensing Division, NGS / NOS / NOAA
1315 East-West Highway
Attn: N/NGS33
Silver Spring, MD 20910
Ph: 301-713-2685 x153
Fax: 301-713-1548
Email: mike.espey@noaa.gov