Lessons Learned in Multi-Platform Hydrographic Surveys

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***Abstract*-The United States Navy stands at the brink of transition from traditional navigation with paper charts to computer-based electronic charting. The Naval Oceanographic Office (NAVOCEANO), collector of worldwide hydrographic data for 172 years, is posturing to support this transition with state-of-the-art survey platforms, instrumentation, and processing and chart production software. Recently, NAVOCEANO, in cooperation with the National Ocean Service of the National Oceanic and Atmospheric Administration (NOS/NOAA), completed hydrographic surveys in the U.S. Pacific territories of Guam and Saipan in support of urgent Navy operational requirements. Data collection was conducted by the new multipurpose survey ship USNS SUMNER, a new independent rapidly deployable survey team called the Fleet Survey Team (FST), and the Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS). Each survey system brought unique capabilities to the toolbox of surveying assets. Each survey system also brought unique perils to the data validator and chart compiler with system errors that first had to be recognized, then the causes determined, and then solutions found. It was indeed fortunate that these three different collection systems were able to work the same survey area, allowing comparison of three different data sets and the discovery of potential systemic errors. Following a very thorough investigation, data from all three systems were corrected and then used for the production of both a paper nautical chart and the Digital Nautical Chart (DNC) library. This new nautical chart information was provided to NOAA and the National Imagery and Mapping Agency (NIMA) for general distribution to both the public and the Fleet.**

I. INTRODUCTION

The Naval Oceanographic Office (NAVOCEANO), located at Stennis Space Center, Mississippi, has 172 years of hydrographic and oceanographic experience with a focused investment in state-of-the-art multi-purpose ships, services, and products. NAVOCEANO operates eight multipurpose survey ships, of which six are of the new T-AGS 60 class, arguably the world's finest oceanographic ships afloat. Furthermore, NAVOCEANO has maintained high standards in the hydrographic community by implementing the latest oceanographic sensor developments, GIS utilization, data visualization, and high-speed data processing facilities, and by building technical expertise with International Hydrographic Organization (IHO) certified Category A and Category B programs in hydrographic science. The Category A course is a one-year master's degree program jointly conducted with the University of Southern Mississippi. In addition, NAVOCEANO has maintained a commitment to the international hydrographic community through its International Surveys Program, which assists foreign nations in conducting hydrographic surveys and producing nautical charts. NAVOCEANO also participates in IHO working groups and other international activities to further advance hydrographic standards.

As navigation technology has changed from paper nautical charts to digital electronic charts, NAVOCEANO has implemented changes to support Naval operations in the digital age and has established the following capabilities as part of its mandate to support the Fleet:

- Highly mobile data collection assets capable of supporting immediate Fleet needs. These include the Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) system and the Fleet Survey Team (FST).
- Significant speedup in the processing, editing, and validation of multibeam sonar, lidar and side-scan sonar imagery data using the Bathy-Hydro Post-Processing (BHPP) suite of data processing and visualization software capable of achieving a 4:1 collection time to processing time ratio.
- Creation of a new Quality Assurance (QA)/Quality Control (QC) Branch to examine the QA/QC process and its role in the evolving production cycle.
- Construction of a Survey Operations Center capable of downloading survey data direct from survey ships anywhere in the world using low-bandwidth Inmarsat B to view NAVOCEANO survey vessels on a virtual world map, visualize how the survey is progressing, and track the status of data collection sensors in real time.
- A Digital Nautical Chart (DNC®) co-production program with the National Imagery and Mapping Agency (NIMA) for rapid turnaround of digital navigation information from survey to chart delivery for

use by the Navy version of the Electronic Chart Display and Information System-Navy (ECDIS-N), other ECDIS, and Electronic Charting Systems (ECS).

- Implementing capabilities to rapidly produce and disseminate battlespace visualization of digital hydrographic and other tactically significant data layers to support ECDIS-N and shipboard Command and Control systems.

From January to March 2001, NAVOCEANO, in cooperation with the National Ocean Service of the National Oceanic and Atmospheric Administration (NOS/NOAA), U.S. Army Corps of Engineers (USACE), and the U.S. Geological Survey (USGS), completed a hydrographic survey campaign in the Western Pacific Ocean area to include Guam, Saipan, Tinian, and Farallon de Medinilla. Although each agency had its own reasons for participation in the cost leveraging primarily of the SHOALS system, NAVOCEANO survey operations were in support of urgent Navy operational requirements to meet Fleet navigational needs.

This paper will discuss the survey operations, data processing and validation, and product production for the Apra Harbor (Guam) and Saipan Harbor areas. These areas were surveyed by the airborne lidar SHOALS system, the rapidly deployable FST, and a new multipurpose ship, USNS SUMNER (T-AGS 61). Each survey system brought unique capabilities to the toolbox of surveying assets. Each survey system also brought unique challenges to the data validator and chart compiler with system errors that first had to be recognized, the causes determined, and then solutions found. It was indeed fortunate that these three different collection platforms were able to work the same survey area, allowing comparison of three different data sets and the discovery of potential systemic errors. This paper will also discuss the validation process which included a very thorough investigation of the error sources and the correction of data from all three systems, and the production of both a paper Field Chart and Digital Nautical Chart (DNC®) libraries.

II. REQUIREMENTS FOR SURVEY OPERATIONS

Between 8 January and 20 March 2001 NAVOCEANO coordinated the operation of three survey platforms: SHOALS, FST, and USNS SUMNER. During planning meetings prior to the Guam operation, SHOALS and the FST were specifically assigned tasks for which they were most capable. Partitioning of responsibilities prevented overlap, wasted time, and inefficiency. The Western Pacific Campaign was initiated because of numerous Navy shallow-water survey requirements around Guam and the Northern Mariana Islands. Multi-agency requirements dictated sharing the technical and financial resources of all participating agencies to ensure cost savings; therefore, Navy, USACE, USGS, and NOS requirements (Fig. 1) were consolidated into a single project:

- The NAVOCEANO initiative addressed numerous military charting, high-resolution data, and special product requirements. These included support of Special Warfare and Amphibious Warfare training, test and evaluation areas, exercise areas, anchorage and vessel basing in Guam and the Northern Mariana Islands, and general military charting requirements. Data collection requirements included, primarily, shallow-water bathymetry in the near shore, but also encompassed depths deeper than lidar capabilities.

- The USACE requirements focused on high-resolution coastal zone bathymetry to 35 meters and shoreline topography to meet coastal engineering requirements. USACE data are used for numerical modeling of storm surge, flood inundation, and evacuation route planning. USACE was also addressing coastal engineering and shoreline dynamics issues.

- USGS interest in the project was the collection of high-resolution data in support of coral reef mapping and environmental studies.

- NOAA/NOS survey interest was the collection of IHO Order 1 survey data and object/navigational hazard detection to be used in updating standard nautical charts. NOS provided complete tide gauge and tidal data support. The NOAA standard tide gauge, which had been recently serviced and checked, transmitted telemetry data available for downloading at 6-minute intervals.

III. PLATFORMS FOR SURVEY OPERATIONS

The survey areas of interest encompassed a depth range from the shoreline to approximately 1000 meters within environments ranging from mangroves and sheltered harbors and coastal waters to shallow offshore anchorages and deeps. No one sensor or platform was capable of acquiring data over the range of depths in these operational regimes and meet the IHO accuracy requirements. No vessel could safely survey

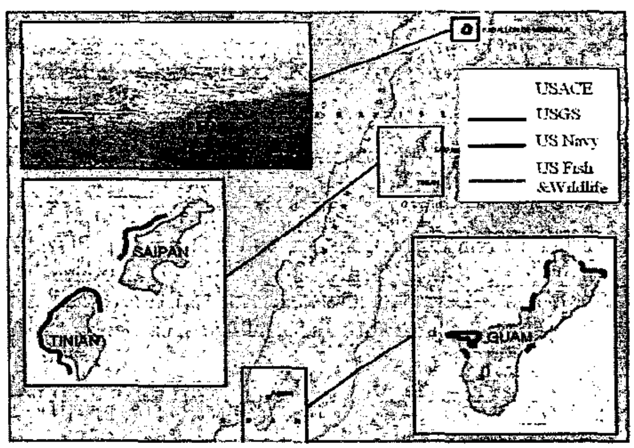

Fig. 1. Survey Areas and Requirements.

up to the shoreline, over the reefs, or into the surf zone. The requirements dictated a multi-sensor and multi-platform approach. The SHOALS system was tasked with the shoreline to 30-meter depth range, hazardous areas, and all areas unsuitable for surface vessels. This included all the USGS and USACE coastal areas, reef habitats, surf zones, and the shoal areas within Apra Harbor, Guam. The FST was tasked with all areas deeper than about 30 meters within Apra Harbor, where water conditions prevented lidar bottom detection and maneuvering constraints precluded SUMNER operations. The FST was also responsible for identifying bottom objects with their side-scan sonar. The USNS SUMNER with its significant multibeam sonar capability greatly expanded the scope and coverage of the project to the offshore areas of Guam and Saipan, unsuitable for the SHOALS and FST systems. SUMNER was also tasked with current meter deployments off Saipan.

A. SHOALS Survey Operations

The SHOALS system is operated by Fugro Chance Inc. for the NAVOCEANO-USACE Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX). Fugro Chance personnel were responsible for SHOALS system operation and maintenance and data collection and processing. Kenn Borek Air of Canada operated the Twin Otter aircraft and provided the aircraft, flight crew, and all aircraft maintenance. Additional information about SHOALS is available at the JALBTCX website (**www.SHOALS**.sam.usace.army.mil).

The project utilized substantial NAVOCEANO and USACE technical resources and worldwide operating experience. Two to three NAVOCEANO personnel were in the field at all times to provide on-scene technical support, survey expertise, field collection of environmental data, and liaison with local and regional officials and organizations for the duration of the project. They were responsible for performing complete data assessment and quality control, identifying problems and discrepancies in the data, ensuring compliance with survey specifications, and working closely with Fugro Chance operators to resolve all survey issues in the field.

The SHOALS survey was organized with respect to Navy/NOS and USACE/USGS requirements. The Navy/NOS areas required IHO Order 1 accuracy because of charting requirements, product requirements, and intended data usage, and as such, required high-accuracy soundings and very reliable object/hazard detection. USACE and USGS requirements were less stringent with no charting requirements. Coastal wave and storm surge modeling do not require the charting accuracy, data density, and fine structure detail dictated by Navy requirements. Coral reef mapping and environmental assessment requirements, however, required high data density, but not the charting accuracy.

The SHOALS effort was organized around these differing requirements to achieve the greatest survey efficiency. USACE areas were flown for single coverage with the system programmed for 8x8-meter spot density and a 220-meter swath. USGS areas were flown for single coverage with the system programmed for 4x4-meter spot density and a 110-meter swath. Navy areas were also flown with the system programmed for 4x4-meter spot density and a 110-meter swath. Where agency requirements overlapped, the area was flown to the higher standard.

To meet the target detection probabilities dictated by the IHO for Order 1 charting, the Navy areas were flown with ≥200% lidar coverage. A second set of lines was flown after a time delay of at least several hours to provide confirmation that laser returns on transient objects, such as fish or turbidity plumes, were easily resolved. The second flight coverage would theoretically, though randomly, interlace laser scan lines between first coverage scan lines and achieve thorough bottom illumination at all survey depths. This was particularly important in water shallower than 7 meters, where insufficient beam spreading had not fully illuminated the area between laser spots at 4x4-meter spot density.

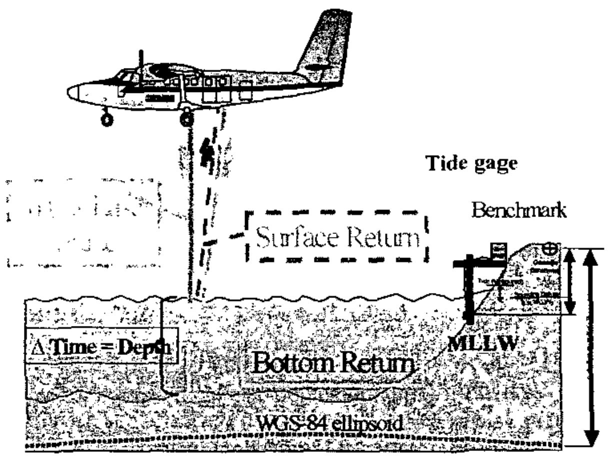

Fig. 2. Chart Depth determined by time between water surface and bottom return, minus the tide correction.

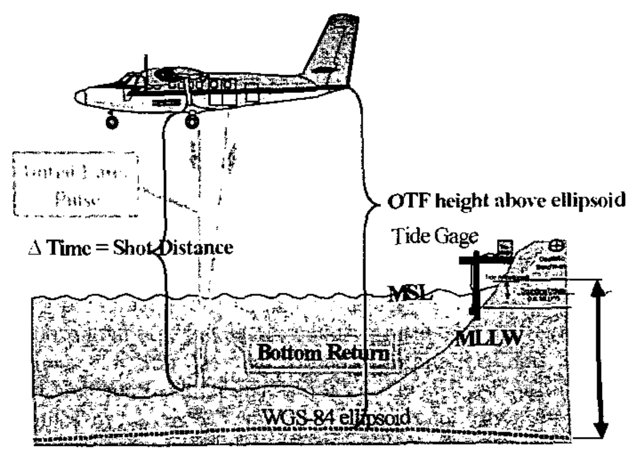

Fig. 3. Chart Depth = Laser Shot Distance - OTF aircraft height above ellipsoid + Offset ellipsoid to MSL – Offset MSL to MLLW.

Second flight coverage data were also used to validate first flight coverage data and to verify the tide correctors applied. Possible targets apparent in first flight coverage data were confirmed, or disproved, by their presence or absence in the second set of flight data. This technique proved quite useful in identifying data "fliers" due to fish, re-suspended sediments, white caps, foam, and aeration in surf zones, and for confirming/disproving doubtful data.

Prior to the arrival of the FST in mid-January, SHOALS was to map Apra Harbor, Guam and deliver a coverage plot to the FST. These coverage data were to be used by FST to plan their portion of the operation and to cover the areas that were too deep for lidar and/or where water clarity posed problems for laser penetration.

Technical problems with the DGPS UHF beacon systems delayed the start of SHOALS production flights by two weeks. In order to provide the FST preliminary coverage maps, the SHOALS survey commenced, utilizing VHF broadcast beacons; however, SHOALS could only use these beacons in the Kinematic-OTF mode of operations. This mode measured the bottom return with respect to aircraft height above the ellipsoid. (See Figs. 2 and 3 for diagrams on the two modes of operations.) Near the end of the survey, replacement DGPS-UHF beacons were delivered. In order to verify that the SHOALS system was operating correctly in the Kinematic-OTF mode, several test lines, using DGPS mode of operation, were run in Apra Harbor. Lidar data from test lines were then compared to the lidar data collected using the Kinematic-OTF mode.

The comparison revealed data offsets of approximately 0.4 meter. This 0.4-meter offset also by coincidence approximated the Mean Sea Level (MSL) to Mean Lower Low Water (MLLW) offset of 0.42 meter (see Fig. 3). In the Kinematic-OTF mode of operations, the SHOALS surveyed relative to the ellipsoid, which required the application of the ellipsoid-to-MSL and MSL-to-MLLW offsets to reduce soundings to MLLW datum. Thus, initially, the problem appeared related to the Kinematic-OTF mode of data reduction. However, the real cause was due to a misunderstanding of how the SHOALS software handled datasets which spanned more than one Julian Day. This misunderstanding resulted in incorrect tidal corrections being applied. These errors were all eventually discovered and corrected, and the tidal data reapplied at NAVOCEANO.

B. Fleet Survey Team Survey Operations

Due to the substantial depth of Apra Harbor, Guam, it was realized in the planning stages that lidar coverage alone in Apra Harbor would be insufficient to meet the survey requirements. The FST was tasked with the acoustic and side-scan sonar surveys of Apra Harbor, which were considered essential in fully mapping the harbor. The floor of Apra Harbor is littered with wrecks, wreckage, obstacles, and junk from World War II and earlier (Fig. 4). Some of the wrecks and obstructions discovered during the survey were previously unknown.

The FST utilized a modified LCM vessel of opportunity, operated by the Naval Station Guam Dive Locker Team. It was outfitted with a Trimble 4700 (G)GPS receiver operating in the DGPS mode, which received differential correctors from shore-based DGPS VHF beacons; Odom Hydrotrac Single Beam Echosounder; SeaBird CTD probe; Odom Digibar SV probe; EdgeTech 272T digital side-scan sonar combined with the Triton-Elics ISIS software suite; and the HYPACK MAX survey data collection suite. Some compromises in the installation resulted in the GPS antenna being offset from the echo sounder, resulting in a significant lever arm. The equipment was configured to support the generation of an IHO Category 1 standard survey with an intended output survey scale of 1:10 000.

The FST survey was split into four prioritized areas with line spacing set at 50 meters in all areas where the depth was 40 meters or greater; interlining was required in depths less than 40 meters to better delineate bottom features. Main lines were run with the Hydrotrac; in addition, alternate lines (100-meter spacing) were swept with the EdgeTech side-scan sonar operating on the 75-meter range scale in order to ensure 150% coverage across the area. All areas were totally ensonified due to the coral nature of the environment. Additional lines were run to complement the SHOALS coverage and to better delineate contours in the shallower areas of the survey as required.

The survey platform and its associated systems performed well, with no serious equipment malfunctions other than occasional short navigational timeouts. Since no gyro was available, azimuth was generated from historic (>3) DGPS position solutions. In order to reduce errors associated with using this method to calculate heading, platform motion, particularly yaw, was minimized by careful boat-handling and line keeping.

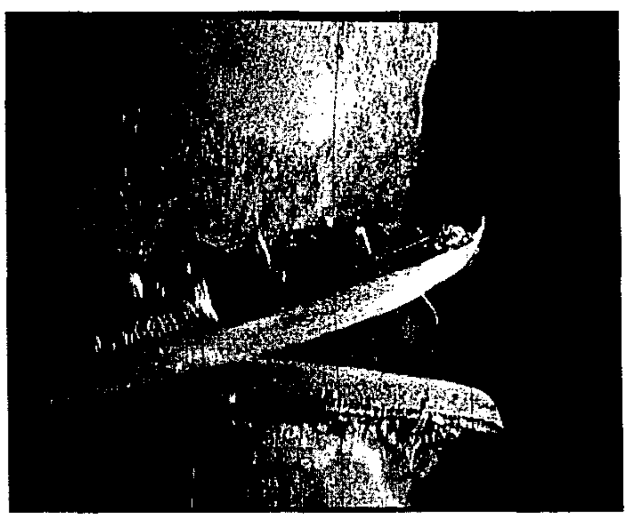

Fig. 4. One of many wrecks found by the FST side scan.

C. USNS SUMNER Survey Operations

The USNS SUMNER is one of six T-AGS 60 class ships used by NAVOCEANO. These ships are designed to provide multipurpose oceanographic survey capabilities in coastal and deep-ocean areas. This includes hydrographic surveying. SUMNER is 329 feet long with a displacement of 4700 L.T. and has diesel electric propulsion with twin props, retractable bow thruster, and Z-drive. A contract crew of about 25 personnel operates the ship, supplemented with a NAVOCEANO scientific party of about 10 personnel for conducting surveys. The SUMNER is equipped with the Science Applications International Corporation (SAIC) Integrated Survey System (ISS-60) for data collection, SIMRAD EM 121 and 1002 multibeam sonars, a sub-bottom profiler, high and low frequency single beam sonars, and a complete suite of oceanographic sensors.

The SUMNER was tasked with survey requirements in waters deeper than 35-40 meters, where their Simrad EM1002 multibeam sonar system would be most effective. SUMNER surveyed the approaches to Apra Harbor, Guam and the offshore anchorage and deep areas around Saipan, and collected about 95% of the data around Farallon de Medinilla. The multibeam systems provided highly detailed 100% bottom coverage. Three Acoustic Doppler Current Profilers were deployed for a 30-day observation period at selected locations within the Saipan anchorages. SUMNER also collected soundings, acoustic backscatter, bottom objects, water column properties (CTD, XBT, SST/SV), tidal currents, 3.5-kHz sub-bottom profiles, and bottom sediments data.

IV. DATA FUSION PROBLEMS AND CORRECTIONS

In the field, the data sets from the three different platforms were processed independently of each other. The SHOALS and SUMNER data sets were processed using the BHPP suite of software including the Area-Based Editor (ABE). The ABE is a software tool that enables visualization and statistical editing of bathymetry data and simultaneous display of imagery data. The ABE utilizes the Pure File Magic (PFM) data structure and I/O Library; thus, other data formats can be easily incorporated. The FST data set was processed using the CARIS HIPS and SIPS suite of software tools.

The only comparison between data sets that occurred in the field was between lidar data collected using the Kinematic-OTF mode and the test lidar data collected using the DGPS mode. Because the source of the errors between these two sets of lidar data could not be initially determined, the remaining on-scene personnel decided to conduct a leadline survey to determine a baseline data set that could not be questioned due to its technological simplicity. The leadline survey consisted of approximately 200 observations.

In the office, all three data sets were processed and validated using the BHPP suite of software tools. This allowed all three data sets and the 200 leadline observations to be statistically compared, individually and to each other, in areas of overlap. Figs. 5 and 6 indicate the data sets collected by each platform in Guam and Saipan, respectively.

The BHPP software allows the user the ability to statistically compare data sets collected with different resolution sensors (i.e., high-resolution EM1002 multibeam data collected by the USNS SUMNER, single-beam data collected by the FST team, and spot-beam data collected using SHOALS). This ability to view different resolution data sets together allowed for the detection of systematic errors that existed within each collection system.

A. Fleet Survey Team Data Set

When viewing and editing the FST data set using the BHPP, it was observed that features common between adjacent survey lines did not match, and soundings from cross-check lines did not consistently match the regular survey lines. Upon further examination of the FST data set, it was determined that contrary to indications, the post-processed HYPACK files were not imported by CARIS HIPS. The offset library (referral of all x,y,z lever-arm corrections to Reference Point) was not exported as indicated;

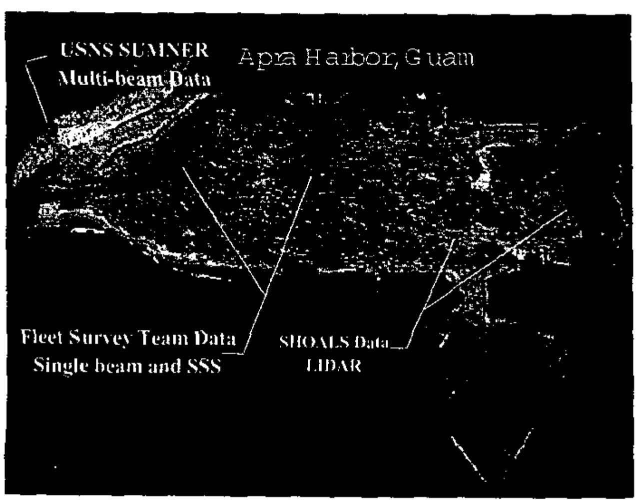

Fig. 5 SHOALS, FST, and SUMNER data fusion for Guam.

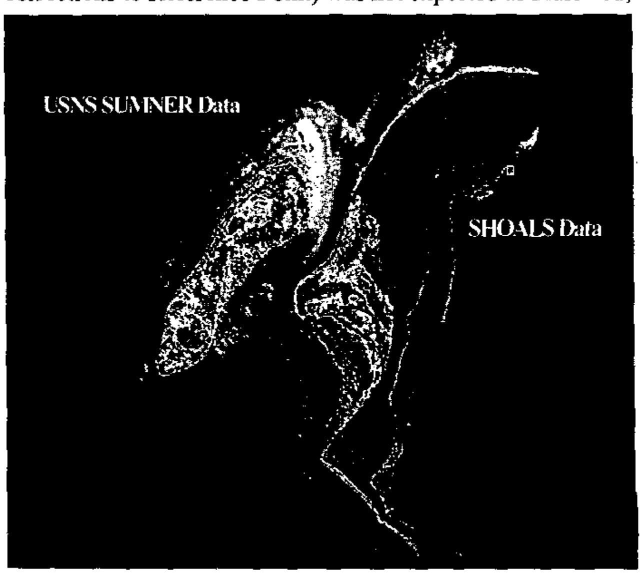

Fig. 6 SHOALS and SUMNER data fusion for Saipan

tides and draft settings also did not export. In short, only the "Raw" data was imported by CARIS HIPS, even though the HYPACK MAX system correctly exported processed data and indicated that it had done so. It was subsequently found that CARIS strips all corrections and accepts only raw navigation and depth solutions. In order to apply the lever-arm and tidal offsets, a software routine was written to directly import HYPACK MAX processed files into a PFM data structure used by the BHPP. Once the lever-arm and tidal offsets were accounted for, there was a good match between adjacent survey lines, as well as between the cross-check lines and the regular survey lines. This data set was then used as the reference area to compare against the other two data sets.

B. SHOALS Data Set

The BHPP was used to compare (both visually and statistically) the SHOALS data set to the FST data set in areas where overlap occurred. This comparison revealed areas where soundings from both data sets were statistically consistent; however, in other areas the soundings from the two data sets differed by as much as 0.8 meter. Upon further discussion between NAVOCEANO and the USACE, it was discovered that incorrect tidal offsets were being applied to SHOALS data sets that spanned more than one Julian day. Once the SHOALS software time-tagged data files spanning more than one Julian Day were corrected, the sounding measurements collected using SHOALS were statistically consistent with the sounding measurements from the FST data set in areas where the two data sets overlapped. Also, the lidar data collected using the Kinematic-OTF mode was statistically consistent with the test lidar data collected using the DGPS mode.

C. USNS SUMNER Data Set

The USNS SUMNER was a very late addition to the project and had not previously been used by NAVOCEANO to conduct shallow-water hydrographic surveys. We solved the following problems:

- The T-AGS 60 class ships use the very complex Integrated Survey System (ISS-60) to monitor and manage the large volume of survey data collected by all the sensors onboard the ship. One of the sensors, the POS/MV, used as the primary source of position to the ISS-60, provides attitude, heading, and heave to the Simrad EM1002 shallow-water multibeam system. The ISS-60 is configured to have the POS/MV apply the motion sensor offsets. On the SUMNER, however, the motion sensor offsets were being applied by the POS/MV and again by the EM1002 multibeam system. This error could not be corrected.

- Changes in draft due to fuel consumption during the course of the survey had not been taken into account. To determine valid draft corrections, several tests were conducted with the SUMNER following the two surveys. Results from these tests were then applied to the soundings collected in both of the survey areas. The recalculated soundings, based on the correction for draft of the USNS SUMNER, resulted in the corrected depths being shoaler by 0.3-0.5 meter.

- Using BHPP visualization software to view and edit the EM1002 data, it was discovered that the outer beams were being refracted upward, resulting in the depths from the outer beams being shoaler than the inner beams. This bending of the outer beams produced ridgelike artifacts in the data (Fig. 7), which were statistically different than the soundings from the inner beams as well as the soundings from the other two data sets (SHOALS and FST). In order to eliminate the errors associated with the outer beams, the edited data were restricted to the inner 120° swath width. Testing is currently ongoing with SIMRAD personnel to correct the problem with the outer beam bending of the EM1002 data.

- SUMNER personnel elected to use the Fugro Starfix Wide Area GPS Service for positioning. Although this service adequately meets IHO Order 1 positioning requirements in many areas of the world, its capabilities do vary by distance from reference stations and ionosphere/sun spot activity, which is worse in the tropics. Our post-survey assessment of the Starfix service in the time and area of these surveys determined that it could meet only IHO Order 2 accuracy requirements. For this reason and because of the uncorrectable motion sensor data, all SUMNER data were downgraded to IHO Order 2.

V. NAVIGATIONAL PRODUCTS

Following a very thorough error assessment, data from all three systems were corrected and then used for the production of Smooth Sheets, a Field Chart of Apra Harbor, and DNC®

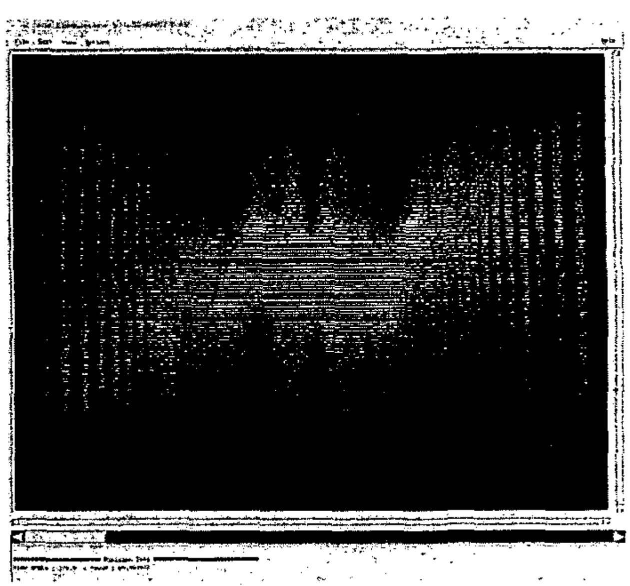

Fig. 7. EM1002 Swath Profile (gsf_geoswath) showing ridge-like effects.

libraries. These products were provided to NOAA and NIMA for general distribution to both the public and the Fleet.

The Smooth Sheets for the surveys and Apra Harbor Field Chart were produced using Intergraph MGE software, which is now being replaced by the CARIS production suite. A Smooth Sheet is the final, legible, accurate plot of a hydrographic survey plotted from verified corrected data and conforming to cartographic standards. Soundings are shoal-biased selected soundings extracted from high-resolution soundings data. This is a "Not for Navigation" product provided to host nations, in this case NOAA/NOS, as the primary hydrographic data source for chart compilations. A Field Chart (Fig. 8) is a navigation-quality limited-distribution chart produced as a temporary chart for use by Navy and other DoD organizations. It is produced only from NAVOCEANO surveys for specific operations as an interim product until the appropriate NIMA or NOAA chart has been produced. NOAA/NOS plans to publish revisions to Chart 81054 (Apra Harbor, Guam) in July 2002 and Chart 81076 (Saipan Harbor) in July 2003. Meanwhile, U.S. Navy ships and other platforms going into Apra Harbor were using the NAVOCEANO Field Chart for navigation.

The system being defined to display electronic charts for the U.S. Navy is called ECDIS-N. In addition to using electronic chart data, ECDIS-N will integrate a variety of other navigational sensors including GPS/DGPS, surface-search radar, gyrocompass, echosounder, and other pertinent navigational information on one display. The functional requirements and performance standards are closely modeled after the International Maritime Organization (IMO) standards for ECDIS. The primary data source ECDIS-N navigational displays will be the NIMA DNC®. The DNC® is an unclassified, vector-based, relational, digital database containing significant maritime features essential for safe marine navigation and is distributed on 29 CD-ROMs. It is a product specification, MIL-D-89023, and requires direct read for display without data manipulation. The DNC® portfolio was initially produced by digitizing approximately 5000 paper charts and consists of over 2400 digital chart libraries. The database is structured using the Digital Geographic Information Exchange Standard (DIGEST) Vector Product Format (VPF), which distributes the data into 12 thematic layers and uses the Feature Attribute Coding Catalog (FACC) to encode chart features and associated attributes. Currently, only DNC® 13 (U.S. West Coast) and DNC® 17 (U.S. East Coast) can be used for navigation because the contained libraries have been brought into routine updating. Chart libraries (Apra Harbor) and (Saipan Harbor) are contained on DNC® 12. Additional information is available at the NIMA website (**www.nima.mil/dncpublic**).

NAVOCEANO contracted the TASC Division of Northrop Grumman to update the Apra Harbor, Guam (DNC® harbor library h1256550) with the new survey data (Fig. 9). The Saipan Harbor (DNC® harbor library h1256520) was updated in-house. Both libraries were updated using the CARIS GIS and DIGEST Object Manager (DOM) software modules. These tools were mainly used in updating features in the various layers, compiling the soundings, creating and editing bathymetric contours, editing geometry and attributes, and rearranging the geometry of linear features to achieve proper topology. Presentation rules for the DNC® used the GEOSYM 4.0 symbol set.

Major changes were made to the Hydrography, Aids to Navigation, and Obstructions layers of the Apra Harbor DNC®. Changes included the addition of 46 bottom characteristics, the repositioning or addition of 53 aids to navigation, and the addition of 48 new obstructions

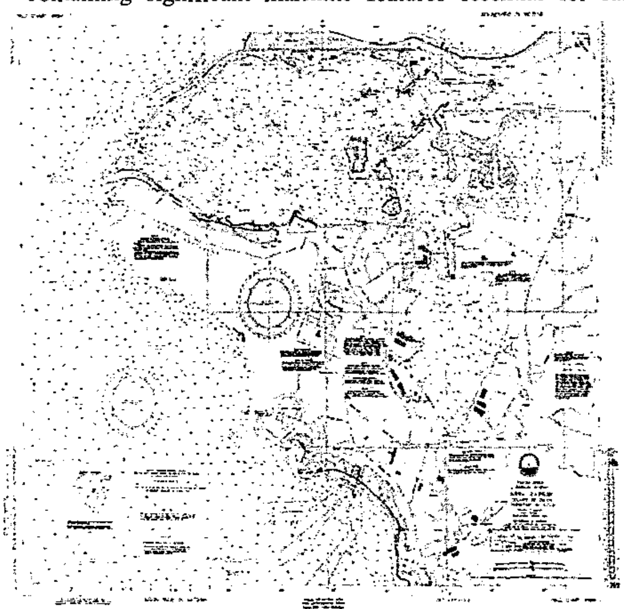

Fig. 8. Field Chart of Apra Harbor, Guam.

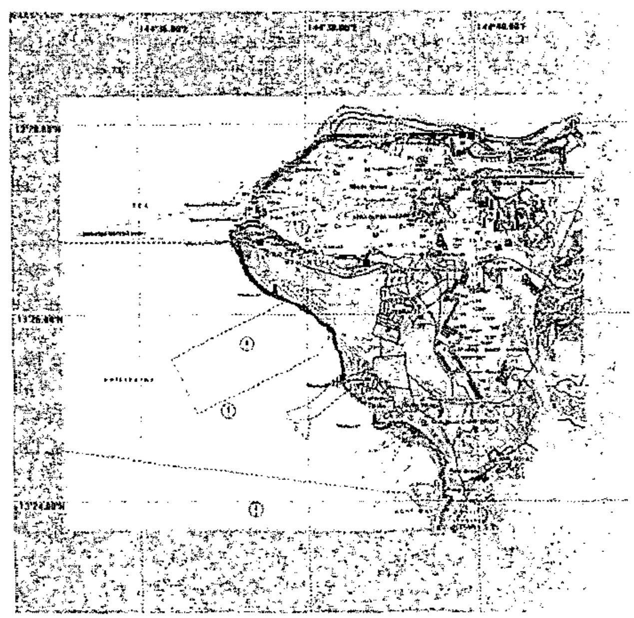

Fig. 9. Updated DNC library for Apra Harbor, Guam.

discovered during the course of the survey. Major changes were made to the Earth Cover, Environment, Hydrography, and Aids to Navigation layers of the Saipan Harbor DNC®. Changes included the addition of 30 foreshore areas, three current flow diagram objects, 17 bottom characteristics, and the repositioning or addition/deletion of 28 aids to navigation. Changes were also made to the Port Facilities and Data Quality layers of both libraries. A significant problem was that the surveys covered only some of the tiles in each library, which made contour matching at tile boundaries a cartographic art, which was especially difficult because original contours were nonstandard metric contours converted from feet. Other significant problems that were overcome were defining the limits of coral and foreshore drying height areas.

VI. SUMMARY COMMENTS

- ❑ Complex multi-platform operations require coherent plans.
- ❑ Multi-platform data collection is an excellent way to discover systemic errors.
- ❑ Take the time to thoroughly check out new systems or configurations and understand how they work.
- ❑ Understand your software completely, its handshakes with other systems, and the application of time tags and correctors.
- ❑ Rooting out sources of error will speed up data processing and product deliveries on subsequent projects.
- ❑ Do not presume that any one data set is superior in quality to another without scientific factual evidence.
- ❑ Use visualization software, such as BHPP, to compare different data sets and fully investigate all discrepancies.
- ❑ If nothing makes sense, the calibrated leadline still provides a definitive baseline measurement.