U.S. DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

DATA ACQUISITION AND PROCESSING REPORT

Type of Survey	**Hydrographic**
Project No.	**M-I907-NF-11 USVI**
Registry No.	**W00216, W00217**

LOCALITY

State	**U. S. Virgin Islands**
General Locality	**Caribbean Sea**

2011

CHIEF OF PARTY

Timothy Battista, Mike Stecher

LIBRARY & ARCHIVES

DATE **March-April, 2011**

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

W00216
W00217

HYDROGRAPHIC STYLE SHEET

INSTRUCTIONS – The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office.

FIELD No
NOAA Ship *Nancy Foster*

State	US Virgin Islands		
General Locality	Caribbean Sea		
Sub-Locality	5nm SE St Johns Island, 5nm South of St. Thomas		
Scale	1:40,000	Date of Survey	March 29, 2011 to April 16, 2011
Instructions dated	February 14, 2011	Project No.	M-I907-NF-11
Vessel	NOAA Ship *Nancy Foster*		
Chief of party	Timothy Battista		
Surveyed by	Timothy Battista, Mike Stecher		
Soundings by	Reson 7125 SV, Simrad/Kongsberg 1002		
Graphic record scaled by	N/A		
Graphic record checked by	N/A		
Automated Plot	N/A		
Verification by			
Soundings in	Meters at MLLW		

REMARKS: All times are UTC.

SUBCONSULTANTS:

NOAA FORM 77-28 SUPERSEDES FORM C&GS-537

ACRONYMS AND ABBREVIATIONS

AWOIS	Automated Wreck and Obstruction Information System
BAG	Bathymetric Attributed Grid
BASE	Bathymetry Associated with Statistical Error
CCMA	Center for Coastal Monitoring and Assessment
CO-OPS	Center for Operational Oceanographic Products and Services
CTD	Conductivity Temperature Depth
CUBE	Combined Uncertainty and Bathymetry Estimator
DGPS	Differential Global Positioning System
FPM	*Field Procedures Manual* (April 2010)
GAMS	GPS Azimuth Measurement Subsystem
GPS	Global Positioning System
HIPS	Hydrographic Information Processing System
HSSD	*Hydrographic Survey Specifications and Deliverables Manual* (April 2010)
HSTP	Hydrographic Systems Technology Programs
HSX	Hypack Hysweep File Format
HTD	Hydrographic Surveys Technical Directives
HVF	HIPS Vessel File
IHO	International Hydrographic Organization
IMU	Inertial Motion Unit
MLLW	Mean Lower Low Water
NMEA	National Marine Electronics Association
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
OMAO	Office of Marine and Aviation Operations (NOAA)
POS/MV	Position and Orientation System for Marine Vessels
PPS	Pulse per second
ROV	Remotely Operated Vehicle
R/V	Research Vessel
SAT	Sea Acceptance Test
SBE	Smooth Best Estimate
SBET	Smooth Best Estimate and Trajectory
SVP	Sound Velocity Profiler
TPE	Total Propagated Error
TPU	Total Propagated Uncertainty
TSG	Thermosalinograph
USCRTF	U.S. Coral Reef Task Force
ZDA	Global Positioning System timing message
ZDF	Tide Zone Definition File

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Data Acquisition and Processing Report
Caribbean Sea, USVI
March 2011 – April 2011
NOAA Ship *Nancy Foster*
Center for Coastal Monitoring & Assessment
Biogeography Branch
Lead Hydrographer, Mike Stecher
Lead Scientist, Timothy Battista

INTRODUCTION

In June 1998, the U.S. Coral Reef Task Force (USCRTF) was established by Presidential Executive Order 13089. The USCRTF mission is to lead, coordinate, and strengthen U.S. government actions to better preserve and protect coral reef ecosystems. The National Oceanic and Atmospheric Administration's (NOAA) Center for Coastal Monitoring and Assessment (CCMA) Biogeography Team is supporting the USCRTF mandate. The Biogeography Team completed its eighth year of an ongoing scientific research mission on board the NOAA Ship *Nancy Foster* from March 29 to April 16, 2011.

The objective of this project was to collect a multibeam bathymetry dataset with 100 percent seafloor ensonification, along with multibeam backscatter suitable for seafloor characterization in a high-priority conservation area. This report applies to surveys W00216 and W00217 that took place around the U.S. Virgin Islands in the Caribbean Basin. Unless otherwise noted, the acquisition and processing procedures used and deliverables produced are in accordance with the NOAA *Hydrographic Survey Specifications and Deliverables Manual* (HSSD) of April 2010, the *Field Procedures Manual* (FPM) of April 2010, and all active Hydrographic Surveys Technical Directives (HTD). The project instructions required complete multibeam coverage in water depths greater than ten meters for both survey sites. The multibeam data was collected to conform to IHO Order 1 (<100m) and Order 2 (>100m) accuracy standards. The strategies developed for each survey area took into account the minimum depths, general bathymetry, and time allotment. The delineation and identification of seafloor habitats within areas mapped during the mission was assisted by the use of an ROV with video and camera capabilities.

All references to equipment, software, or data acquisition and processing methods were valid at the time of document preparation. All changes to data acquisition and processing methods will be specifically addressed in the Descriptive Reports of the project surveys.

A. EQUIPMENT

Detailed descriptions of the equipment and systems, including hardware and software, used for bathymetric data acquisition and processing appear below.

Table 1. NOAA Ship Nancy Foster Hardware

Hydrographic Systems Inventory Cruise# M-I907-NF-10				HARDWARE
Equipment type	Manufacturer	Model	Serial #	Firmware
Transducer	Kongsberg/Simrad	EM1002	288	N/A
Transceiver Unit	Kongsberg/Simrad	EM1002	303	N/A
Reson	Reson	7125	1812025	MR 7.1.1
Reson Projector Unit	Reson	TC 2160	2308096	N/A
Reson Projector Unit	Reson	TC 2163	4408349	N/A
Reson Receiver Unit	Reson	EM 7200	2908034	N/A
Inertial GPS PCS	Applanix	POS/MV 320 V4	2249	3.2
IMU	Applanix	LN 200	447	N/A
DGPS	Trimble	DSM 132	224096283	3.0
SVP	SBE	SBE 19	0355	N/A
SVP	SBE	SBE 19	1448	N/A
SVP	Reson	SVP 71	2008048	N/A

A1. SURVEY VESSEL

The NOAA Ship *Nancy Foster* (R352) is fifty-seven meters in length, has a beam of twelve meters, and draws approximately three meters of water. During the Charleston, South Carolina drydock period in November of 2005, numerous survey hardware and software installations were implemented by NOAA's Office of Marine and Aviation Operations (OMAO) to make multibeam data acquisition a more integral component of the ship's research support. OMAO funded the permanent installation of a Simrad EM1002 multibeam sonar, an Applanix POS/MV positioning system, ancillary sensors, and support equipment. The *Nancy Foster* was also permanently mobilized with a Reson 7125 multibeam system during a dry dock period in February of 2011.

Fig. 1: NOAA Ship *Nancy Foster*

A2. MULTIBEAM SYSTEMS

A2.a Kongsberg EM1002

A Simrad EM1002 multibeam echosounder is permanently hull-mounted between two fiberglass hydrodynamic fittings starboard of the keel line, aft of the bow. The EM1002 is a 95-kHz system with a 150° swath consisting of 111 individually formed, electronically roll-stabilized 2° beams, with a maximum ping rate of 10Hz, depending on water depth. The EM1002 has three different automatically adjusted pulse lengths to maximize coverage in deeper waters at 0.2, 0.7 and 2 milliseconds respectively. A combination of phase and amplitude detection was used, resulting in measurement accuracy practically independent of beam angle. The system is compensated in real-time for sound velocity changes at the transducer array, to assist the electronic beam steering capabilities.

Fig 2: EM1002 transducer fairing

Fig 3: EM1002 transducer

The EM1002 sonar system is controlled with a UNIX-based operator system (SUN Solaris 8) that utilizes the Common Desktop Environment and Kongsberg's MERLIN v5.2.2 acquisition and control program. Before surveying began, and periodically thereafter, the EM1002 system self-test (BIST test) was performed to confirm the sonar's operating status. No sonar errors were observed during the survey. As per advice from the Kongsberg representative during the SAT, the automatic and default parameters were used to control the sonar during data acquisition. The EM1002 backscatter default options were verified with Adel Sterling and the Hawaii Mapping Resource Group, who have extensive experience acquiring backscatter imagery with the EM1002 system onboard the R/V *Kilo Moana*. The equidistant beam-spacing mode was chosen to give a uniform distribution of soundings on the seafloor. The ping rate was set by the system and was automatically adjusted according to the depth below the transducer. Only limited runtime parameters changed during the survey including the maximum port and starboard angles, which did not exceed 60°.

A2.b Reson 7125 SV

A Reson SeaBat 7125 SV dual-frequency multibeam sonar with an integrated SVP-71 sound velocity profiler (SVP) was mounted onto the hull of the Nancy Foster during a dry dock period in February, 2011. The sonar was mounted onto the hull and is located port of the keel, and forward of the reference point of the vessel. The Reson 7125 operates at either 400 kHz or 200 kHz, producing a 128° swath of 512 uniform beams with a beam width of 0.5° x 1.0°. For the M-I907-NF cruise the Reson 7125 was operated in the 400 kHz, 512 beam, equidistant mode. Sonar setting changes were kept at a minimum with the power set to full (220 dBs), spreading at 30, absorption at 110 dB/km and a variable pulse length between 30-90 µs in steps of 10. Range adjustments were made during acquisition as dictated by changes in the depth. Hypack HYSWEEP was used to acquire the multibeam and snippets data.

Fig 4: Reson 7125 mounted onto the hull of the Nancy Foster

A3. POSITION, HEADING and MOTION REFERENCE UNITS

A3.a Applanix Position & Orientation System for Marine Vessels 320 Version 4 (POS/MV)

The *Nancy Foster* is outfitted with an Applanix POS/MV 320 V4, augmented by a Trimble DSM132 Differential Global Positioning System (DGPS). The POS/MV incorporates an inertial reference system used to measure attitude, heading, and position for the survey vessel. The POS/MV system comprises an inertial motion unit (IMU), dual Global Positioning System (GPS) antennas, and a data processor. GAMS (GPS Azimuth Measurement Subsystem) calibrations were performed on the POS/MV unit prior to survey operations. The GAMS

calibration procedure was conducted in accordance with instructions in chapter 4 of the *POS/MV V4 Installation and Operation Guide,* 2005.

The POS/MV also provided time synchronization of the sonar and acquisition computer using a combination of outputs. The Reson processors and Hypack logging computer provided both a pulse per second (PPS) and a National Marine Electronics Association (NMEA) GPS timing message (ZDA). These messages contained timing strings that synchronized the clocks to the POS/MV.

The POS/MV was configured to log all the raw observable groups needed to post-process the real-time sensor data with the ethernet logging controls. Under typical survey conditions, several POS/MV .000 file were logged each survey day. The TrueHeave™ data group was also logged to these files.

A3.b Trimble DSM132 Differential GPS Receiver

The Trimble DSM132 acquired corrections from the U.S. Coast Guard beacon located at Isabel, Puerto Rico (295 kHz) and provided differential corrections to the POS/MV. In addition, the DSM132 acted as a redundant positioning system onboard the *Nancy Foster* for quality control purposes. The DSM132 uses an intergraded beacon receiver and acquired differential GPS correctors from the same beacon used by the primary system. A pre-cruise comparison between the positioning systems was observed and documented while the vessel was stationary in port at St. Thomas.

A4. SOUND SPEED MEASURMENT SYSTEMS

Sound speed sensors were calibrated prior to the start of acquisition. Factory calibration results are included in the separate Section II, *Sound Speed Data* of the Descriptive Report for the survey.

A4.a SBE Thermosalinograph

The *Nancy Foster* is equipped with a hull-mounted SBE 45 thermosalinograph (TSG) near the EM1002 transducer. The TSG measures near-surface conductivity and temperature to calculate sound velocity in real time. The data from the TSG was streamed to the EM1002's MERLIN acquisition-and-control software to aid in electronic beam steering.

A4.b SBE 19*Plus*

The primary Conductivity Temperature Depth CTDs for determining sound velocity throughout the water column was a Seabird Electronics SBE 19*Plus*. Sound velocity casts were deployed approximately every four hours during survey operations. Sound velocity casts were processed with NOAA's Velocwin V8.85 software and converted to Simrad & CARIS format. The *Nancy Foster*'s hydraulic winch was rigged through the block of the port J-Frame davit, which provided a consistent rate of descent for acquisition of the sound velocity data.

A4.c Reson SVP-71

The SVP-71 measures the speed of sound near the Reson 7125 transducers to provide real-time surface sound-speed values. The sound speed is output to the RESON 7125's processing unit. The 7125 requires sound velocity information for beam-forming and cannot be used to acquire data without the real-time sound velocity information.

A5. ACQUISITION AND PROCESSING SYSTEMS

A5.a Hypack Hysweep and Geocoder

For this survey the Hypack 2011 software package was used to acquire the 7125 multibeam echo sounder and backscatter data. Hysweep is a module of the Hypack software suite that allows for real-time data planning and acquisition. Hysweep combines geo-referenced bathymetric digital terrain models and reference files such as raster charts to display real-time bathymetric bottom coverage. Data is acquired in three formats: .RAW, .HSX (containing bathymetry), and .S7K (containing snippets data).

The Geocoder program used was an implementation provided by Hypack. The primary use of the program is to produce corrected backscatter imagery of the gathered snippets data. Hypack's .S7K and .HSX files were used to assemble the snippets data.

A5.b Kongsberg MERLIN v5.2.2

Kongsberg's MERLIN v5.2.2 multibeam control and data acquisition software was used for EM1002 multibeam data collection. The software operates on a SOLARIS-based Sun Microstation workstation.

A5.c Hydrographic Systems Technology Programs (HSTP) Software

Sound-speed data was processed with Velocwin v8.85, an in-house software produced and maintained by NOAA's Hydrographic Systems and Technology Programs (HSTP) division. Velocwin creates and archives water column profiles, performs quality assurance, and processes pressure-based depth data. Velocwin creates a standard file format for sound-speed profiles applied to multibeam data.

A5.d CARIS

Bathymetric survey data was converted and processed in CARIS HIPS v7.0 SP2 Hotfix 8 with modifications to the default CUBE (Combined Uncertainty Bathymetric Estimator) Parameters.XML. The default CUBE Parameters.XML was replaced with the new file issued to all NOAA hydrographic field units included with the *Hydrographic Surveys Technical Directive* 2009-2. This updated .XML file used new resolution-dependent maximum propagation distance values required in the *HSSD* 2010. Processing methodology followed the standard CARIS HIPS CUBE workflow including data conversion, filtering, sound velocity, tide

correction, merging, and cleaning. CARIS HIPS also calculated the Total Propagated Error (TPE) used to produce the Bathymetry Associated with Statistical Error (BASE) and CUBE surfaces which assisted the hydrographer in data cleaning and analysis and in producing surface deliverables.

Table 2. Acquisition & Processing Software

Hydrographic Systems Inventory	Cruise# M-I907-NF-10		SOFTWARE
Equipment type	Manufacturer	Model	Software Version
Inertial GPS PCS	Applanix	POS/MV 320 V4	4.3.5.0
Navigation	Coastal Oceanographics	Survey	2011
Acquisition	Coastal Oceanographics	Hysweep	2011
Acquisition	Kongsberg/Simrad	MERLIN	v5.2.2
Acquisition	Sun Microsystems	TT32220431	Solaris 8
Processing	NOAA	Velocwin	8.85
Processing	CARIS	HIPS & SIPS	7.0 SP2 HF8
7k Control Center 7125	Reson	7125	MR 7.1.1
7k Control Center 7125	Reson	7K UI	3.10.2.8
7k Control Center 7125	Reson	7K Center	3.5.3.12
7k Control Center 7125	Reson	7K IO	3.3.0.19

A6. Survey Methodology

A6.a Mobilizations

Mobilization of the *Nancy Foster* occurred in San Jaun , Puerto Rico at the USCG Pier on March 27-28, 2011. Vessel offsets and associated measurement uncertainties were calculated from two vessel surveys performed on February 7, 2006 by the Power & Control Systems Group of L3 Communications and on February 28, 2011 by the IMTEC Group, Ltd. These values were reconfirmed with hand tape measurements prior to the start of survey operations and used in the HIPS vessel files for the *Nancy Foster*'s two sonar systems. Once installations were completed and the hydrographer was confident that all sensors were operational, the survey vessels underwent system calibration tests.

A6.b Survey Coverage

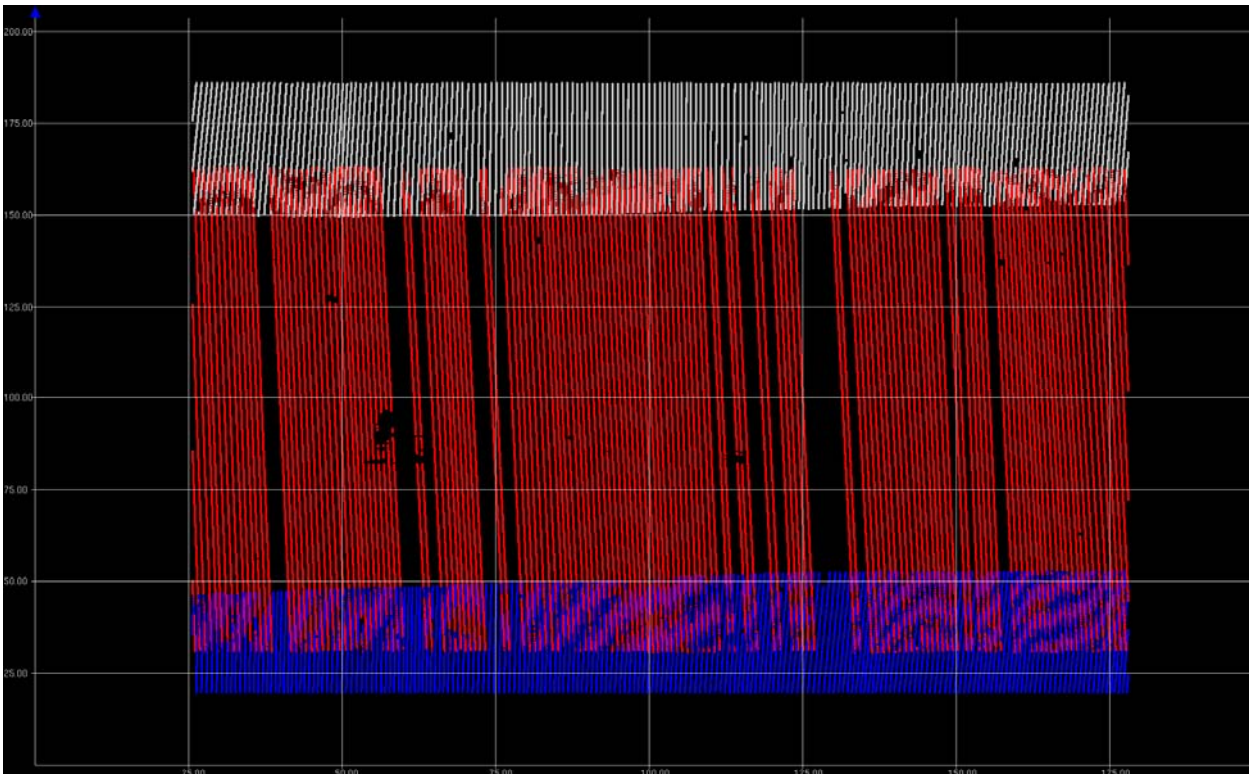
Survey coverage was based on the survey limits depicted by the Hydrographic Survey Project Instructions, M-I907-NF-11 U.S. Virgin Islands Mapping Project. The survey project boundaries of W00216 and W00217 were completed. Registry Number W00218 was not surveyed due to time constraints.

Registry Number's W00216 and W00217 were surveyed with line orientation appropriate for each of the survey boundaries and approximately parallel to contour. Additional multibeam coverage was collected over several uncharted wrecks within W00217 to meet requirements for

complete coverage detection at the least depth.

Occasional 7125 ping drops were encountered with surveys W00216 and W00217. A substantial amount of ship time was spent on holidays related to ping drop outs on both sheets.

Fig 5: Reson 7125 ping drop outs



A6.c Multibeam Sonar Operations

Full multibeam coverage was a requirement for this survey. Multibeam operations utilized the techniques defined by the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2010). The sonar systems were also tuned to simultaneously maximize bathymetric and backscatter data quality by not over-saturating sonar returns. The multibeam sonar was operated at different range scales throughout the survey by adjusting the depth range to obtain the best coverage in varying depths of water

A7. Quality Assurance

Acquisition and processing methods followed systematic and standardized workflows as defined by the NOS *Field Procedures Manual,* April 2010.

B. QUALITY CONTROL

B1. Data Acquisition

B1.a Multibeam

Incremental adjustments to the sonar including changes in range and gain were made during acquisition to ensure acquisition of the best quality bathymetric and backscatter data. Vessel speed was adjusted in accordance with the National Ocean Service's (NOS) *Hydrographic Surveys Specifications and Deliverables* (April 2010) to ensure required along-track coverage. Typical windows for monitoring raw sensor information included timing synchronization, surface-sound velocity, vessel motion, GPS quality, intensity, and satellite coverage.

Pre-cruise position confidence checks and multibeam lead line checks were conducted to confirm horizontal and vertical positioning accuracies. An SVP comparison check was performed by lashing the two SBE 19*Plus* units together and lowering them simultaneously to the seafloor. The sound speed profiles were computed for each of the sensors and compared to confirm that instrumentation was functioning within survey tolerances.

B2. Data Processing

B2.a Uncertainty Modeling

Error values for the multibeam and positioning systems were compiled from manufacturer specification sheets for each sensor and from values set forth in Section 4.2.3.6 and Appendix 4 – CARIS HVF Uncertainty Values of the *FPM*.

Uncertainty values relating to the vessel's two survey systems were entered into the HIPS Vessel File (HVF) for each system. The estimated tidal error contribution to the total survey error budget in the vicinity of W00216 and W00217 is 0.12 meters at the 95% confidence level (divided by 2, 1 sigma = .06), and includes the estimated gauge measurement error, tidal datum computation error, and tidal zoning error. Sound-speed uncertainties for the survey were based on the defaults listed in the Total Propagated Uncertainty (TPU) value spreadsheet and were entered during the Compute TPE step in CARIS HIPS.

B2.b Vessel Files

Two HVF files were created to correspond to each sonar configuration used during the survey. The vessel file contains all offsets and system biases for the survey vessels and its systems, as well as error estimates for latency, sensor offset measurements, attitude and navigation measurements, and draft measurements. Sensor offsets values were calculated from the vessel surveys, which were conducted prior to the start of field operations.

The dynamic draft survey was performed during the Sea Acceptance Test (SAT) offshore of Charleston, S.C. in March 2006. OMAO representatives performed the survey and evaluated the results. The dynamic draft was determined using the reference surface method as per the 2010

FPM. Results of the dynamic draft survey were also entered into the vessel configuration files. The *Nancy Foster HVF* reports including TPU values are located in Appendix I.

B2.c Static Draft

Draft was measured pre- and-post cruise from draft marks on the port side of the vessel's hull for the EM1002 and the 7125. The total draft change for the 7125 and the EM1002 draft change was negligible.

B2.d Sound Velocity

Sound-speed profiles were applied to each line using the "nearest-in-distance-within-time" six-hours option in the CARIS SVP correction routine. Velocity casts were taken at four-hour frequency intervals with the SBE 19*Plus*. The online surveyors made periodic comparisons and verifications of sound-velocity measurements that were made during survey operations between the SVP-71 and the SBE 19*Plus*. In addition, the two SBE 19*Plus* units were combined, deployed, and processed to confirm SBE calibration coefficients.

B3. CARIS Data Processing

Multibeam data processing followed the standard HIPS workflow for CUBE editing except that the hypothesis surface was not edited. Instead, fliers influencing the CUBE surface were rejected and critical soundings not incorporated in the CUBE surface were designated.

The list of correctors and filters applied to the bathymetric data in HIPS appears below. Several of the steps are interim processes and were re-applied as needed.

1. Apply True Heave (not applied to W00216, W00217)
2. Load Delta Draft
3. Load Tide
4. Apply sheet-wide concatenated sound-speed profiles
   - Nearest in distance within time
5. Merge
6. Compute TPU
7. Filters applied based on the following criteria:
   - Reject soundings with poor quality flags (0 and 1 for Reson)
   - Add data to CUBE surface
     - Resolution dependent on depth
     - IHO S-44 Order 1
     - Density & Local Disambiguation method
     - Advanced NOAA settings specific to surface resolution
8. Surface Filter
   - Errors from Standard Deviation
   - 2.6 (99.06%) Confidence Interval

After filtering, each survey sheet was subdivided by creating two field sheets, one for the W00216 and one for W00217. The BASE surfaces were created using the CUBE algorithm and parameters contained in the NOAA Cubeparams.xml file as provided with HTD 2009-2. The Cubeparams.xml will be included with the HIPS Vessel Files with the survey data. CUBE surfaces were created over the survey areas using grid-resolution thresholds and resolution-dependent maximum propagation distances for complete coverage surveys as specified in the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2010). The NOAA parameter configurations for resolutions used are listed in Table 3.

Table 3. Surface Resolutions

Surface Resolutions		CUBE Parameters
Depth Range	**Grid Resolution**	**Configuration Name**
0 to 22 meters	1 meter	NOAA_1m
20 to 44 meters	2 meter	NOAA_2m
40 to 88 meters	4 meter	NOAA_4m
80 to 176 meters	8 meter	NOAA_8m
160+ meters	16 meter	NOAA_16m

The CUBE workflow included the review and focused editing of multiple CUBE child layers including Density, Hypothesis Count & Strength, Node Standard Deviation, and Uncertainty. Survey coverage was reviewed to ensure that there were no substantial holidays spanning the entire survey swath and that there were no data gaps present over significant features. The HIPS density layer of each grid was reviewed to ensure that the minimum sounding density of three soundings per node was achieved for 95 percent of nodes populated by mainscheme survey lines and that significant features had a designated sounding overlying the least depth.

A layer determining “IHO-ness” was also added to the CUBE surfaces to allow the Hydrographer to verify spatially where the survey meets specific IHO Orders. Ninety-five percent of the data is highlighted in the layer, which allows the Hydrographer to show whether the data meets the appropriate IHO order as specified in section 5.1.1.1 of the *HSSD.* An image of the IHO layer and its derived statistics will be included with the Descriptive Report for each survey. All crosslines were also used to create IHO compliance statistics using the HIPS crossline QC tool.

B4. Final Bathymetric Processing

Upon the completion of editing multibeam data in HIPS, finalized CUBE grids were generated using the “greater of the two” option for the final uncertainty value. Finalized surfaces were then reviewed in the HIPS 3D graphics window with an extreme vertical exaggeration to verify that all fliers have been removed from the surfaces. The BASE Surface to BAG (Bathymetric Attributed Grid) function was then used on each CUBE Depth surface and exported from HIPS for submittal.

C. CORRECTIONS TO ECHO SOUNDINGS

C1. Vessel HVFs

CARIS HIPS Vessel Files (HVFs) were created to define the vessel's offsets and equipment uncertainty. The HVFs were used for converting and processing multibeam data collected by the surveying platform. The HVFs used for this project are included with the digital data submitted with the survey.

C2. Vessel Offsets

On February 7, 2006 the NOAA Ship *Nancy Foster* had her sensor offsets surveyed by the Power & Control Systems Group of L3 Communications. The IMU, GPS antennas, EM1002 transducer and the center of rotation were surveyed with respect to the reference point, which is slightly aft of the IMU in the forepeak of the vessel. An additional survey to locate the newly mounted 7125 was performed on February 28, 2011 by The IMTEC Group, Ltd.

These offsets were entered into the MERLIN acquisition software, POS/MV software, and the appropriate areas of the CARIS vessel configuration files. The vessel survey reports are included in Appendix I.

C3. Patch Tests

Multibeam patch tests were conducted for each of the *Nancy Foster*'s two sonar systems. The purpose of the patch test is to measure alignment offsets between the IMU sensor and the multibeam transducer, while also determining time delays between the time-tagged sensor data. Each patch test consisted of a series of lines run in a specific pattern, which were then used in pairs to analyze roll, pitch, and heading alignment bias angles.

Roll alignment was determined by evaluating the reciprocal lines run over a flat bottom. The pitch tests consisted of set of reciprocal lines located on a steep slope. The yaw error was determined by running parallel lines over the same area. All lines were run at approximately three knots to six knots. Patch tests were run in the local survey area.

Selected pairs of lines were then analyzed in HIPS Calibration editor to measure the angular sensor bias values. Visual inspection of the data confirmed each adjustment. Patch test values for both sonar systems are listed in Table 4.

Table 4. Patch Test Values

M-I907-NF-11 Patch Test Values				
	Pitch	**Roll**	**Yaw**	**Latency**
EM1002	0.14	-0.08	-0.40	0.00
7125-SV	0.10	0.18	0.40	0.00

C4. Static and Dynamic Draft

Static draft values were obtained from visual observations of the projection draft marks on the starboard side of the *Nancy Foster* for the EM1002 and the 7125. The static draft recorded on March 28, 2011 was 3.71m while tied up in San Juan, Puerto Rico. Subtracting the initial draft value of 3.71m from the fixed offset (1.68m) for the Reference Point to the EM1002 gives the final draft reading of -2.03m. A draft value of -2.11m was determined for the 7125. The draft values were entered into the MERLIN software for the EM1002 and into the HVF for the 7125 and confirmed with leadline readings. The final EM1002 and 7125 draft reading at the end of the cruise (April 16, 2011) was negligible.

The dynamic draft survey was performed during the Sea Acceptance Test (SAT) offshore of Charleston, South Carolina in March of 2006. Representatives from the OMAO performed the survey and evaluated the results. The dynamic draft was determined using the reference surface method as per the NOS *Field Procedures Manual*. Results of the dynamic draft survey were entered into the vessel configuration files.

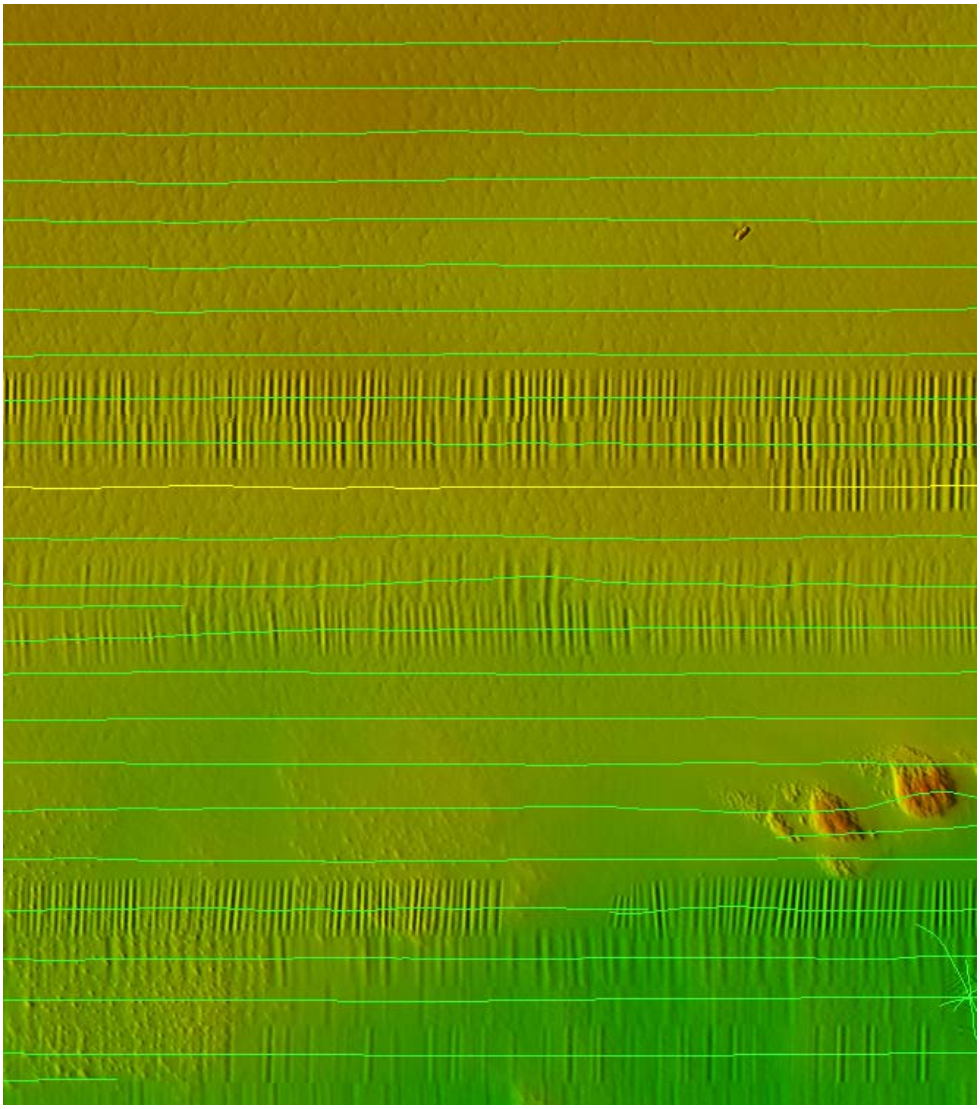
C5. Attitude

All attitude corrections are generated by the POS/MV using data from the IMU-200 Inertial Measurement Unit. The 7125 had real-time roll stabilization applied except for when some troubleshooting was conducted on day number 103 between 05:15 and 22:00. This has been accounted for in the HVF for the 7125. The EM1002 has heave, pitch and roll applied in real time. Attitude was not applied for the EM1002 data in post-processing.

C6. True Heave

The *Nancy Foster* is equipped with the POS/MV TrueHeave™ (TH) option. True Heave™ is a "delayed" heave corrector as opposed to "real-time" heave corrector and is fully described in Section 6 of the *POS/MV Version 4 Installation and Operation Manual*. TH is logged along with other POSPac data in the daily POS files through the Ethernet Logging function in the POS/MV controller software. To ensure proper calculation of TH, files are logged for at least three minutes prior to the beginning of acquisition and three minutes past the end of each day's survey operations. Due to network data drop outs in the POSPac data, TH was not applied for surveys W00216 or W00217. Figure 6 graphically displays examples where TH data drops out occurred. The locations of smooth seafloor are where data drop outs where not encountered, locations of "speed bumps" along vessel track are where data drop outs occurred.

Fig 6: POS/MV network data drop outs



C7. Tide and Water Level Corrections

Existing water level stations were used in conjunction with height and time correctors in a CARIS tide zone definition file (ZDF). Predicted tides, adjusted to Mean Lower Low Water (MLLW), and ZDFs were supplied by NOAA CO-OPS prior to the commencement of survey operations. Verified six-minute-interval water level and final tide-zone correctors were applied while post-processing the data. During the computation of the TPE, survey-specific parameters including the estimated tidal errors were applied. The estimated tidal-error contribution to the total survey error budget was determined by CO-OPS to be 0.12m at the 95% confidence level. The primary and subordinate stations experienced no downtime during periods of hydrographic survey.

C8. Sound Velocity Correction

After each cast the sound speed data was reviewed for outliers or anomalies that could impact data quality. Additionally, the sound speed measured by the SBE 19*Plus* at the surface was compared to the Reson 7125 and EM1002 head velocities for agreement, to ensure that both systems were working properly. In addition to these periodic comparisons, a comparison check was performed by lashing two SBE 19*Plus* units together and simultaneously lowering them to the bottom. All comparisons were well within survey specification. Factory calibration results are included in Section II – *Sound Speed* of the Descriptive Reports.

For each survey all casts were concatenated into a master SVP file that included time, position, depth, and sound speed. The sound-speed correction was applied to each line using the nearest-in-distance-within-time (six-hour) option in the HIPS SVP correction routine.

C9. Lead Line Comparisons

Lead line checks were performed against both of the multibeam echosounders prior to data acquisition. While the vessel was tied up alongside the pier, lead lines were taken starboard of each of the multibeam systems. Digital data was logged simultaneously during the lead line procedure for each system. The multibeam data was then converted and queried in Caris HIPS to confirm that the acoustic depths matched the lead lines. No bias was detected as each of the lead line readings agreed with the multibeam soundings.

D. Letter of approval

As Lead Hydrographer, I have ensured that standard field surveying and processing procedures were followed during this project in accordance with the Hydrographic Manual, Fourth Edition; Hydrographic Survey Guidelines; Field Procedures Manual, and the NOS Hydrographic Surveys Specifications and Deliverables Manual, as updated for 2010.

I acknowledge that all of the information contained in this report is complete and accurate to the best of my knowledge.

Approved and Forwarded: _____

Michael Stecher
NOAA Contractor
CCMA Biogeography Branch
ACSM Certified Hydrographer #237

APPENDIX I

VESSEL REPORTS, OFFSETS AND DIAGRAMS

Vessel Name: NF_7125_USVI_400khz.hvf
Vessel created: November 30, 2011

Depth Sensor:

Sensor Class: Swath
Time Stamp: 2011-066 00:00

Comments:
Time Correction(s) 0.000

Transduer #1:

Pitch Offset: 0.100
Roll Offset: 0.180
Azimuth Offset: 0.400

DeltaX: 0.397
DeltaY: -2.179
DeltaZ: 1.090

Manufacturer: Reson
Model: sb7125d
Serial Number:

Navigation Sensor:

Time Stamp: 2011-066 00:00

Comments: (null)
Time Correction(s) 0.000
DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

Manufacturer: (null)
Model: (null)
Serial Number: (null)

Gyro Sensor:

```
      Time Stamp:  2011-066 00:00

      Comments:
      Time Correction(s) 0.000

_____________________________________________________________________
Heave Sensor:

      Time Stamp:  2011-066 00:00

      Comments:
      Apply Yes
      Time Correction(s) 0.000
      DeltaX:     0.000
      DeltaY:     0.000
      DeltaZ:     0.000
      Offset:     0.000

      Manufacturer:      (null)
      Model:             (null)
      Serial Number:     (null)

_____________________________________________________________________
Pitch Sensor:

      Time Stamp:  2011-066 00:00

      Comments:
      Apply Yes
      Time Correction(s) 0.000
      Pitch offset: 0.000

      Manufacturer:      (null)
      Model:             (null)
      Serial Number:     (null)

_____________________________________________________________________
Roll Sensor:

      Time Stamp:  2011-066 00:00

      Comments: (null)
      Apply No
      Time Correction(s) 0.000
      Roll offset: 0.000

      Manufacturer:      (null)
      Model:             (null)
      Serial Number:     (null)


      Time Stamp:  2011-103 05:15

      Comments:
```

```
      Apply Yes
      Time Correction(s) 0.000
      Roll offset: 0.000

      Manufacturer:
      Model:
      Serial Number:


      Time Stamp:  2011-103 22:00

      Comments:
      Apply No
      Time Correction(s) 0.000
      Roll offset: 0.000

      Manufacturer:
      Model:
      Serial Number:
```

```
Draft Sensor:

      Time Stamp:  2011-066 00:00

      Apply Yes
      Comments: (null)
      Time Correction(s) 0.000

      Entry 1) Draft: 0.007   Speed: 5.054
      Entry 2) Draft: 0.041   Speed: 6.143
      Entry 3) Draft: 0.002   Speed: 7.911
      Entry 4) Draft: 0.032   Speed: 9.778
```

```
TPU

      Time Stamp:  2011-066 00:00

      Comments:
      Offsets

      Motion sensing unit to the transducer 1
            X Head 1 0.399
            Y Head 1 -2.918
            Z Head 1 1.219
      Motion sensing unit to the transducer 2
            X Head 2 0.000
            Y Head 2 0.000
            Z Head 2 0.000
      Navigation antenna to the transducer 1
            X Head 1 5.147
            Y Head 1 -8.755
            Z Head 1 17.392
      Navigation antenna to the transducer 2
```

```
            X Head 2 0.000
            Y Head 2 0.000
            Z Head 2 0.000

      Roll offset of transducer number 1 0.000
      Roll offset of transducer number 2 0.000

      Heave Error: 0.050 or 5.000'' of heave amplitude.
      Measurement errors: 0.002
      Motion sensing unit alignment errors
      Gyro:0.000  Pitch:0.000 Roll:0.000
      Gyro measurement error: 0.020
      Roll measurement error: 0.020
      Pitch measurement error: 0.020
      Navigation measurement error: 1.000
      Transducer timing error: 0.010
      Navigation timing error: 0.010
      Gyro timing error: 0.010
      Heave timing error: 0.010
      PitchTimingStdDev: 0.010
      Roll timing error: 0.010
      Sound Velocity speed measurement error: 0.000
      Surface sound speed measurement error: 0.000
      Tide measurement error: 0.000
      Tide zoning error: 0.000
      Speed over ground measurement error: 0.015
      Dynamic loading measurement error: 0.150
      Static draft measurement error: 0.150
      Delta draft measurement error: 0.030
      StDev Comment: (null)
```

```
Svp Sensor:

      Time Stamp:  2011-066 00:00

      Comments:
      Time Correction(s) 0.000

      Svp #1:
      -------------
      Pitch Offset:     0.000
      Roll Offset:      0.000
      Azimuth Offset:   0.000

      DeltaX:     0.397
      DeltaY:     -2.179
      DeltaZ:     1.090

      SVP #2:
      -------------
      Pitch Offset:     0.000
      Roll Offset:      0.000
      Azimuth Offset:   0.000
```

```
      DeltaX:     0.000
      DeltaY:     0.000
      DeltaZ:     0.000

_____________________________________________________________________
WaterLine:

      Time Stamp:  2011-066 00:00

      Comments: (null)
      Apply Yes
      WaterLine -2.110
_____________________________________________________________________
```

Vessel Name: NF_EM1002_USVI.hvf
Vessel created: November 30, 2011

```
Depth Sensor:

      Sensor Class:      Swath
      Time Stamp:  2006-064 00:00

      Comments: SAT
      Time Correction(s) 0.000

      Transduer #1:
      -------------
      Pitch Offset:     0.900
      Roll Offset:      -0.110
      Azimuth Offset:   -0.200

      DeltaX:     0.000
      DeltaY:     0.000
      DeltaZ:     0.000

      Manufacturer:
      Model:             em1002
      Serial Number:

Depth Sensor:

      Sensor Class:      Swath
      Time Stamp:  2007-044 00:00

      Comments: 2007_Patch
      Time Correction(s) 0.000

      Transduer #1:
      -------------
      Pitch Offset:     1.490
      Roll Offset:      0.040
      Azimuth Offset:   0.500

      DeltaX:     0.000
      DeltaY:     0.000
      DeltaZ:     0.000

      Manufacturer:
      Model:             em1002
      Serial Number:

Depth Sensor:

      Sensor Class:      Swath
      Time Stamp:  2008-051 00:00
```

```
      Comments: USVI_patch
      Time Correction(s) 0.000

      Transduer #1:
      -------------
      Pitch Offset:     0.140
      Roll Offset:      -0.080
      Azimuth Offset:   -0.400

      DeltaX:     0.000
      DeltaY:     0.000
      DeltaZ:     0.000

      Manufacturer:
      Model:             em1002
      Serial Number:

_____________________________________________________________
Navigation Sensor:

      Time Stamp:  2006-064 00:00

      Comments:
      Time Correction(s) 0.000
      DeltaX:     0.000
      DeltaY:     0.000
      DeltaZ:     0.000

      Manufacturer:
      Model:
      Serial Number:

_____________________________________________________________
Gyro Sensor:

      Time Stamp:  2006-064 00:00

      Comments: (null)
      Time Correction(s) 0.000

      Entry 0) Draft: 0.000   Speed: 0.000
_____________________________________________________________
Heave Sensor:

      Time Stamp:  2006-064 00:00

      Comments: Caris TechNote - SV Corrections for Simrad.pdf  072303
      Apply No
      Time Correction(s) 0.000
      DeltaX:     0.000
      DeltaY:     0.000
      DeltaZ:     0.000
      Offset:     0.000
```

```
      Manufacturer:      (null)
      Model:             (null)
      Serial Number:     (null)

_____________________________________________________________
Pitch Sensor:

      Time Stamp:  2003-111 00:00

      Comments: Caris TechNote - SV Corrections for Simrad.pdf  072303
      Apply No
      Time Correction(s) 0.000
      Pitch offset: 0.000

      Manufacturer:      (null)
      Model:             (null)
      Serial Number:     (null)

_____________________________________________________________
Roll Sensor:

      Time Stamp:  2006-064 00:00

      Comments: Caris TechNote - SV Corrections for Simrad.pdf  072303
      Apply No
      Time Correction(s) 0.000
      Roll offset: 0.000

      Manufacturer:      (null)
      Model:             (null)
      Serial Number:     (null)

_____________________________________________________________
Draft Sensor:

      Time Stamp:  2006-064 00:00

      Apply Yes
      Comments: (null)
      Time Correction(s) 0.000

      Entry 1) Draft: 0.007   Speed: 5.054
      Entry 2) Draft: 0.041   Speed: 6.143
      Entry 3) Draft: 0.002   Speed: 7.911
      Entry 4) Draft: 0.032   Speed: 9.778

_____________________________________________________________
TPU

      Time Stamp:  2006-064 00:01

      Comments:
      Offsets
```

```
      Motion sensing unit to the transducer 1
            X Head 1 1.856
            Y Head 1 0.074
            Z Head 1 1.800
      Motion sensing unit to the transducer 2
            X Head 2 0.000
            Y Head 2 0.000
            Z Head 2 0.000
      Navigation antenna to the transducer 1
            X Head 1 6.596
            Y Head 1 5.760
            Z Head 1 17.984
      Navigation antenna to the transducer 2
            X Head 2 0.000
            Y Head 2 0.000
            Z Head 2 0.000

      Roll offset of transducer number 1 -0.014
      Roll offset of transducer number 2 0.000

      Heave Error: 0.050 or 5.000'' of heave amplitude.
      Measurement errors: 0.020
      Motion sensing unit alignment errors
      Gyro:0.000  Pitch:0.000 Roll:0.000
      Gyro measurement error: 0.020
      Roll measurement error: 0.020
      Pitch measurement error: 0.020
      Navigation measurement error: 2.000
      Transducer timing error: 0.000
      Navigation timing error: 0.010
      Gyro timing error: 0.010
      Heave timing error: 0.010
      PitchTimingStdDev: 0.010
      Roll timing error: 0.010
      Sound Velocity speed measurement error: 0.600
      Surface sound speed measurement error: 0.500
      Tide measurement error: 0.010
      Tide zoning error: 0.100
      Speed over ground measurement error: 0.250
      Dynamic loading measurement error: 0.000
      Static draft measurement error: 0.100
      Delta draft measurement error: 0.150
      StDev Comment: (null)
```

```
Svp Sensor:

      Time Stamp:  2006-064 00:00

      Comments: (null)
      Time Correction(s) 0.000

      Svp #1:
      -------------
      Pitch Offset:     0.000
```

```
Roll Offset:      0.000
Azimuth Offset:   0.000

DeltaX:     1.856
DeltaY:     0.811
DeltaZ:     1.676

SVP #2:
-------------
Pitch Offset:     0.000
Roll Offset:      0.000
Azimuth Offset:   0.000

DeltaX:     0.000
DeltaY:     0.000
DeltaZ:     0.000


Time Stamp:  2007-044 00:00

Comments: (null)
Time Correction(s) 0.000

Svp #1:
-------------
Pitch Offset:     0.000
Roll Offset:      0.000
Azimuth Offset:   0.000

DeltaX:     1.856
DeltaY:     0.811
DeltaZ:     1.676

SVP #2:
-------------
Pitch Offset:     0.000
Roll Offset:      0.000
Azimuth Offset:   0.000

DeltaX:     0.000
DeltaY:     0.000
DeltaZ:     0.000


Time Stamp:  2008-051 00:00

Comments: (null)
Time Correction(s) 0.000

Svp #1:
-------------
Pitch Offset:     0.000
Roll Offset:      0.000
Azimuth Offset:   0.000
```

```
      DeltaX:     1.856
      DeltaY:     0.811
      DeltaZ:     1.676

      SVP #2:
      -------------
      Pitch Offset:     0.000
      Roll Offset:      0.000
      Azimuth Offset:   0.000

      DeltaX:     0.000
      DeltaY:     0.000
      DeltaZ:     0.000
```

```
WaterLine:

      Time Stamp:  2006-064 00:00

      Comments:
      Apply No
      WaterLine -2.030
```

---

communications
Power & Control Systems Group
PacOrd

2/8/2006

Subj : NOAA SHIP Nancy Foster Survey

Ref: (a) SW225-AO-MMA-010/OP762/ALIGN THEORY, Theory of Combat System Alignment
(b) Table 1 of ITEM NO. 501

Encl: (1) Foundation Leveling Data Sheets

PacOrd personnel accomplished the survey of the equipment listed in table 1 of work item # 501 on board the NOAA SHIP Nancy Foster.

The granite blocks Roll and Pitch planes were set to the ship's gravity plane. The granite block was then used as the reference for all readings requiring a comparison to the ship's gravity plane.

The ship's centerline was transferred up from the keel, to the granite block 0°-180° reference line through an access cut into the hull of the ship. The granite block reference lines were then used as the reference for all readings requiring centerline reference.

The IMU foundation had to be removed, drilled and tapped for the new style IMU and reset.

The 12KHZ Transducer pitch angle exceeds the ±0.25° allowed by four minutes (reading is +0.3166°), a waiver was received from NOAA for this condition.

All other readings are within tolerance.

The final survey data is summarized in enclosure (1).

Byron K. Dunn
CSA Engineer

IMU FWD Bench Mark	339.0	17.4	±0.5cm	-19.5	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°
IMU Alignment Cube	161.1	169.2	±0.5cm	-4.4	±0.5cm	0.0000	±0.1°	-0.0111	±0.01°	-0.0528	±0.01°
ADCP AFT Bench Mark	-1169.8	-26.7	±0.5cm	-38.4	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°
ADCP FWD Bench Mark	-148.7	-26.7	±0.5cm	-38.4	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°
ADCP Alignment Cube	-668.5	-208.0	±0.5cm	18.4	±0.5cm	0.0000	±0.1°	0.0389	±0.01°	0.0444	±0.01°
Gyro Bench Mark Fwd	216.5	22.4	±0.5cm	-1164.5	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°
Gyro Bench Mark Aft	-98.5	22.4	±0.5cm	-1156.9	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°
Keel Bench Mark Fwd	318.6	1.9	±0.5cm	108.3	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°
Keel Bench Mark Aft	-118.3	1.9	±0.5cm	108.3	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°
12Khz Stbd	-634.4	-157.8	±5cm	154.6	±2cm	N/A	-	0.3167	±0.25°	-0.1167	±0.25°
200KHZ Transducer	-236.7	-90.2	±5cm	108.3	±2cm	N/A	-	0.0917	±0.25°	-0.0333	±0.25°
Moon Pool Adapter	-2248.7	121.3	±5cm	111.8	±2cm	N/A	-	-0.0250	±0.25°	0.1500	±0.25°

Port Down = Positive

Bow Down = Positive

X dimension readings forward of Granite Block = positive, aft of Granite Block =negative

Y dimension readings starboard of Granite Block = positive, port of Granite Block =negative

Z dimension readings lower than Granite Block = positive, higher than Granite Block =negative

Figure 3-53. Sign Polarity Convention

NOAA Ship Nancy Foster, R-352
Orthogonal Survey & Sonar Installation
February 2011

FINAL REPORT

February 28, 2011

Prepared By:
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NOAA Ship Nancy Foster
Orthogonal Survey February 2011
Final Report- Rev "0"

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PROJECT OVERVIEW

REVISIONS:

Rev. 0 – Initial Release February 28, 2011

NOAA Ship Nancy Foster
Orthogonal Survey February 2011
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PROJECT OVERVIEW

Purpose

The purpose of this commentary is to summarize the procedures and analytical methods employed to perform the 3-D coordinate total station inspection that produced the data in this report for those unfamiliar with the equipment and process.

Dimensional data resulting from the inspection is included with the report.

General Comments

This report summarizes coordinate measurement data taken on the NOAA vessel Nancy Foster February 8 through 23, 2011. The vessel was located in a floating dry dock at Detyens Shipyard, Charleston, SC.

Coordinate measurements were taken to characterize the vessel and create the required reference coordinate system for reporting azimuth, pitch, roll and coordinate data.

Coordinate measurements were made to define elements as described in WI507 Rev 1.

3-D Coordinate Measurement Equipment

A Sokkia NET 1200 enhanced electronic total station operated through a notebook computer running New River Kinematics Spatial Analyzer™ measurement and analysis software was utilized. This system measures 3-D spherical coordinates by recording an azimuth and zenith angle simultaneously with the near infrared distance coaxial with the telescope line of sight for each observation. Spatial Analyzer measurement and analysis software converts the spherical coordinate data to a Cartesian coordinate system that can be defined by the user. Measurements are made to either adhesive or kinematic targets that have a retro-reflective target face.

Temporary "benchmarks" or reference points were placed throughout the dry-dock area and on the vessel as required to allow for re-locating the instrument to a new position or "Station" and tie all of the data to the common coordinate system for comparison.

The measuring system used for this final inspection report is one of several owned by The IMTEC Group, Ltd. The NET 1200 total station, S/N 110350 was calibrated, traceable to N.I.S.T. and in accordance with A.N.S.I. Z-540-1, at the Sokkia USA Factory Service Center June 14, 2010.

NOAA Ship Nancy Foster
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Nomenclature

In order to communicate in the language of large-scale metrology, Key terms used in this report are presented.

- Benchmark- A mark on a stable object of predetermined position and elevation used as a reference point.
- Best-Fit-The condition whereby the values of the parameters of a mathematical model (such as a shape like a rectangle) are derived by computing the model values to a set of measured targets. When the result is optimized, it is also referred to as a least-squares adjusted fit.
- Buck In-To align to or set a line of sight to a predetermined axis
- Coordinate system-A 3-dimensional space defined by mutually orthogonal lines to which points are referenced
- Observation-The distance and horizontal and zenith angles obtained from a single pointing of a total station to a point of interest or target.
- Target- A *Target* is defined as a point that is determined directly from measurements
- Transformation-The mathematical relationship between targets and/or points in different systems. When a transformation is computed, the values of the parameters that define the mathematical model are solved for.
- Transform-To compute the orientation of a Station, Group, System or Frame relative to another Station, System, Group or Frame.

Reference Coordinate System

The following parameters were used to define the reference coordinate system for reporting the survey data:

Origin:	Top Dead Center of the Granite Block, X=0.000, Y=0.000, Z=0.000
X-Axis:	Line faired through the centerline of the keel from Frames 10 to 82 at ~10 frame intervals
Y-Axis:	Orthogonal to X-Axis
Z-Axis:	Perpendicular to Keel Plane, orthogonal to X-Axis
Rotation:	Pitch set by Keel Plane, Roll set by Fantail plane
System:	X+ Fwd, Y+ Stbd, Z+ Down (towards keel)

Measurement Procedure

Adhesive targets with retro reflective target face were used throughout the survey as temporary benchmarks for relocating the instrument to new stations. Kinematic (a target with a known offset) retro reflective targets such as the RT-50M swivel targets used to measure some of the features defining the specified elements to be reported. The RT-50M was also frequently used as a temporary benchmark. Where possible, a retro reflective surface target was used to eliminate any offsets.

The Sokkia NET 1200 total station operated through a notebook computer running Spatial Analyzer™ industrial measurement software was used to measure the targets and record observations.

NOAA Ship Nancy Foster
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Vessel Features

- The Granite Block was surveyed and used as the Origin for this survey. This required an access hole to be cut in the hull on the port side of the vessel just above the keel.
- The location of the POS MV GPS antennae.
- Request was made to survey the existing IMU. As-found survey data showed it to be 11' 33" to Stbd which confirmed what shipboard personnel suspected. Decision was made to adjust it back to zero azimuth. Due to the mounting configuration, inclination was disturbed while adjusting the azimuth and was also reset as close as achievable to the ship's pitch and roll planes.
- Request was made to survey the location of the existing EM 1002 transducer in the Stbd side fairing.

The alignment team assisted with the installation of the following components:

- Reson Seachest – Verified installation met azimuth and inclination requirements of 1° Heading, 1°- 2°Pitch & 1°Roll.
- Reson 7125 Multibeam system – Derived final coordinates to the Main, 200 KHz & 400 KHz transducers. Heading, Pitch and Roll values not required by Reson.
- New Port Fairing – Assisted shipyard personnel with proper fit-up of fairing to hull by providing a cut line around the perimeter where it would meet the hull. During installation, the fairing was set to < .5 degree Azimuth and Inclination relative to the vessel.
- Original ADCP 150 KHz and Knudsen 12 KHz transducers were reinstalled in the new fairing. The mounting rings were set to within the azimuth and inclination specification from WI507 Rev 1, page 507-10, Table 1 and monitored during the welding process to ensure they remained within the required specification.
- A new Simrad EK60 Echo Sounder system consisting of 4 transducers was also installed in the new port fairing. The mounting rings for this system were verified for required azimuth and inclination as well and coordinates were obtained to the center of each.
- A Valeport SVS was installed on the Stbd side of the hull aft of frame 31 and coordinates obtained to the center of the probe face in the extended position.

NOAA Ship Nancy Foster
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3-D X, Y, Z coordinates, Post Processing

In some cases, the features or targets defining the elements required by the survey were made to a kinematic target with a known offset orthogonal to the vessel's final reference coordinate system. After the each survey was complete, these offsets were applied to report the final X, Y, Z value of the element.

The pitch and roll values for the planer elements were processed mathematically in the Spatial Analyzer software. The azimuths were also processed mathematically from data points recorded during the survey.

Data files

One measurement file was used to perform the survey.

All measurement files were backed up at the completion of a set of observations from a particular station and on a daily basis.

The measurements were performed from different instrument locations referred to as "Stations", e.g. Sta 0, Sta 1, Sta N, etc.

Station transformations are used to bring a new instrument location into the current vessel coordinate system (see measurement procedure). The result produces some residuals.

Measurement Precision and Uncertainty

Based on a sample analysis of the results of the observations taken during the performance of this inspection, the Spatial Analyzer software reports a maximum standard deviation of slightly less than 1 mm for all observations.

Based on 125 sample observations:

Ux Ave = 0.8mm
Uy Ave = 0.8mm
Uz Ave = 1.0mm
Umax = 1.2 mm

Uncertainties are reported to be:

Point to Point, any element or target within the vessel survey to another element or feature in the survey

$X, Y, \& Z \leq 2.0$ mm

Region to Region, i.e., GPS antenna to Reason Sea Chest :

$X \leq 3.0$ mm

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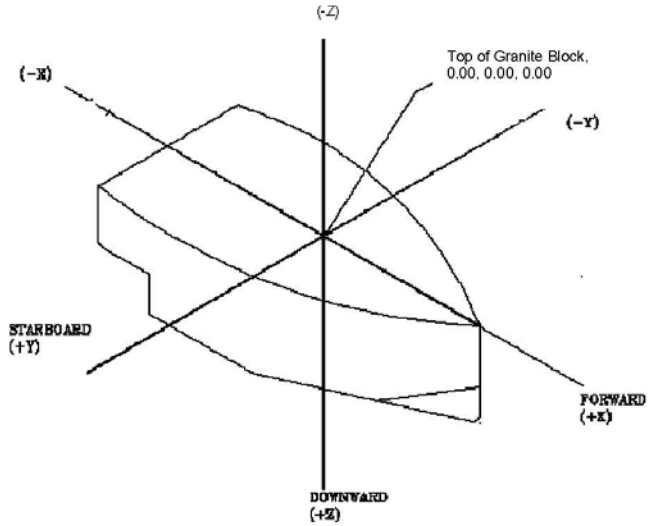
$Y \leq 3.0$ mm
$Z \leq 3.0$ mm

Angular precision is based on analysis of features measured and calculation of the mathematical relationship of these features.

The angular measurement precision of the NET1200 is < 1 arc second in azimuth and zenith. There can be some error introduced by targeting. Random and systematic errors can be introduced by the working environment.

The expected angular precision is analyzed to be:

Azimuth:	≤ 00°00' 30"
Pitch:	≤ 00°01' 30"
Roll:	≤ 00°01' 30"



Vessel Coordinate System, Nancy Foster

NOAA Ship Nancy Foster
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Table 1 - NOAA Nancy Foster Element Coordinate Summary - February 2011
(Dimensions in Centimeters)

Ship Elements	X	Y	Z
GRANITE BLOCK (1)	0.0	0.0	0.0
IMU (2)	73.9	-0.2	-12.0
FWD POS/MV ANTENNA	657.7	-475.0	-1629.3
AFT POS/MV ANTENNA	431.7	-473.4	-1627.9
ADCP 150 KHZ	-603.7	-156.3	155.1
KNUDSEN 12 KHZ TRANSDUCER	-721.9	-155.7	154.8
EM 1002 MULTIBEAM	82.4	182.3	169.7
EK60 - ES120-7C (3)	-559.3	-156.4	154.9
EK60 - ES38-B (3)	-661.1	-156.0	154.6
EK60 - ES70-C (3)	-775.7	-155.5	153.2
EK60 - ES200-7C (3)	-810.4	-155.4	153.3
RESON 7125 - MAIN	-173.3	54.7	108.4
RESON 7125 - 200KHZ	-217.8	67.8	109.9
RESON 7125 - 400KHZ	-217.9	39.7	109.9
VALEPORT SVS	-357.5	155.2	110.6

Benchmarks	X	Y	Z
IMU FWD	339.3	23.5	-19.6
IMU AFT	-146.7	23.9	-19.5
IMU ALIGNMENT CUBE TOP CENTER	161.5	178.5	-7.5
AFT DECK PORT	-3783.5	-527.0	-384.3
AFT DECK STBD	-3782.7	525.2	-385.1
AFT DECK ALIGNMENT CUBE TOP CENTER	-3592.3	583.2	-469.3
FLYING BRIDGE PORT	468.9	-562.4	-1421.9
FLYING BRIDGE STBD	469.3	558.6	-1420.5
FLYING BRIDGE ALIGNMENT CUBE TOP	648.4	0.0	-1431.0
KEEL FWD	279.4	-1.5	110.9
KEEL AFT	-171.6	-1.4	110.2

Notes:
(1) Granite Block grouted in place.
(2) IMU was repositioned to ship's Heading, Pitch and Roll
(3) Measurements are to the center of mounting face. Additional offset to transducer face has not been applied.

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NOAA Ship Nancy Foster
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Table 2 - NOAA Nancy Foster Pitch, Roll & Heading Summary - February 2011
Decimal Degrees

Ship Elements	Azimuth	Rotation	Pitch	Rotation	Roll	Rotation
GRANITE BLOCK	-0.0442	PORT	0.0698	Bow Up	-0.0025	Stbd Up
IMU	-0.0006	PORT	0.0075	Bow Up	-0.0169	Stbd Up
FWD POS/MV ANTENNA	N/A		N/A		N/A	
AFT POS/MV ANTENNA	N/A		N/A		N/A	
ADCP 150 KHZ	-0.2284	PORT	-0.0938	Bow Dn	-0.0146	Stbd Up
KNUDSEN 12 KHZ TRANSDUCER	0.0319	STBD	-0.0147	Bow Dn	-0.0818	Stbd Up
EM 1002 MULTIBEAM	N/A		N/A		N/A	
EK60 - ES120-7C	0.7459	STBD	0.4399	Bow Up	-0.8502	Stbd Up
EK60 - ES38-B	-1.1866	PORT	-0.2496	Bow Dn	-0.4000	Stbd Up
EK60 - ES70-C	-0.6582	PORT	-0.1178	Bow Dn	-0.3949	Stbd Up
EK60 - ES200-7C	-0.7286	PORT	-0.2808	Bow Dn	0.3034	Stbd Dn
RESON SEACHEST	-0.0369	PORT	0.3439	Bow Up	0.3027	Stbd Dn

NOAA Ship Nancy Foster
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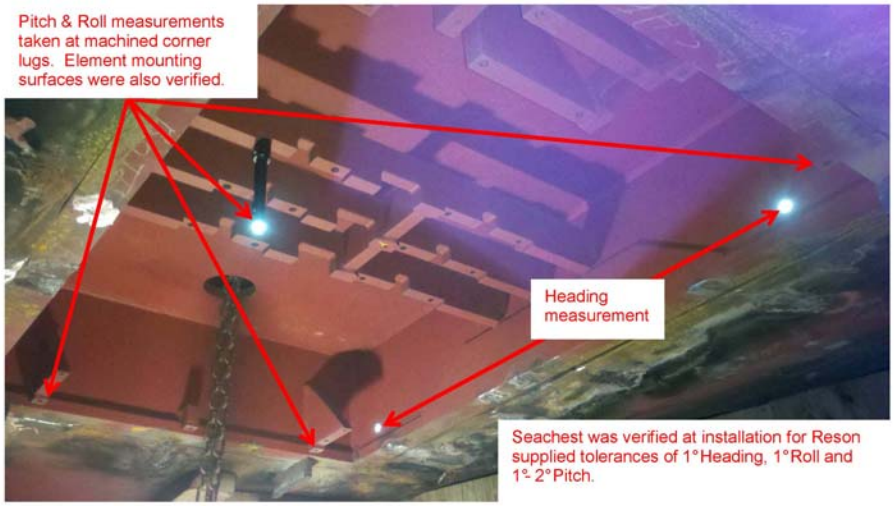
Reson 7125 Sea Chest



Reson 7125 Elements

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NOAA Ship Nancy Foster
Orthogonal Survey February 2011
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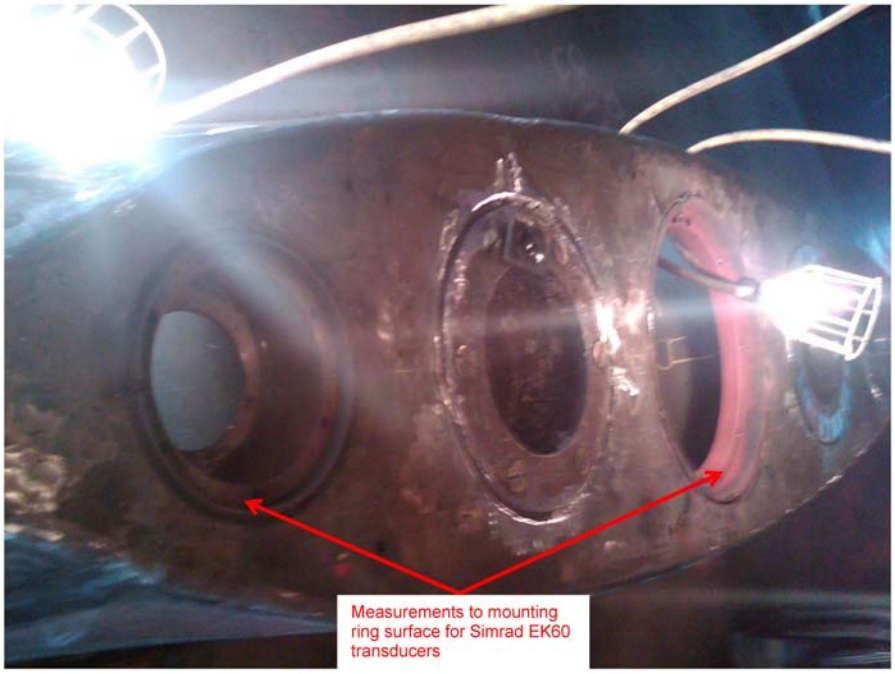
New Port Fairing Transducer Rings



Valeport SVS

POS MV ANTENNA

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APPENDIX II
POS/MV 320 V4 CONFIGURATION REPORTS

Extract POS COnfig Version 1.0

October 20 2010 04:12 pm

Source Name: POS_EM1002_Config.nvm
Output File: C:\Users\bfrancis\Desktop\EM1002\302_posconfig

Message 37 - Base GPS 1 Setup

Input Data Type Port 1 - Accept RTCM 1/9

Message 38 - Base GPS 2 Setup

Input Data Type Port 2 - Accept RTCM 1/9

Message 34 - COM Port Setup

Number of COM ports = 5
COM1 - Protocol: 19200,No Parity,8 data,1 stop,None
Input Selection: No Input
Output Selection: NMEA Message

COM2 - Protocol: 19200,No Parity,8 data,1 stop,None
Input Selection: No Input
Output Selection: Real-time Binary

COM3 - Protocol: 9600,No Parity,8 data,1 stop,None
Input Selection: Base GPS 1
Output Selection: NMEA Message

COM4 - Protocol: 115200,No Parity,8 data,1 stop,None
Input Selection: No Input
Output Selection: Real-time Binary

COM5 - Protocol: 19200,No Parity,8 data,1 stop,None
Input Selection: No Input
Output Selection: NMEA Message

xx

Message 51 - Display Port Control

Number of groups selected for Display Port = 25
1 2 3 4 5 6 7 8 9 10 11 12
13 14 17 20 23 24 99 102 103 104 105 110
20000

Message 53 - Logging Port Control

Number of groups selected for Logging Port = 0
Logging Port Output Rate 1 Hz
AutoLog Select Disabled

Message 135 - NMEA Message Select

Number of Port 3
Assigned port number COM1
Update Rate Selection 1 Hz
Output Selection GGA ZDA VTG
talker ID $IN
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Heave Up
Assigned port number COM3
Update Rate Selection 1 Hz
Output Selection GGA HDT ZDA VTG SHR UTC
talker ID $IN
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Heave Up
Assigned port number COM5
Update Rate Selection 1 Hz
Output Selection ZDA
talker ID $IN
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Heave Up

Message 136 - Binary Message Select

Number of Port 2
Assigned port number COM2
Update Rate Selection 100 Hz

Output Selection SIMRAD-1000(TB)
Selected frame Sensor1
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Heave Up

Assigned port number COM4
Update Rate Selection 50 Hz
Output Selection TSS
Selected frame Sensor1
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Heave Up

Message 33 - Event Discrete Setup

Event 1 Trigger Positive edge
Event 2 Trigger Positive edge

Message 30 - Primary GPS Setup

GPS AutoConfig True

Message 31 - Secondary GPS Setup

GPS AutoConfig True

Message 24 - User Accuracy Specifications

User Attitude Accuracy 0.05
User Heading Accuracy 0.05
User Position Accuracy 2
User Velocity Accuracy 0.5

Message 52 - Real-time Data Port Control

Number of groups selected for Real-time Data Port = 5
3 7 20 102 111
Data Port Output Rate 50 Hz

Message 61 - Data Port Control

Number of groups selected for Data Port = 15
1 2 4 5 9 10 99 102 110

Ref to IMU Lever Arm 0.738 0.001 -0.125 [Wavemaster User => 0.730 -0.021 -0.052]
Ref to Pri GPS Lever Arm 6.571 -4.740 -16.308
Ref to Aux1 GPS Lever Arm 5.371 -4.740 -16.308
Ref to Aux2 GPS Lever Arm 0.000 0.000 0.000
IMU to Ref Mounting Angle 0.000 111 113 10001 10009 10011 10012
Data Port Output Rate 20 Hz

Message 20 - General Installation Parameters

0.000 0.000
AutoStart Enabled
Multipath Low

Message 120 - Sensor Parameter Set-up

Sensor1 Ref Mount Angle 0.000 0.000 0.000
Sensor2 Ref Mount Angle 0.000 0.000 0.000
Ref Sensor1 Lever Arm 0.000 0.000 0.000
Ref Sensor1 Lever Arm 0.000 0.000 0.000
Ref to CoR Lever Arm -12.295 0.000 -1.965

Message 121 - Vessel Installation Parameter Set-up

Ref to Vessel Lever Arm 0.000 0.000 0.000

Message 106 - Heave Filter Set-up

Heave Bandwidth 12.000
Heave Damping Ratio 0.707

Message 105 - Analog Port Set-up

Roll Scale 1.00
Pitch Scale 1.00
Heave Scale 1.00
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Clockwise
Formula Select - TSS Trig
Analog Port Enabled True
Output Frame Sensor 1

Message 21 - GAMS Installation Parameters

Two Antenna Separation 2.253
Baseline Vector -2.253 0.027 0.011
Heading Calibration Threshold 0.700
Heading Correction 0.000

Extract POS COnfig Version 1.0
Copyright (C) 2006 Applanix - A Trimble Company

October 20 2010 04:11 pm

Source Name: POS_7125_Config.nvm
Output File: C:\Users\bfrancis\Desktop\7125\7125_posconfig

Message 37 - Base GPS 1 Setup

Input Data Type Port 1 - Accept RTCM 1/9

Message 38 - Base GPS 2 Setup

Input Data Type Port 2 - Accept RTCM 1/9

Message 34 - COM Port Setup

Number of COM ports = 5
COM1 - Protocol: 19200, No Parity, 8 data, 1 stop, None
Input Selection: No Input
Output Selection: NMEA Message

COM2 - Protocol: 19200, No Parity, 8 data, 1 stop, None
Input Selection: No Input
Output Selection: Real-time Binary

COM3 - Protocol: 9600, No Parity, 8 data, 1 stop, None
Input Selection: Base GPS 1
Output Selection: NMEA Message

COM4 - Protocol: 115200, No Parity, 8 data, 1 stop, None
Input Selection: No Input
Output Selection: Real-time Binary

COM5 - Protocol: 19200, No Parity, 8 data, 1 stop, None
Input Selection: No Input
Output Selection: NMEA Message

Message 51 - Display Port Control

Number of groups selected for Display Port = 25
1 2 3 4 5 6 7 8 9 10 11 12
13 14 17 20 23 24 99 102 103 104 105 110
20000

Message 53 - Logging Port Control

Number of groups selected for Logging Port = 0
Logging Port Output Rate 1 Hz
AutoLog Select Disabled

Message 135 - NMEA Message Select

Number of Port 3
Assigned port number COM1
Update Rate Selection 1 Hz
Output Selection GGA ZDA VTG
talker ID $IN
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Heave Up
Assigned port number COM3
Update Rate Selection 1 Hz
Output Selection GGA HDT ZDA VTG SHR UTC
talker ID $IN
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Heave Up
Assigned port number COM5
Update Rate Selection 1 Hz
Output Selection ZDA
talker ID $IN
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Heave Up

Message 136 - Binary Message Select

Number of Port 2
Assigned port number COM2
Update Rate Selection 100 Hz
Output Selection SIMRAD-1000(TB)
Selected frame Sensor1
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Heave Up

Assigned port number COM4
Update Rate Selection 50 Hz
Output Selection TSS
Selected frame Sensor1
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Heave Up

Message 33 - Event Discrete Setup

Event 1 Trigger Positive edge
Event 2 Trigger Positive edge

Message 30 - Primary GPS Setup

GPS AutoConfig True

Message 31 - Secondary GPS Setup

GPS AutoConfig True

Message 24 - User Accuracy Specifications

User Attitude Accuracy 0.05
User Heading Accuracy 0.05
User Position Accuracy 2
User Velocity Accuracy 0.5

Message 52 - Real-time Data Port Control

Number of groups selected for Real-time Data Port = 5
3 7 20 102 111
Data Port Output Rate 50 Hz

Message 61 - Data Port Control

Number of groups selected for Data Port = 15
1 2 4 5 9 10 99 102 110 111 113 10001
10009 10011 10012
Data Port Output Rate 20 Hz

Message 20 - General Installation Parameters

Ref to IMU Lever Arm	-0.000	-0.000	0.000	[Wavemaster User => -0.008 -0.022 0.073]
Ref to Pri GPS Lever Arm		5.833	-4.470	-16.183
Ref to Aux1 GPS Lever Arm		5.371	-4.740	-16.308
Ref to Aux2 GPS Lever Arm		0.000	0.000	0.000
IMU to Ref Mounting Angle		0.000	0.000	0.000

AutoStart Enabled
Multipath Low

Message 120 - Sensor Parameter Set-up

Sensor1 Ref Mount Angle	0.000	0.000	0.000	
Sensor2 Ref Mount Angle	0.000	0.000	0.000	
Ref Sensor1 Lever Arm	0.000	0.000	0.000	
Ref Sensor1 Lever Arm		0.000	0.000	0.000
Ref to CoR Lever Arm		0.000	0.000	0.000

Message 121 - Vessel Installation Parameter Set-up

Ref to Vessel Lever Arm	0.000	0.000	0.000

Message 106 - Heave Filter Set-up

Heave Bandwidth 12.000
Heave Damping Ratio 0.707

Message 105 - Analog Port Set-up

Roll Scale 1.00
Pitch Scale 1.00
Heave Scale 1.00
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Clockwise
Formula Select - TSS Trig
Analog Port Enabled True

Output Frame Sensor 1

Message 21 - GAMS Installation Parameters

Two Antenna Separation 2.253
Baseline Vector -2.253 0.027 0.011
Heading Calibration Threshold 0.700
Heading Correction 0.000