U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

# DATA ACQUISITION & PROCESSING REPORT

Type of Survey: Hydrographic Survey

Project Number: OPR-K339-KR-12

Time Frame: May-July 2012

## LOCALITY

State: Louisiana

General Locality: Gulf of Mexico

Sub-locality: Approaches to Barataria Bay, LA

**2012**

CHIEF OF PARTY

George G. Reynolds

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Date:

| NOAA FORM 77-28<br>(11-72) | U.S. DEPARTMENT OF COMMERCE<br>NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION | REGISTRY NUMBERS: |
|---|---|---|
| **HYDROGRAPHIC TITLE SHEET** | | H12425, H12426<br>H12427, H12428 |

| | |
|---|---|
| State: | **Louisiana** |
| General Locality: | **Gulf of Mexico** |
| Sub-Locality: | **Approaches to Barataria Bay, LA** |
| Scale: | **1:20,000 & 1:40,000** |
| Date of Survey: | **May 25, 2012 to July 9, 2012** |
| Instructions Dated: | **March 30, 2012** |
| Project No.: | **OPR-K339-KR-12** |
| Vessel: | **R/V Ferrel - Official Number 1182802** |
| Chief of Party: | **George G. Reynolds** |
| Surveyed By: | **Ocean Surveys, Inc.** |
| Soundings by: | **Multibeam Echosounder** |
| Imagery by: | **Side Scan Sonar** |
| Verification by: | **Atlantic Hydrographic Branch** |
| Soundings Acquired in: | **Meters at MLLW** |
| H-Cell Compilation Units: | |

Remarks: The purpose of this survey is to update existing NOS nautical charts in a high commercial traffic area. All times are recorded in UTC. Data recorded and presented relative to UTM Zone 16 North.

Contractor: Ocean Surveys, Inc.
129 Mill Rock Rd E
Old Saybrook, CT 06475

THE INFORMATION PRESENTED IN THIS REPORT AND THE ACCOMPANYING BASE SURFACES REPRESENTS THE RESULTS OF SURVEYS PERFORMED BY OCEAN SURVEYS, INC. DURING THE PERIOD OF 25 MAY 2012 TO 9 JULY 2012 AND CAN ONLY BE CONSIDERED AS INDICATING THE CONDITIONS EXISTING AT THAT TIME. REUSE OF THIS INFORMATION BY CLIENT OR OTHERS BEYOND THE SPECIFIC SCOPE OF WORK FOR WHICH IT WAS ACQUIRED SHALL BE AT THE SOLE RISK OF THE USER AND WITHOUT LIABILITY TO OSI.

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**APPENDICES**

I Vessel Reports
II Echosounder Reports
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# A. EQUIPMENT

## A.1 Survey Vessel: *R/V Ferrel*

All survey operations were conducted from the *R/V Ferrel* (Figure 1). *R/V Ferrel*, O.N. 1182802, is a 44.5-meter steel vessel, with a 9.8-meter beam and 1.8-meter draft. *R/V Ferrel* is powered by two CAT D 353 diesel engines.


Figure 1. *R/V Ferrel* configured for hydrographic survey operations.

The *R/V Ferrel* was modified to support hydrographic survey operations by Oceans Surveys, Inc, hereinafter referred to as OSI. The following summarizes the major adaptations and/or custom survey support hardware installed on the *R/V Ferrel*:

1. An ISO office container was installed on the main deck to house acquisition and processing computer stations along with major survey system control modules and computer systems.
2. A measured and indexed Inertial Measurement Unit (IMU) mounting plate was installed on the ship's fore-aft (roll) centerline at the approximate pitch center of rotation. The POS-MV IMU was installed on this plate which resides just below the plane of the ship's waterline on the lower deck.

3. A retractable multibeam transducer pole, constructed of thick-wall steel pipe, was attached to the starboard side of the vessel at the approximate pitch centerline. The pole was attached at two points; a “saddle plate” on the deck of the vessel and a “receiver plate” at the chine of the vessel. The transducer pole is forced, by means of a wire rope winch connection, into the V-notch receiver plate, thereby eliminating pole movement. The transducer pole was fitted with fairings on the trailing edge to minimize cavitation. The bottom of the transducer pole was fitted with termination flange configured with a small copper orifice. This configuration allowed the transducer pole to be used as a stilling well.
4. A hydraulically actuated A-frame was installed on the starboard quarter of the ship. The SSS towfish was flown from the A-frame. Two (2) electric/hydraulic multi-purpose slip ring winches (SSS primary and spare) were installed on the main deck.
5. A moving vessel profiler (MVP) was installed on the port quarter of the ship.

A full survey of the *R/V Ferrel* was conducted March 31, 2010 by OSI during which reference points (permanent shipboard benchmarks) were established on the *R/V Ferrell* to define a fixed reference frame, vessel reference point (RP), draft measurement locations and sensor mounting locations. These points were “surveyed” using a precision total station optical theodolite and electronic distance meter while the vessel was hauled out and held static at a dry dock facility.

Prior to the start of survey operations for OPR-K339-KR-12, a full offset verification to confirm instrument and shipboard benchmark locations aboard the *R/V Ferrel* was completed by OSI employing a steel tape measure on May 24, 2012. All checks confirmed values derived during the original full static survey.

The multibeam transducer pole is capable of variable draft settings. During the 2012 vessel mobilization (and subsequent multibeam system change) the transducer phase center-to-RP value was established relative to shipboard benchmarks employing a steel tape measure. Survey offsets and estimated measurement accuracies were incorporated into the CARIS vessel configuration file.

Major data acquisition system components employed on this survey are summarized in Table 1 below. A brief description of the equipment follows.

**Table 1**
**Acquisition Equipment**

| System | Data | Manufacturer | Model/ Version No. | Firmware/Software Ver. | Serial Number (s) |
|---|---|---|---|---|---|
| Side Scan Sonar | Imagery/Contacts | Klein | 5000 | N/A | 357 |
| Multibeam Echo Sounder Processor | Soundings | Reson | 7101 | 7K Center SW Ver. 4.5.3.1 | 1815022 |
| Multibeam Echo Sounder Transducer | Soundings | Reson | 7101 | 8101.1.08.C215 | 3707078 |
| Multibeam Echo Sounder Processor | Soundings | Reson | 7125 | SV2 FP2.1 /4.5.10.3 | 1820proto004 |
| Multibeam Echo Sounder Transducer | Soundings | Reson | 7125 | Projector<br>Receiver | TC2181<br>EM7216 |
| Sound Speed Profiler (2) | QC Comparison Sound Speed | Sea-Bird | SeaCAT SBE 19+ CTD | 2.3 | 6359<br>6513 |
| Surface Sound Speed (2) | Sound Speed | Sea-Bird | MicroCAT SBE37 | 3.1 | 6372<br>7531 |
| Moving Vessel Profiler | Sound Speed | ODIM | MVP-30 | N/A | 10646 |
| Sound Speed/Depth (2) | Sound Speed | AML | Micro SVPT | N/A | 201521 (7786)<br>201527 (7777) |
| Navigation, Vessel Attitude & Heading | Position, Attitude, Heading | Applanix/ Trimble | POS MV 320 V.4 | HW 2.9-7<br>SW 05.03 | TPU 2483<br>IMU 390 |
| Navigation | Position | Trimble | MS750 | 1.58 | 220209817 |
| U.S.C.G. Differential Beacon Receivers (2) | DGPS correctors | Trimble | ProBeacon | 3 | 0220033958<br>0220181939 |
| SSS Cable Payout Indicator | SSS Fish Layback | Hydrographic Consultants | SCC16” | 2 | 1603 |
| Land Survey GPS | Position | Trimble | 5700 | V3.01 | 220332818 |
| Water Level Gauge | Static Draft | Hazen | HTG5000 | N/A | 363764R |

| System | Data | Manufacturer | Model/ Version No. | Firmware/Software Ver. | Serial Number (s) |
|---|---|---|---|---|---|
| Water Level and Atmospheric Pressure Logger | Static Draft | Onset | HOBO U20 | HOBOware Pro Ver. 3.2.2 | 10040116 10075523 |
| Lead Line | Bar Check | OSI | Lead Disk | N/A | M1 |
| Stadia Rod | Static Draft | Crain | CR-4.0M | N/A | OSI SR-02 |
| Autopilot | Vessel Steering | Simrad | AP50 | V1R4 | 22083083 |

## A.2 Echo Sounding Equipment

### A.2.1 Side Scan Sonar System

#### A.2.1.1 Klein 5000

Side scan sonar imagery was acquired employing a Klein 5000 single-frequency sonar operating at 455 kHz. The available range scales are 50, 75, 100, and 150 meters (m). The system was operated at 50, 75, and 100 m ranges. The system has an along-track resolution of 20 centimeters (cm) to 36 cm and an across-track resolution of 7.5 to 30 cm. The system consists of a Transceiver Processor Unit (TPU), coaxial double armored steel tow cable, hydraulic powered slip ring winch, digital cable payout meter, and sonar towfish. System components were interfaced to the acquisition system and other ancillary devices, via a local network hub or serial cable connections. The towfish was equipped with an optional pressure sensor which was used to measure towfish depth.

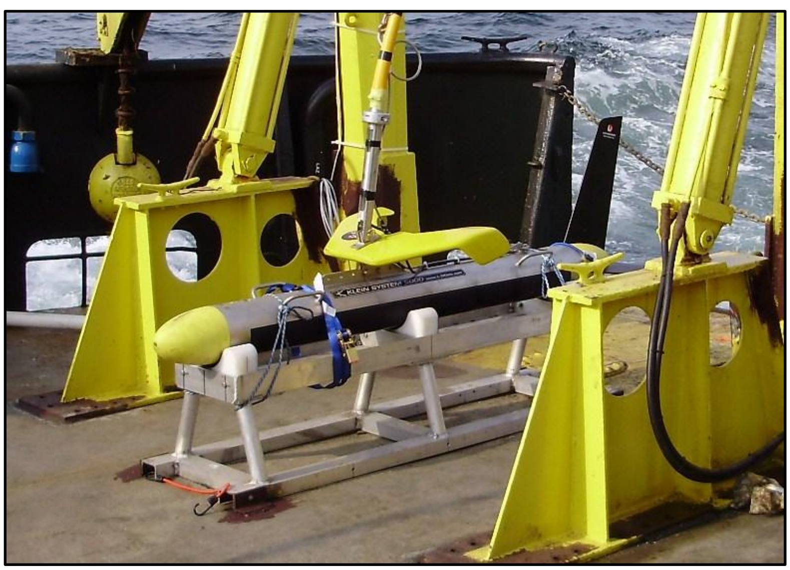


Figure 2. Klein 5000 on deck.

### A.2.2 Multibeam Echosounders

#### A.2.2.1 Reson SeaBat 7101

The SeaBat 7101 is a 240 kHz Multibeam Echosounder (MBES) System, which measures the relative water depths across a 150º wide swath perpendicular to a vessel's track. The 7101 system illuminates a swath of the seafloor that is 150º across track by 1.5º along track with a maximum ping rate of 40 Hz. The system can be configured to collect 239 or 511 equidistant beams (ED) or 101 equiangular beams (EA) with a depth resolution of 1.25 cm. The installed system was equipped with the Extended Range projector and designed to comply with International Hydrographic Organization (IHO) standards to measure seafloor depths to a maximum range of 500 meters. Digital data were output through the Ethernet data port and displayed in real time on a high-resolution color monitor.

Figure 3. Reson SeaBat 7101 transducer as mounted.

The transducer X, Y, Z position and angular offsets (relative to the vessel frame and the vessel reference position (RP)), were measured during the original full static survey (2010). These values were confirmed prior to Project OPR-K339-KR-12. The initial patch and performance tests employing the Reson 7101 were completed on May 26, 2012 (DN 147) prior to commencement of survey operations for Project OPR-K339-KR-12. Verification patch and performance tests were run on June 14-15, 2012 (DNs 166-167) prior to replacing the Reson 7101 with a Reson 7125. Patch test results are presented in Table 3 of DAPR Appendix II. Performance test results are summarized in Table 6 of DAPR Appendix II.

A.2.2.2 Reson SeaBat 7125

The SeaBat 7125 is a dual-frequency MBES System with operational frequencies of 200 kHz or 400 kHz. For project OPR-K339-KR-12, the echosounder's 400 kHz capability was employed. At this frequency the 7125 system illuminates a swath of the seafloor that is 140º across track by 1º along track with a maximum ping rate of 50 Hz. The system can be configured to collect 240 or 512 equidistant beams with a depth resolution of 6 mm. The 512-equidistant beam configuration was used for Project OPR-K339-KR-12. This sonar system, as equipped with the 400 kHz projector, is designed to comply with International Hydrographic Organization (IHO) standards to measure seafloor depths to a maximum range of 175 meters. Digital data were output through the Ethernet data port and displayed in real time on a high-resolution color monitor.

Figure 4. Reson 7125 transducer as mounted.

The transducer X, Y, Z position and angular offsets (relative to the vessel frame and a vessel reference position (RP)), were referenced to values derived during the original full static survey (2010). These values were confirmed during the "partial" survey prior to use of this sonar on Project OPR-K339-KR-12. A patch test and performance test were completed on June 15, 2012 (DN 167) prior to commencement of survey operations employing this sonar for Project OPR-K339-KR-12. A verification patch test and performance test were run on July 9, 2012 (DN 191) following the completion of survey operations. Patch test results are presented in Table 4 of DAPR Appendix II. Performance test results are summarized in Table 6 of DAPR Appendix II.

## A.3 Manual Sounding Equipment

### A.3.1 Lead Line

The lead line was constructed by OSI utilizing a 9 kilogram, 0.3-meter round lead disk attached to a stainless steel cable with permanent index markers established at measured 5-meter intervals.

Prior to survey data acquisition, the lead line was calibrated on May 24, 2012 (DN 145) with a steel survey tape to verify index mark accuracy.

## A.4 Positioning and Attitude Equipment

### A.4.1 Applanix POS MV

An Applanix POS MV 320 V.4 system was installed on the survey vessels to provide position and attitude data. The POS MV (Position and Orientation System for Marine Vessels) consists of a rack mountable POS Computer System (PCS), a separate Inertial Measurement Unit (IMU) and two GPS receivers.

The POS MV combines the IMU and GPS sensor data into an integrated and blended navigation solution. There are two navigation algorithms incorporated into the system, namely tightly coupled and loosely coupled inertial/GPS integration. Tightly coupled inertial/GPS integration involves the processing of GPS pseudo range, phase and Doppler observables. In this case, the GPS receiver is strictly a sensor of the GPS observables and the navigation functions in the GPS receiver are not used. With loosely coupled inertial/GPS integration, the GPS position and velocity solution are processed to aid the inertial navigator.

The POS MV generates attitude data in three axes (roll, pitch and heading). Roll and pitch measurements are made within an accuracy of 0.02°. Heave measurements supplied by the POS MV maintain an accuracy of 5-centimeters or 5% of the measured vertical displacement for movements that have a period of up to 20 seconds.

The GPS Azimuth Measurement Subsystem (GAMS) allows the POS MV system to achieve high-accuracy heading measurement. The GAMS subsystem uses two GPS receivers and antennas to determine a GPS-enhanced heading that is accurate to 0.02° or better (using a ≥two-meter antenna baseline) when blended with the inertial navigation solution. The system uses this heading information as aiding data together with the position, velocity and raw observations information supplied by the primary GPS receiver. GAMS heading was employed for all survey data acquisition and GAMS status was monitored continuously during survey operations using the MV-POSView controller software.

IMU and antenna offsets and mounting angles, relative to the vessel frame and a vessel RP, were measured during the original (2010) full static survey and confirmed prior to commencement of Project OPR-K339-KR-12. An Applanix-specified GAMS calibration procedure was conducted prior to survey data acquisition on May 25, 2012 (DN 145).

### A.4.2 DGPS

Individual Trimble Pro Beacon DGPS beacon receivers were manually tuned to one of the two local USCG differential beacon stations and interfaced to the project GPS systems (POS-MV and Trimble MS750). Refer to the Vertical and Horizontal Control Report for additional details of DGPS position correctors.

### A.4.3 Other Positioning and Attitude Equipment

#### A.4.3.1 Secondary Positioning: Trimble MS750

A secondary or “position integrity alarm” GPS system consisted of a Trimble MS750 GPS operating in DGPS mode.

#### A.4.3.2 SSS Cable Out Indicator

Determination of SSS cable out values was accomplished by means of a Hydrographic Consultant, Ltd. SCC Smart Sensor Cable Payout Indicator. The payout indicator consists of a topside display/controller, deck cable, and 16-inch (0.4-meter) diameter block fitted with a magnetically triggered counting sensor.

The cable out indicator was calibrated according to manufacturer specifications before data acquisition by measuring the sheave circumference and entering a calibration value into the topside controller software.

## A.5 Sound Speed Equipment

The surface sound speed sensor, the primary and secondary sound speed profilers, and the ODIM MVP were manufacturer calibrated just before survey data acquisition. Copies of the calibration sheets are included with the DR in Separate II.

### A.5.1 Sound Speed Profiles

#### A.5.1.1 CTD Profilers: SBE 19+ CTD

“Comparison Cast” water column conductivity, temperature, and pressure (depth) profiles were acquired using a Sea-Bird Electronics (SBE) 19+ SEACAT profiler CTD. The SBE 19+ SEACAT profiler acquires high resolution water column measurements at a continuous rate of 4 Hz.

A.5.1.2 Sound Speed Profilers: ODIM MVP30

The ODIM MVP30 Moving Vessel Profiler allows sound speed profiles to be collected while the vessel is underway. The ODIM MVP consists of towfish-mounted sensors (AML sound speed, temperature, and depth “micro SVPT”), a conductor cable, and an electric winch. The MVP may be deployed manually using the winch controls or remotely using the ODIM MVP Controller Software. When operated in “FreeWheel” mode while underway, the MVP falls near-vertically to a preset depth off the bottom, collecting sound speed and temperature/depth measurements at a frequency of 10Hz. The MVP 30 was the primary sound speed profiler employed during this survey. Sound speed data from the SBE19+ and SBE37 were frequently referenced to confirm proper operation of the MVP 30 (AML) sensors.


Figure 5. MVP 30 as mounted on the vessel stern.

A.5.2 Surface Sound Speed: SBE 37

The Sea-Bird Electronics MicroCAT SBE 37 is a high-accuracy conductivity and temperature sensor capable of calculating and transmitting sound speed via a standard RS232 serial data interface. The SBE 37 transmitted real-time surface sound speed data to the Reson 7101 and Reson 7125 multibeam systems and the HYPACK acquisition computer via the Reson interface.

A.6 Horizontal and Vertical Control Equipment

A.6.1 Precise Positioning: Trimble 5700 GPS

Prior to and during the course of the survey the accuracy of the primary positioning system was verified by means of a physical measurement to temporary horizontal control/navigation checkpoints located at the vessel’s fueling dock. The checkpoints were established using a Trimble 5700 GPS system configured with a Trimble Zephyr Geodetic antenna.

A.6.2 Pressure Gauges: Hazen and Hobo Water Level Gauges

Data from either a Hazen water level gauge or a Hobo water level logger were used to calculate vessel static draft values while the vessel was offshore. For both instruments, the physical offset between the sensor and vessel draft was established dockside during a series of physical draft measurements v. sensor value observations (static dockside calibration). During offshore operations, sensor data were logged at times when the vessel was at full stop. Sensor readings were adjusted based on the derived fixed offset values for each instrument established during the static dockside calibration procedure. This approach allowed the field team to accurately track vessel static draft despite offshore conditions.

The Hazen gauge consists of a vented pressure transducer connected to a top-side transmitter. The transmitter communicates with a remote receiver via radio link. The Hazen gauge transducer was installed well below the waterline at a fixed elevation within the multibeam transducer pole (stilling well). As mentioned earlier, the sealed base of the multibeam pole was configured with a small copper orifice, in effect making the transducer pole a stilling well. The sensor was configured to record a water level every 9 seconds. The receiver was interfaced with the acquisition computer through a serial port and the water level reading was logged to a HYPACK .RAW file for at least 10 minutes while the ship was at a full stop. The average sensor value (for the term of the observation) was used for each offshore static draft calculation.

When the Hazen gauge was not in use a Hobo water level data logger was deployed well below the water line at a fixed elevation within the multibeam transducer pole (stilling well). The data logger recorded water level with a logging interval of 1 second during a time period of at least 10 minutes while the ship was at full stop. A second Hobo sensor was deployed on the deck of the boat and configured to record atmospheric pressure. Hobo data processing software was utilized to determine the final water level values. During Hobo gauge data processing, atmospheric pressure is subtracted from the absolute pressure value recorded with the non-vented sensor installed in the stilling well. The software also allows for water density compensation. The resultant water level value is then used in the static draft calculation.

A.6.3 Stadia Rod

A fiberglass stadia rod was employed throughout the survey for various tasks requiring a rigid measuring tool. Due to the relatively high freeboard of the *R/V Ferrel*, static draft measurements were accomplished employing the stadia rod. Static draft measurements were made relative to permanent shipboard benchmarks which were related to the vessel RP during the 2010 full ship survey (confirmed during 2012 “partial” survey). Prior to utilization, the rod graduations were compared to a steel tape measure to confirm accuracy.

A.7 Additional Acquisition Equipment

A.7.1 Bottom Sampler

A pipe dredge was employed to obtain seafloor sediment samples within the survey area. A PowerWinch system aboard the *R/V Ferrel* was employed to recover the unit.

A.7.2 Auto Pilot

A Simrad AP50 Marine Autopilot was installed to steer the vessel during concurrent MBES and SSS mainscheme data acquisition. When activated, the Autopilot controlled the rudder adjustments to keep the vessel on line.

A.8 Computer Hardware and Software

A.8.1 Computer Hardware

**Table 2**
**Computer Hardware**

| Use | Manufacturer | Model | Operating System |
|---|---|---|---|
| MBES Acquisition | Dell | Vostro 420 | Windows XP |
| SSS Acquisition | Dell | Vostro 420 | Windows XP |
| MVP Acquisition | Hewlett Packard | HP 530 | Windows XP |
| Data Processing | CyberPowerPC | GX3000Z | Windows 7 |
| Data Processing | CyberPowerPC | GX3000Z | Windows 7 |

MBES acquisition was completed using HYPACK software installed on a Windows XP computer which has a 3.16 GHz Intel Core 2 Duo processor, a 320 gigabyte (GB) hard drive, a 2 terabyte (TB) hard drive and 4.0 GB of RAM. This computer was also used to monitor the MV POSView controller and record POSPac data.

Side scan sonar data were logged with SonarWiz software using a Windows XP computer which has a 3.16 GHz Intel Core 2 Duo processor, a 320 GB hard drive, a 2 TB hard drive and 4.0 GB of RAM.

Data processing was completed using two computers operating with Windows 7 with 3.50 Ghz Intel Core i7-2700K 64-bit processors (8 core CPU), 120 GB program drives, 1 TB solid state drives in speed configuration, 2 TB hard drives in redundant configuration, and 16 GB of RAM.

A.8.2 Computer Software

Computer software utilized during this survey is itemized in Table 3 below.

**Table 3**
**Computer Software**

| Manufacturer | Application | Version | Version Date |
|---|---|---|---|
| HYPACK | HYPACK SURVEY | 11 | Mar. 3, 2011 |
| HYPACK | HYSWEEP SURVEY | 11 | Feb. 4, 2011 |
| Chesapeake Technology, Inc. | SonarWiz | 5 | Apr. 20, 2012 |
| L3 Klein | SonarPro | 11.3 | Aug. 13, 2008 |
| Universal Systems, Ltd. | CARIS HIPS/SIPS | 7.1 | Apr. 19, 2012 |
| Universal Systems, Ltd. | CARIS Notebook | 3.1 | Aug. 23, 2011 |
| NOAA | NOAA Velocwin | 8.92 | May 8, 2008 |
| Global Mapper Software LLC | Global Mapper | 13 | Dec. 10, 2011 |
| AutoDesk Inc. | AutoCAD | 2004 | Feb. 14, 2003 |
| Microsoft | Office (WORD, EXCEL) | 2010 | Apr. 15, 2010 |
| Sea-Bird Electronics | SeaTerm | 1.59 | 2009 |
| Sea-Bird Electronics | SBE Data Processing | 7.18b | 2009 |
| Applanix | MV POS View | 5 | Dec. 2, 2009 |
| Applanix | POSPac MMS | 6.1 | Jun. 15, 2012 |
| Hydrographic Consultants | CALLOAD | 2.0 | Dec. 18, 2005 |
| Trimble | MS Controller | 1.1.0.0 | May 21, 2002 |
| Trimble | Pro Beacon PC Interface | 5.0 | March 2, 2010 |
| ODIM Brooke Ocean | MVP Controller | 2.430 | Jan. 20, 2010 |

### A.8.2.1 HYPACK SURVEY

Survey vessel trackline control and position fixing were accomplished by using the data-logging and navigation software package (HYPACK). Vessel position data were output from the POS MV at 50 Hz frequency and transmitted to the navigation computer system, which processed these data in real-time into the desired mapping coordinate system (UTM Zone 16 North, NAD 83). The entire assigned survey spans two UTM zones (15 North and 16 North). However, for acquisition and processing continuity only UTM Zone 16 North was referenced. Raw and processed position data were continuously logged onto the computer hard drive and displayed on a video monitor, enabling the vessel's helmsman (and autopilot) to guide the survey vessel accurately along pre-selected tracklines. Tracklines and survey features were displayed on the helm monitor with geographic reference data that included current NOS raster nautical charts (RNCs) and S-57 electronic nautical charts (ENCs). Multibeam echosounder data were monitored in real-time using 2-D and 3-D data display windows. Motion and predicted tide-corrected sounding data were displayed as HYPACK gridded depth models and coverage matrices. HYPACK "targets" were also recorded to mark the location and time of significant observations during data acquisition, such as CTD cast positions or bottom sample locations.

Raw, geographic position data (NAD83 degrees latitude and longitude) were time tagged with UTC time by the POS MV and recorded by HYPACK in .RAW format line files.

The HYPACK computer was also used for sensor monitoring and data quality review while data were acquired. Utilities in the acquisition module of HYPACK notify the operator with a visual alert in the event of a sensor malfunction or, in some cases, when a sensor parameter drifts out of operator-set limits (e.g. DGPS position comparison or sound speed change).

A.8.2.2 HYPACK HYSWEEP

Multibeam data were logged with HYPACK HYSWEEP software which was run simultaneously with HYPACK SURVEY.

Multibeam raw beam ranges, intensities, and quality flags were time tagged with UTC time by the Reson 71P processor and recorded by HYPACK in HSX format line files.

Motion and attitude data (heave, pitch, roll, and heading) were time tagged with UTC time by the POS MV and recorded by HYPACK in HSX format line files.

Data were copied, via network connection, onto processing computers located on the ship for editing. Raw, processed and supporting data (acquisition logs, sound speed profiles, etc.) were also transferred to OSI's home office via courier delivery.

A.8.2.3 Chesapeake Technologies, Inc. (CTI) SonarWiz

A dedicated computer was used to record and display side scan sonar imagery. Chesapeake Technologies' SonarWiz 5 was configured to display a slant-range corrected, scrolling waterfall of the 455 kHz frequency side scan imagery data during operations. Scrolling imagery was monitored continuously for data quality and to identify significant features. SonarWiz compiled side scan sonar data along with vessel position, towfish position, layback and cable out values and recorded raw data in XTF format files.

Significant side scan contacts were targeted in the SonarWiz waterfall window, simultaneously creating a target in HYPACK SURVEY. The HYPACK targets were tagged with a unique ID by SonarWiz and updated with a descriptive field comment. All potential side scan contacts selected from the real-time waterfall were saved to the daily HYPACK target file.

SonarWiz was configured to receive navigation data from the POS MV, pressure sensor data from the towfish, and cable out from the topside cable counter controller. Towfish depth was calculated from the pressure sensor data. Towfish layback was calculated in SonarWiz from depth and cable out using Pythagorean's Theorem and a percentage of cable out value to correct for the catenary effect. The towfish position was calculated assuming that the towfish was directly behind the vessel relative to the navigation track. Towfish position parameters (e.g. altitude, depth, cable out, layback and lat/long) were recorded in the raw XTF file.

SonarWiz was configured to operate in "master" mode which allowed this software to control sonar functions such as range scale changes and pressure sensor calibration.

A.8.2.4 L3 Klein SonarPro

L3 Klein SonarPro software was operated in "slave mode" and configured to display an uncorrected, scrolling waterfall display of the side scan sonar data. Scrolling imagery was monitored continuously for data quality and to identify water column noise or interference (e.g. dolphins, boat wake, etc.).

A.8.2.5 Applanix MV POSView

The MV POSView controller software was used to configure and monitor the POS MV navigation and inertial motion unit system. IMU, navigation and GAMS status were monitored continuously at the navigation and acquisition stations. Visual alarms were configured to alert the operator in the event that attitude, position, velocity, heading or heave accuracy was degraded.

A.8.2.6 Trimble MS Controller

The Trimble MS Controller Software was installed on the multibeam acquisition computer and used to configure and calibrate the Trimble MS750 Receiver. It is a simulated keypad and display that shows current position and a number of additional data fields, providing access to several status and system setup menus.

A.8.2.7 Trimble ProBeacon

The Trimble ProBeacon PC Interface program was installed on the multibeam acquisition computer and used to configure the Trimble ProBeacon to receive DGPS correctors from the selected USCG station. The PC Interface Program was run through a DOS command window to enter the receiver frequency, check the receiver status and monitor the RTCM messages.

A.8.2.8 ODIM Brooke Ocean MVP Controller

A dedicated laptop computer was used to operate the ODIM MVP30 Controller Software. The System Configuration Window was used to interface the MVP towfish, MVP winch and the navigation and depth data strings output from HYPACK. Position, depth and vessel speed data were received from HYPACK and sound speed profiles were export to HYSWEEP to be used for real-time correction of the multibeam waterfall display.

The deployment configuration, alarms and data logging options were set in the Configuration Window, including profile depth limit, max cable out and docked cable out. Sound speed profiles (SV Files) were saved to the MVP laptop and the .CALC files were post processed and converted to CARIS .SVP files using Velocwin. During manual casts, completed once per day with the vessel at rest, the MVP fish was allowed to reach full water depth.

The Main Operator Window was used to remotely "cast" the towfish and to monitor the towfish parameters and alarms. Graphical tabs in the Main Operator Window were used to monitor towfish depth and surface sound speed. The "view profile" button was utilized to review the current sound speed profile. The manual logging option was toggled on during the acquisition of stationary, full water column, MVP casts.

#### A.8.2.9 Hydrographic Consultants, Ltd. CALLOAD

CALLOAD was installed on the side scan acquisition computer and used to calibrate and configure the SCC Smart Cable Counter. Sheave circumference, quantity of magnets and preset cable out values were input into CALLOAD to reset the cable counter. This process was completed frequently throughout side scan sonar operations between data acquisition runs.

#### A.8.2.10 CARIS HIPS and SIPS

All multibeam echosounder data were converted from raw HYPACK format data files to HDCS format and processed using CARIS Hydrographic Information Processing System (HIPS) software Versions 7.1.1 and 7.1.2 for 64-bit processors.

All SSS data were converted from raw XTF format line files to HDCS format and processed using the CARIS Sonar Image Processing System (SIPS) software Versions 7.1.1 and 7.1.2 for 64-bit processors.

HIPS/SIPS Version 7.1.1 was utilized on the processing computers aboard the *R/V Ferrel* for all preliminary data processing. Service pack 2 was released near the end of survey operations on June 6, 2012; therefore, HIPS/SIPS Version 7.1.2 was utilized for office processing.

#### A.8.2.11 CARIS Notebook

An S-57 attributed feature file was created in CARIS Notebook to emphasize navigationally significant objects discovered during the survey and to provide information for these objects that could not be portrayed in the BASE surfaces. New and updated chart features were included in the S57 feature file for submission with the hydrographic survey data. Notebook was also used to complete chart comparisons.

A.8.2.12 AutoCAD 2004

AutoCAD drafting and geographic information system was employed for pre-survey planning, line file construction, hydrographic data QC and the production of presentation graphics.

A.8.2.13 Microsoft Office Word and Excel

MS Excel was used for log keeping (field and processing), organization and preparation of field and office tasks, report table production and statistical data analysis. MS Word was used for report generation.

A.8.2.14 Adobe Acrobat

Adobe Acrobat was used to prepare final reports with digital signatures in accordance with the Statement of Work (SOW) and Hydrographic Survey Specifications and Deliverables 2012 (HSSDM).

A.8.2.15 Global Mapper

This 3-D visualization software and geographic information system was employed to create detailed sun-illuminated Digital Terrain Model (DTM) images, display vector geographic data and convert file formats. These data were used for QC checks and presentation purposes.

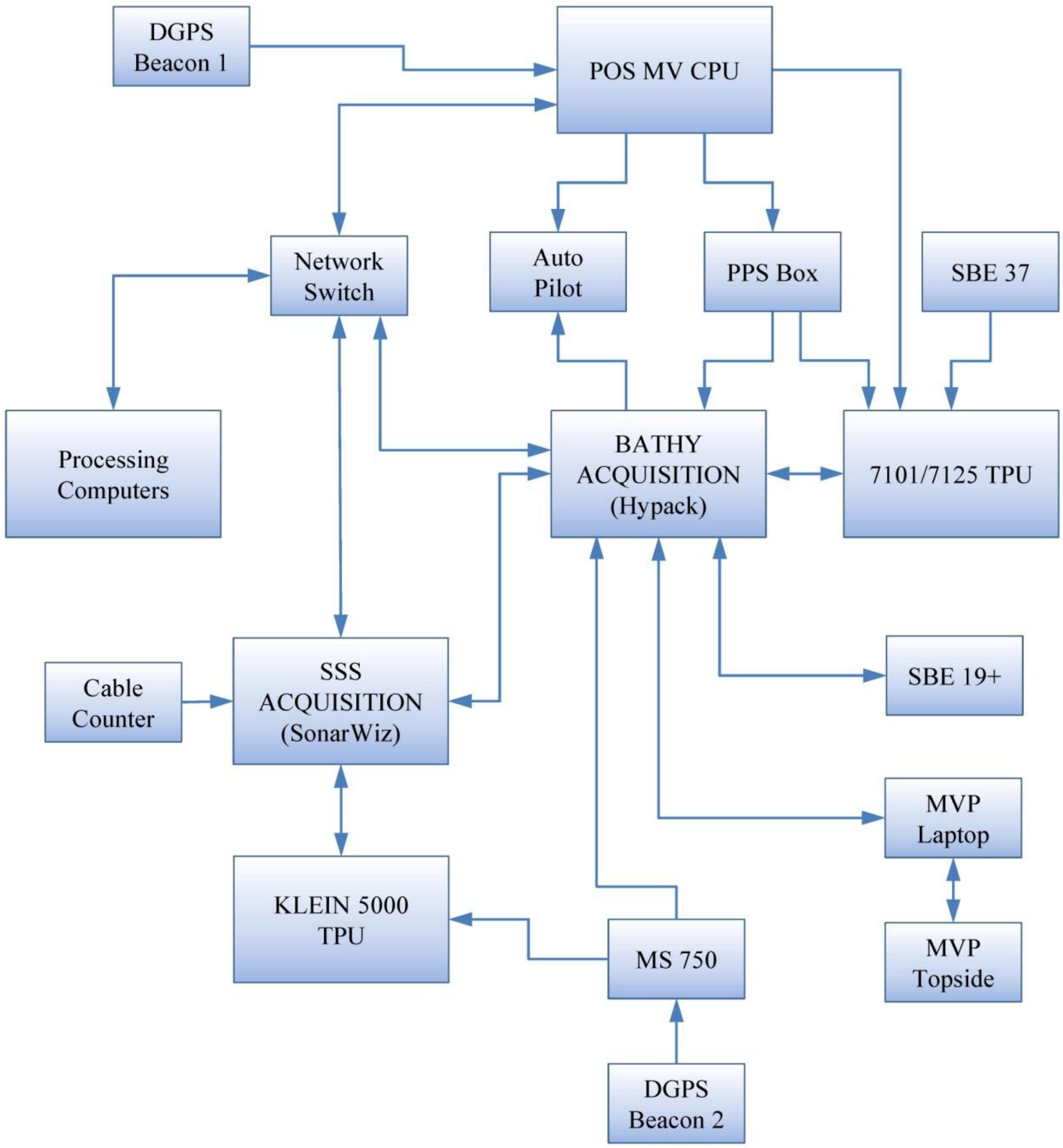
A.8.2.16 Applanix POSPac MMS Post-Processing Data

POSPac data were acquired and logged during survey operations. POSPac MMS is a post-processing software module, which, given acceptable distance and geometry between the survey vessel and nearby CORS stations, significantly increases the efficiency, accuracy, and robustness of mapping and surveying using GPS data. Using POSPac MMS in post processing, reliable decimeter level or better accuracy can be obtained from existing reference station networks without having a dedicated station located close to the project area.

A.8.2.17 NOAA Velocwin

Velocwin was used to convert the MVP cast data into CARIS SVF format. Along with the Sea-Bird Electronics “Sea Term” and “SBE Data Processing” software the Velocwin software was also used for daily/weekly sound velocity comparisons. Per instructions received from the COTR, OSI continued to use Velocwin which employs the “Wilson” equation for computing sound speed for the CTD weekly comparison cast data.

A.8.2.18 Acquisition System Block Diagram




Acquisition System Block Diagram

# B. QUALITY CONTROL

## B.1 Data Acquisition

All data acquisition and processing were performed under the supervision of the Chief of Party. Field acquisition was performed under the supervision of a Lead Hydrographer and a Senior Hydrographer, each with well over three years of experience conducting hydrographic surveys.

Prior to the survey, a review of the current charted data was conducted to identify critical features and areas including platforms, obstructions and wrecks. Line plans were created to achieve 200% SSS coverage with concurrent MBES, with lines planned for side scan acquisition at 75-meter and 100-meter ranges. The line plans meet the Set Line Spacing Coverage requirement specified in the OPR-K339-KR-12 Project Instructions; full MBES coverage was not required. Specific line plans and survey coverage are described in the individual survey descriptive reports.

Data acquisition quality control was established and performed to ensure survey data met requirements specified in the SOW and HSSDM.

### B.1.1 Bathymetry: Multibeam Echosounder (MBES)

Transducer offsets for the Reson 7101 and 7125 were measured relative to previously established permanent shipboard benchmarks and to the vessel reference position (RP) using a steel tape measure. The benchmarks were established in 2010 when a full static survey of the *R/V Ferrel* was completed using standard optical survey equipment and techniques. Transducer mounting angles were based on angles derived during the initial full static survey. This was possible since the transducer pole and transducer mounting flange are “keyed,” indexed, hardware components with mounting angles fixed relative to the vessel frame and RP. The IMU “bulls eye” or reference point, located on the top of the IMU served as the vessel RP. For detailed information regarding system offsets refer to Section C Correction to Echo Soundings.

The Reson 7101 and 7125 processors were interfaced with the POS MV such that UTC date and time information from the POS MV was used to accurately time stamp the Reson output data string. The Reson 71P processor received a pulse-per-second (PPS) signal and a serial $ZDA NMEA timing string from the POS MV. The POS MV also supplied a SIMRAD 3000 message to the Reson TPU allowing for real-time roll stabilization. Surface sound speed recorded at the transducer head with the SBE 37 was output to the Reson 71P processing unit via a serial connection to be used in beam-forming. Raw sounding data were output from the Reson 7101/7125 TPU to the HYPACK acquisition computer via an Ethernet connection.

The POS MV received DGPS correctors from the Trimble ProBeacon. POS MV position, heading and attitude data strings were output to the HYAPCK acquisition computer via an Ethernet connection.

HYPACK SURVEY and HYSWEEP SURVEY were configured to record position, heading, attitude and depth to RAW and HSX data files. For the real-time display, system offsets for the IMU and for the transducer phase center were entered into the HYPACK configuration files. These offsets were subsequently incorporated into the CARIS data processing routine.

Prior to the start of data collection using the Reson 7101 or the Reson 7125, the vessel static draft was measured and the transducer draft was confirmed by means of a “bar check” while alongside the fueling dock. The bar check procedure consists of lowering the lead line disk to various indexed depths (calibration points) directly below the multibeam transducer and recording the nadir depth value output from the Reson 7101/7125 as returned from the acoustic target. A “spot check” was also completed which consisted of sounding the seafloor directly below the multibeam transducer with the lead line while simultaneously observing the multibeam nadir depth. All bar checks and spot checks indicate that the multibeam sonar systems were performing within expected accuracy limits.

The initial vessel and MBES calibration to establish the dynamic draft correction table (squat test) and residual transducer alignment offsets (patch test) was completed on May 25, 2012. The Reson 7101 was in use at this time. On June 15, 2012, the Reson 7101 system was replaced with a Reson 7125 system. A patch test was completed for the Reson 7125 at this time. For each system a “post-deployment” patch test was also completed to ensure that each transducer’s alignment remained consistent over the course of the survey. Calibration results are presented in detail in section C. Correction to Echo Soundings.

The SeaBat display and user interface installed on the Reson 7101/7125 TPU were used to configure MBES settings, to monitor sounding collection, and to adjust system parameters in real time. The Reson 7101 was operated in the 511-equidistant beam mode, utilizing a swath of 140 degrees and the Extended Range (ER) projector selected. The Reson 7125 was operated in Best Coverage mode, which returned 512-equidistant beams, utilizing the maximum swath of 140 degrees. Roll stabilization was activated for both systems and absolute depth gates were conservatively employed to reject fliers.

The Reson sounding profile “wedge” was monitored in real time. Power and gain settings were monitored and adjusted to optimize bottom detection. Range settings were monitored and adjusted for observed depths to maximize ping rates.

Bathymetry, position, motion and heading data were logged in HYPACK SURVEY and HYSWEEP SURVEY. Position information from the primary and secondary DGPS receivers were continuously compared in HYPACK and status indicators were monitored in real time. By means of a utility in the HYPACK program a position disparity that exceeded three meters (primary v. secondary positioning system) would be reported by means of a visual alarm on the data acquisition screen.

In HYSWEEP, real-time SWMB waterfall and digital terrain model coverage displays corrected for draft, motion, preliminary tides and sound speed were monitored. Survey coverage was tracked in the HYPACK SURVEY display window with a matrix file updated in real time. MBES survey line names were composed of the year, vessel, Julian day, UTC time and line number, for example: 2012Fe1451723_93.hsx/.raw, where “Fe” stands for Ferrel.

The POSView software was used to monitor position, heading and motion accuracy status indicators. Applanix “TrueHeave” and POSPac data were acquired and recorded during survey operations. The TrueHeave algorithm uses a delayed filtering technique to increase heave measurement accuracy, reducing error caused by IMU drift and long-period ocean swell. TrueHeave and POSPac data were logged at least 5 minutes prior to and after MBES acquisition. TrueHeave files were named for each Julian day (ex: DN182.000) and saved in individual day folders. Once the file size reached 64 MB, a new file was created; therefore, each day of survey has multiple TrueHeave files.

The POS MV heave bandwidth filter was configured with a dampening coefficient of 0.707. The cutoff period of the high-pass filter was determined by estimating the swell period encountered during the survey. A heave bandwidth filter of 10 seconds was employed during the survey.

During the daily “UTC midnight” changeover, the vessel was stopped and a number of functions performed, a static draft measurement was obtained (conditions permitting), a new Applanix Trueheave file was begun, a bar check was performed (weekly) to verify echosounder draft offsets and system sounding accuracy, a CTD comparison cast was performed (weekly or more frequently), side scan sonar depth sensor function and accuracy was confirmed.

### B.1.2 Imagery: Side Scan Sonar

Prior to commencing survey operations, the location of the top of the side scan sonar sheave, at its operational, deployed position was verified with respect to the vessel RP. The vertical offset between the SSS sheave reference point and the water line was also confirmed. The position of the sheave marks the starting point for the cable out measurement used to calculate towfish layback. The survey vessel “steering point” was the fore-aft location of the vessel RP and the athwart-ship or starboard offset of the side scan sonar cable sheave.

The Klein 5000 TPU was interfaced with the SSS acquisition computer transmitting the raw SSS profiles over an Ethernet connection. Speed information from the MS 750 was input into the Klein 5000 TPU, which used the VTG data string to adjust the real time waterfall display.

Chesapeake Technologies, Inc. SonarWiz side scan acquisition software was used to log the side scan imagery and position information to XTF files. SonarWiz was interfaced with the Klein 5000, a cable out indicator and the POS MV. Ship position and heading were input from the POS MV into the SSS acquisition computer. The length of cable deployed, ship navigation and heading, along with towfish depth converted from the towfish pressure sensor were used to determine an accurate towfish position relative to the vessel reference point. Imagery, layback, cable out, ship position, towfish position, depth and altitude were all logged to the raw XTF file. SSS survey line names included Julian day, UTC time (hhmmss) and line number, for example: 153-164300-4020.xtf.

Cable out readings were verified daily at the beginning of survey operations, and at regular intervals throughout the day, by observing measured index marks on the towfish cable with respect to the reference position at the top of the sheave. The pressure sensor within the Klein 5000 towfish was calibrated at the surface (depth zeroed) frequently throughout the day to account for changes in atmospheric pressure.

During acquisition the SonarWiz display was configured to monitor a slant-range corrected SSS waterfall display in real time. Contact targets were positioned from the slant-range corrected data and displayed on the helmsman HYPACK map through a serial connection to the multibeam acquisition computer. An uncorrected SSS waterfall display was monitored in real time to observe water column interference and nadir contacts.

As a QC check of the imagery in SonarWiz, the waterfall display within the Klein “SonarPro” side scan sonar software was employed in display mode only.

Two hundred percent (200%) SSS coverage was attained in the survey area employing line spacing and side scan sonar range scales tabulated in Table 4 below. The sheave reference point was used as the navigation tracking point when acquiring mainscheme survey lines, ensuring overlapping coverage between SSS lines.

**Table 4**
**SSS Line Spacing and Range Scales**

| Trackline Offset (meters) | SSS Range Scale (meters) |
|---|---|
| 40 | 50 |
| 65 | 75 |
| 85 | 100 |

Vessel speed was maintained such that any 1 $m^3$ objects would be ensonified more than three times per pass at the operating range scale. Approximate vessel speed for mainscheme SSS acquisition was 7-8 knots. The towfish height was adjusted to fly at 8-20 percent of the range scale, with a visual alarm setup to indicate when the fish was nearing the upper and lower limits of the height threshold. Refraction and surface noise effects were minimized by changing the depth/altitude at which the towfish was flown.

Confidence checks observed across the full range (e.g. scour marks and bottom type changes) were recorded frequently (attempted once per line) to verify system operation and object detection capabilities. Confidence checks were recorded with line names, observation times, and comments in the daily acquisition log.

### B.1.3 Sound Speed

#### B.1.3.1 Sound Speed Profiles

Sound speed profile data were acquired with the ODIM MVP30 approximately every 15 minutes, except when the time interval occurred while the vessel was turning. The MVP operator acquired casts more frequently if high variability was noted in the surface sound speed. Profiles were acquired to a depth ~2 meters off the bottom when operating in freewheel mode. Attempts were made to acquire all casts within the survey extents provided by the Office of Coast Survey (OCS) and to obtain a profile each day with a maximum depth equivalent to that encountered during MBES survey operations. The moving vessel profiler was operated in accordance with the ODIM Brooke Ocean's MVP30 Operation and Maintenance Manual.

The ODIM MVP Controller software was configured to receive navigation data from HYPACK via the MVP.dll. HYSWEEP SURVEY was configured to receive MVP casts in real time to correct the real time waterfall and profile displays with the most recent sound speed profile. MVP cast position, sound speed and depth data were logged to CALC files saved to the designated MVP laptop computer. Profiles were named for Julian day and cast number, for example: MVP_DN191_0005.calc.

Frequently during the daily "UTC midnight" changeover, while the *R/V Ferrel* was at a full-stop offshore, the MVP was manually deployed to the full seafloor depth while an SBE 19+ CTD was simultaneously deployed for a comparison cast. This satisfied the HSSDM-specified "independent sound speed measurement system confidence check" requirement. SBE 19+ CTD comparison casts were used for quality assurance only and were not utilized in sound speed correction of soundings. Raw CTD data were uploaded via a serial port to a designated PC following each cast and before the "Weekly DQA" comparison was made. Sea-Bird CTDs were operated in accordance with Coast Surveys Development Lab (CSDL) guidance: 3 minutes of warm up at the surface, 2 minutes operation at the surface, 1 meter per second depth descent.

#### B.1.3.2 Surface Sound Speed

The SBE 37 was installed behind the multibeam transducer at the draft of the transducer phase center. Real-time surface sound speed values were transmitted to the Reson 71P topside unit and subsequently recorded with multibeam echosounder data in the raw HYPACK .HSX data files. Sound speed data were also utilized by HYSWEEP SURVEY which was configured to display a visual alarm if the surface sound speed changed +/- 2 m/s. Variations in surface sound speed were monitored and evaluated as an indicator of surface water temperature/salinity fluctuation and potential water column variation which would necessitate additional sound speed profile measurements.

Daily sound velocity quality assurance (DQA) checks were performed using NOAA's Velocwin software by comparing the SBE 37 surface sound speed to the surface sound speed of the MVP manual comparison cast.

### B.1.4 Horizontal and Vertical Control

The U.S. Coast Guard (USCG) Differential GPS (DGPS) station in English Turn, LA served as the primary horizontal position control and USCG station in Eglin, FL served as the secondary horizontal position control. The POS MV received pseudo range corrections from the English Turn station and the MS 750 received pseudo range corrections from the Eglin station.

Prior to the start of survey operations, navigation checkpoints were established at the vessel fueling dock located in Port Fourchon, LA employing a Trimble 5700 with a Zephyr geodetic antenna. Dual-frequency GPS observations were recorded at three locations along the length of the fuel dock to help ensure vessel access during the course of the survey. The dual-frequency GPS observables were submitted to the National Geodetic Survey's (NGS) On-line Positioning User Service (OPUS) and processed to determine the positions of the temporary control points. Each data file that was submitted was processed with respect to at least 5 CORS sites. NGS provided an OPUS Report which included both ITRF and NAD83 coordinates along with position accuracy information. These reports are provided in the Horizontal and Vertical Control Report (HVCR).

Position confidence checks of the POS MV and the MS 750 were accomplished at the start of survey and at least bi-weekly, during fueling or weather delay stops in Port Fourchon. The distance between the vessel reference point and the horizontal control point computed by the navigation system was compared to the distance between the vessel reference point and the horizontal control point as measured with a steel tape. In all cases, dockside navigation system accuracy testing demonstrated that the POS-MV, employing USCG correctors, had an accuracy of better than 1.0 meters. A tabulation of navigation system performance checks is included in DAPR Appendix III.

During data acquisition, the MV-POSView controller software was used to monitor real-time position accuracy, with the accuracy alarm set at 2.0 meters.

Per the Project Instructions water level data from NOS-NOAA tide station 876-2075 in Port Fourchon, LA was used for vertical control. Predicted tide files were downloaded from the Center for Operational Oceanographic Products and Services (CO-OPS) website, http://opendap.co-ops.nos.noaa.gov/axis/text.html, prior to survey operations. Predicted tide files were used during preliminary processing. Preliminary tides from the Port Fourchon station were downloaded and reviewed on a daily basis for data gaps. Verified tides were downloaded and reviewed weekly.

### B.1.5 Feature Verification

When necessary, development/investigation MBES only lines were run over AWOIS items, significant contacts and other features observed in MBES and SSS records to determine a least depth and to meet the Object Detection Coverage specification in the HSSDM (Section 5.2.2.1). Once an item was deemed significant, nearly significant, or simply required more data to make a determination, the contact or outstanding sounding position was exported to an ASCII file, converted to a Notebook file and exported as a .000 file that could be opened in HYPACK SURVEY to display the investigation position.

A series of short MBES lines were run over the feature from multiple directions to obtain soundings on the object at various angles, with high sounding density. During feature development lines, vessel speed was slowed to approximately 4-6 knots.

### B.1.6 Bottom Sampling

Bottom samples were acquired in close proximity to the recommended positions included in the Project Reference File (PRF), provided with the OPR-K339-KR-12 Project Instructions. A pipe dredge was deployed from the A-frame located on the stern of the vessel to acquire seafloor sediment samples. Bottom sample locations were logged in a target file in HYPACK SURVEY. Once the sample was on deck it was photographed and classified based on the criteria outlined in Appendix 10 Bottom Classification in the HSSDM.

### B.1.7 Other

#### B.1.7.1 Autopilot

The Simrad AP50 Marine Autopilot was configured to receive heading from the POS MV, and speed, position and the Autopilot (APB) message from HYPACK. Once in control, the Autopilot maintained the vessel steering point within approximately 2 meters of the selected trackline.

#### B.1.7.2 Digital Acquisition Logs

An acquisition log was maintained in Microsoft Excel to record all pertinent information related to acquisition, such as:

- Daily operations and locations
- Weather and sea state observations
- MBES and SSS survey line ID and start time
- Date and Time of MVP and TrueHeave (POSPac) files
- Navigation System Performance Checks, Bar Check Table, Vessel Water Level Tabulation and Sound Speed Comparison Table
- Systematic changes (i.e. range scale change, equipment repairs or replacements)
- SSS Confidence Checks

- Significant SSS contacts or Bathy features
- Excessive Noise in the SSS/MBES records due to fish, vessel traffic, or surface noise
- Deviations from planned tracklines or Data Gaps
- System “crashes” or Position Outages
- Line Miles and Survey Statistics

## B.2 Data Processing

### B.2.1 Bathymetry

#### I. Data Conversion and Preliminary Sounding Correction

Preliminary data processing occurred simultaneously with data acquisition. Therefore, at regular intervals throughout a survey day, raw MBES data, MVP casts, and TrueHeave files were copied across the network to a Preprocess folder located on the Processing Computer as they became available. The Acquisition computer’s directory and log were reviewed to verify line names and file size and to remove any aborted lines from preprocess prior to converting the data in CARIS HIPS. All lines and MVP casts successfully copied from the acquisition computer were entered into the survey processing log, which was used to track the processing progress of each line and to enter all notes pertinent to individual lines or days.

Vessel configuration files (.\HVF) were created in CARIS HIPS Vessel Editor prior to data conversion. The HVF files contained transducer offsets relative to the RP, alignment offsets derived from the calibration testing, as well as the waterline height and standard deviation values for all surveyed parameters (used to model sounding uncertainty). Duplicate HVFs were created for each MBES system to convert lines into HDCS folders according to classification, i.e. mainscheme lines, cross lines, and development lines. Waterline correctors were updated in the HVF files as new values became available. See Section C Corrections to Echo Soundings for additional information regarding vessel configuration files.

Multibeam sonar data conversion and application of sounding correctors were completed using the CARIS HIPS Batch Processor. The Batch Processor runs a user defined script which accomplished the following standard tasks in succession:

1. Convert the HSX and RAW data to the HDCS data format.
2. Load zoned, predicted tides or preliminary tides if available.
3. Load daily True Heave files.
4. Load and apply concatenated sound speed (SS) profile data. SS profiles were loaded with the CARIS *nearest in distance within time* correction method. During CARIS SV Correction, the following correctors were applied: sound speed, heave, pitch, roll and waterline.

5. Merge data to apply vessel offsets/alignment, position, gyro, tide, and dynamic draft correctors to bathymetry. HIPS/SIPS computes the fully corrected depth and position of each sounding during the Merge process.
6. Compute TPU (Figure 6). Total Propagated Uncertainty (TPU) is calculated in CARIS HIPS from contributing uncertainties in the echosounder, positioning and motion sensor measurements as well as uncertainties associated with sound speed and water level correction. The standard CARIS devicemodel.xml was used to create the HIPS Vessel File (HVF). Tide uncertainty values for measured and zoned tides were provided in the OPR-K339-KR-12 Tides Statement of Work as 0.11 meters. Sound speed TPU values were estimated from manufacturer accuracy of the ODIM MVP-30 and SBE37 and from guidance in the OCS Field Procedures Manual (FPM) Appendix 4, April 2012 under CARIS HVF Uncertainty Values. Given that the MVP was cast approximately every 15 minutes an uncertainty value of 1 m/s was chosen for the measured sound speed.

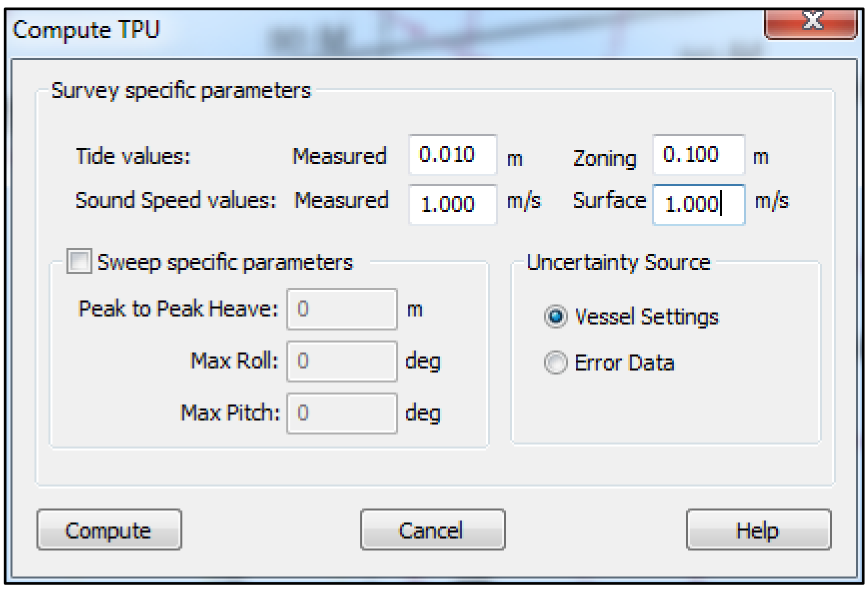



Figure 6. Uncertainty values entered into the Compute TPU process in CARIS HIPS & SIPS.

II. Preliminary BASE Surfaces

Preliminary field sheets and CUBE surfaces were created for reviewing and cleaning full-density soundings. Daily data review and cleaning were performed using 1-meter resolution CUBE surfaces as a guide for directed editing. CUBE surfaces with a 2-meter resolution were created to evaluate coverage. For item investigations, 0.5-meter resolution CUBE surfaces were generated over the feature and the surrounding seafloor.

After the lines were run through the batch process, they were added to the 1-m Cleaning surfaces and the 2-m Coverage surfaces. Depth, Standard Deviation and Shoal surface models were viewed with vertical exaggeration and sun illumination to highlight areas that would require immediate investigation. Standard deviation surfaces were reviewed to evaluate data for consistency between overlapping coverage and cross lines, and to detect potential systematic position, motion, tide, or sound velocity errors. Highest standard deviation values were observed over obstruction features, seafloor depressions and offshore platforms.

The 2-m and 0.5-m coverage surfaces were reviewed for any data gaps in excess of 3 nodes in width and to ensure that Object Detection Coverage was obtained over significant shoals and features. Density layers were reviewed to verify that 95% of all nodes in the Set Line Spacing coverage surfaces were populated with at least 3 soundings and that 95% of all nodes in the Object Detection Coverage surfaces were populated with at least 5 soundings.

III. Data Cleaning and Processing

Line attitude and navigation data were reviewed in their respective CARIS editors to ensure that there were no problems with the correctors, such as gaps in attitude or navigation jumps. Extreme speed jumps were rejected with interpolation and data were re-merged, if needed.

The CARIS Swath Editor was used to clean noise, multipath returns, and gross fliers which are most easily reviewed and edited in this time-based (ping) display. Soundings were colored by depth and reviewed in multi-directional profile and 3-dimensional displays. Tracklines and swath boundaries were viewed in the CARIS Map window in reference to BASE surfaces, charted data (RNC/ENC), SSS contacts and field annotations (HYPACK target files). A complete final sounding review was performed for the entire survey coverage area and tracked with subset tiles.

The CARIS Subset Editor was used to clean fully-corrected, geospatially located soundings in 2-D and 3-D displays. Soundings were colored with line, depth and uncertainty attributes. Areas with multiple sounding coverages from adjacent survey lines were evaluated to increase confidence in outer beams and over significant features. Subset boundaries were viewed in the CARIS Map window in reference to BASE surfaces, charted data (RNC/ENC), and SSS contacts.

Full density soundings were reviewed for each SSS contact in the CARIS Subset Editor and a sounding was designated for the representative least depth of each contact (or Primary/Secondary contact pair).

Beam filters were used to reject soundings in specific lines that exhibited excessive sound speed uncertainty in the outer beams.

An Outstanding flag was given to soundings on features or possible features that required further investigation or development. Outstanding sounding positions were export from CARIS to an ASCII file that was converted into an S57 .000 file in CARIS Notebook.

The Designated Sounding flag identifies the shoalest sounding of a feature. The purpose of the Designated Sounding flag is to ensure that the shoalest depths over significant seabed features or shoals are maintained in BASE surfaces, charts and other standard hydrographic products. When a designated sounding was selected on a feature it indicated that no further investigation was required.

The Designated Sounding flag was applied to features taller than 0.25 meters, which ensured that the least depth of all features insignificant or significant in height resolved with the MBES would be adequately represented in the final surfaces. Near nadir soundings were designated as least depths on features in lieu of outer beam soundings whenever possible. In the instance that soundings from multiple MBES lines suggested different least depths, the contact heights measured in side scan editor were reviewed to assist with least depth designation.

Once the surface deliverables were finalized, chart comparisons were completed with the surveyed depths and charted depths located on all affected Raster Nautical Charts (RNCs) and Electronic Nautical Charts (ENCs). The final chart comparison was completed using charts downloaded from the OCS website, nauticalcharts.noaa.gov, on August 4, 2012. CARIS Notebook and CARIS HIPS & SIPS were utilized to overlay the surveyed depths as surfaces and as soundings and surveyed features over the RNCs and ENCs. Surveyed data were compared to all charted depths, contours and features, with agreements, discrepancies and disprovals addressed in each survey's descriptive report.

#### B.2.1.2 Methods Used to Maintain Data Integrity

Preprocess data were copied onto processing computers located on the ship for editing. The hard drives on the processing computers retained both the raw and processed data. The processing computers, DP1 and DP2, were backed up to external, 2-terabyte hard drives each day, with a rotating cadre of 5 hard drives for each processing computer. Backups of the raw, processed and supporting data (acquisition logs) were transferred to OSI's home office via courier delivery during vessel in-ports. Upon completion of field work, DP1 and DP2 were used to complete survey processing at OSI's home office.

#### B.2.1.3 Methods Used to Generate Bathymetric Grids

After MBES sounding editing was complete, final BASE surfaces were created using the CUBE algorithm as incorporated in CARIS HIPS and SIPS. The CUBE algorithm generates surface models from multiple hypotheses that represent the most accurate possible depths at any given position. Hypotheses with lower combined Total Propagated Uncertainty (TPU) are given higher significance for incorporation into the final surfaces. Also, soundings closest to a grid node have a greater weight on the node depth value than soundings that are further away.

The following options were selected when final CUBE surfaces were created:

- Surface Type – CUBE
- IHO (International Hydrographic Organization) S-44 Order 1a
- Include Status – Accepted, Examined, Outstanding
- Additional Attributes – Shoal and Deep
- Disambiguation Method – Density & Locale

CUBE parameter configuration varied with surface resolution. The CUBE parameters Capture Distance Scale and Capture Distance Minimum were modified according to grid resolution to meet the requirement that the maximum propagation distance for a node shall be no more than the grid resolution divided by the $\sqrt{2}$.

The Capture Distance Scale (CDS) defines a radial distance from the node which is based upon a percentage of water depth. All soundings within this radius are included in the Density value (and propagated to the node).

The Capture Distance Minimum (CDM) defines a fixed radial distance in meters from the node in which all soundings are included in the Density value (and propagated to the node).

During CUBE surface creation, the maximum value of the two capture distance parameters is used to set the actual capture distance. To ensure that the CDM was the determining factor for the radius of influence for each node, a CDS value of 0.50 % was used for the creation of all surfaces.

Example for a 2-meter BASE surface in depths less than 20 meters:

CDS = 0.005
CDM = 2 / ($\sqrt{2}$) = 1.414

The CDS radius maximum value (0.005 * 20 = 0.1 meters) will not exceed the CDM value (1.414 meters) for the maximum depth, and therefore the Density Attribute Layer will represent those soundings that lie within a fixed radial distance (1.414 meters) for all nodes.

Table 5 displays the CDS and CDM values entered for the various grid resolutions used.

**Table 5**
**CUBE Parameters Applied in Surface Generation**

| Grid Resolution (m) | Capture Distance Scale (%) | Capture Distance Minimum (m) |
|---|---|---|
| 0.05 | 0.05 | 0.35 |
| 1 | 0.05 | 0.71 |
| 2 | 0.05 | 1.41 |
| 4 | 0.05 | 2.83 |

Survey areas were compiled of surfaces with multiple grid resolutions to meet the coverage requirements specified in the Project Instructions: 200% SSS with concurrent Set Line Spacing SBES or MBES, or Object Detection MBES. Full multibeam coverage was not obtained in the survey area; however, all significant contacts and bathy features were developed to meet Object Detection coverage standards.

To meet the requirements for Set Line Spacing coverage, a grid resolution of 2 meters was used in waters 20 meters or less deep and a grid resolution of 4 meters was used in depths greater than 16 meters deep. No surveyed depths exceeded 40 meters.

All significant features located in waters less than 30 meters deep were developed with MBES to meet Object Detection coverage standards. Surfaces were generated over all significant contacts with a grid resolution of 0.5 meters in depths less than 20 meters and a grid resolution of 1 meter in depths between 19 to 40 meters. The object detection surfaces were centered over the significant features and covered a minimum area of 400 $m^2$, per Section 6.3.2 Significant Contacts in the HSSDM.

In survey areas where multiple grid resolutions were necessary, the surfaces overlapped to ensure no gaps existed in the finalized surface. The attributes associated with each grid node are as follows:

- Depth Value
- Uncertainty
- Standard Deviation
- Mean, Deep and Shoal Depths
- Sounding Density
- CUBE Surfaces: Hypothesis Count, Hypothesis Strength & User Nominated

B.2.1.4 Methods Used to Derive Final Depths

The Set Line Spacing Coverage grids were "finalized" in CARIS according to depth. Per the CARIS HIPS & SIPS 7.1 Users Guide, a finalized BASE surface "is a finished version of the surface that is ready for export." Designated soundings were incorporated into the BASE surfaces when finalized; making certain the least depth is honored in the grid. When finalizing the set line spacing coverage surfaces, the final uncertainty was chosen from the greater of either the uncertainty value from the source surface or the standard deviation value from the source surface. The Depth Threshold option was selected to ensure that the 2m surface did not include any areas deeper than 20 meters and the 4m surface did not include any areas shallower than 16 meters.

The Object Detection Coverage grids over significant features were finalized without application of depth thresholds. Final uncertainty was chosen from the greater of either the uncertainty value from the source surface or the standard deviation value from the source surface. Designated soundings were incorporated into the finalized surfaces.

All final BASE surfaces were combined at the resolution of the largest grid size of any one contributing surface. The combined final surface was used to generate contours and soundings for chart comparisons and final product review.

Final BASE surface resolutions are unique for each survey area and are described specifically in the respective descriptive reports.

### B.2.2 Imagery

Preliminary data processing occurred simultaneously with data acquisition. Therefore at regular intervals throughout a survey day, raw XTF files were copied across the network to a Preprocess folder located on the Processing Computer as they became available. The Acquisition computer's directory and log were reviewed to verify line names and file size and to remove any aborted lines from preprocess prior to converting the data in CARIS HIPS. All lines successfully copied from the acquisition computer were entered into the survey processing log, which was used to track the processing progress of each line and to enter all notes pertinent to individual lines or days.

SSS CARIS Vessel Configuration files were created to convert CTI SonarWiz XTF data files. The SSS vessel file is a "zero" configuration because all tow point offset and layback calculations were performed in SonarWiz. No additional towfish position calculation was necessary in CARIS SIPS. Duplicate HVFs were created for each 100% side scan coverage (100 and 200) and for side scan development lines.

The pre-process SonarWiz XTF data were converted to the HDCS data format in CARIS' Conversion Wizard. Vessel trackline positions were converted from the XTF ship position field. Towfish positions were converted from the XTF sensor position field and fish heading was computed from course made good (CMG) from vessel navigation. SonarWiz calculated the towfish position from layback, fish altitude, and fish depth; therefore, it was not necessary to re-compute the towfish navigation or position in CARIS SIPS. Survey lines with odd numbers were converted under the 100% coverage HVF and survey lines with even numbers were converted under the 200% coverage HVF.

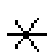
Navigation time stamp irregularities were edited and navigation data were reviewed in the CARIS Navigation Editor. Extreme speed jumps were rejected with interpolation. Each side scan line was reviewed in CARIS Attitude Editor to ensure that the towfish attitude, depth, height, and cable out were converted from the XTF file and that there were not gaps or problems with these parameters.

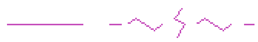
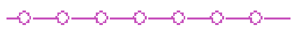
CARIS Side Scan Editor was used to review and edit bottom tracking, slant range correct the data, and to apply image processing correction. Processing was completed as follows:

1. Review the raw side scan data in Side Scan Editor and correct any bottom tracking errors by re-digitizing the bottom trace.
2. Slant range correct the side scan lines with a resolution of 0.03 meters to convert the across track axis from time to distance and remove the water column from the imagery. Calculate an average speed of sound value from MVP casts acquired that same day of side scan acquisition. Sound speed values used for slant range correction varied between 1535 m/s and 1539 m/s. The slant range correction sound speed used for each day of side scan acquisition is noted in the processing log.
3. Lines were AVG corrected to normalize angular response across the swath.
4. Lines were TVG corrected to balance the beam signature of the port and starboard channels.

During pre-survey planning, the CARIS HIPS and SIPS ContactFeatures.hcf file, located in the CARIS\HIPS(x64)\System directory, was modified by OSI to include additional Contact Feature types with which to classify contacts in Side Scan Editor. The additional contact types are included in Table 6 below, along with their graphical display in CARIS HIPS and common remarks that would accompany the contact type. The OSI-modified ContactFeatures.hcf file was provided with the project deliverables Processed directory.

**Table 6**
**Modified OSI Contact Types Selected in Side Scan Editor**

| Contact Type | | Remarks |
|---|---|---|
|  | Rock | • Rk<br>• Group of rks |
|  | Unknown Contact | • Unknown Contact<br>• Unknown Contact, Possible Rk/Fish |
|  | Fish Contact | • Fish<br>• Fish, detached shadow<br>• Dolphins |
|  | Contact with Insignificant Height | • Ftr with insig ht |

| Contact Type | | Remarks |
|---|---|---|
|  | Obstruction | • Obstruction<br>• Obstruction/Debris |
|  | Wreck | • Wreck<br>• Wreck/Debris |
|  | Platform | • Oil Platform |
|  | Underwater Cable | • Chd Cable<br>• Unchd Cable |
|  | Pipeline | • Chd Pipeline<br>• Unchd Pipeline |

Once image processing was completed contacts were selected in the Side Scan Editor waterfall. Objects were identified by the presence of sonar shadows. Shadow lengths were measured and converted to heights. Contacts with significant heights or horizontal dimension were positioned and created at the top (closest to nadir) of the shadow, and attributed with the following information: feature type (rock, obstruction, platform, unknown), height, width & length (if significant), and processor remarks. Heights were measured with the shadow tool and lengths and widths were measured with the distance tool. An example of an attributed contact selected in Side Scan Editor is displayed in Figure 7.

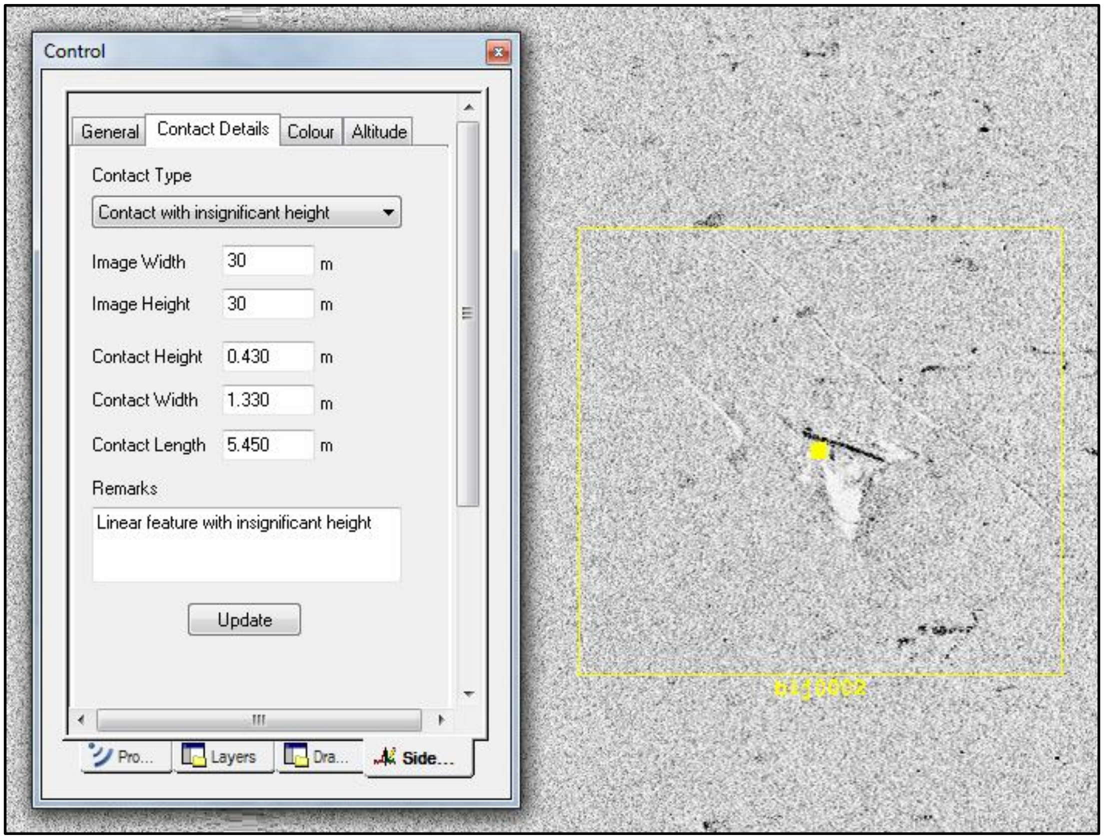



Figure 7. Attributed side scan contact selected in Side Scan Editor waterfall display.

SSS lines were reviewed a minimum of two times by more than one surveyor while in the field to make certain that all significant contacts were selected that may require investigation. The contacts selected in Side Scan Editor were positioned in the Display window. The accuracy of the side scan towfish navigation and contact positioning was regularly confirmed in the display window when the same contact was selected from overlapping side scan coverages. All contacts were reviewed in CARIS Subset Editor with full sounding density with the rejected soundings visible, as well.

The 100 and 200 percent coverage mosaics were generated in CARIS HIPS and SIPS frequently using the Mosaic Editor. First all lines from the 100 percent coverage HVF were selected and GeoBars (Georeferenced Backscatter Rasters) were created for each line. The GeoBars were generated with a resolution of 0.25 meters and were saved in the HDCS line folder for each side scan line. With all the GeoBars loaded for the 100 percent side scan coverage, mosaics were generated in the survey coverage fieldsheets with a 1 m resolution. The same steps were followed to generate the 200 percent coverage mosaic.

The 100 and 200 percent coverage mosaics were reviewed in HIPS and SIPS for coverage gaps and poor quality imagery that would necessitate SSS fill-in lines. Fill-in lines were collected as deemed necessary. At the completion of survey operations, final 100 and 200 percent coverage mosaics were export from CARIS HIPS and SIPS to individual GeoTiffs.

B.2.2.2 Methods Used to Maintain Data Integrity

Preprocess data were copied onto processing computers located on the ship for editing. The hard drives on the processing computers retained the raw and processed data. The processing computers, DP1 and DP2, were backed up to external, 1-terabyte hard drives each day, with a rotating cadre of 5 hard drives for each processing computer. Backups of the raw, processed and supporting data (acquisition logs) were transferred to Ocean Surveys' home office via courier delivery during vessel imports.

Upon completion of field work, DP1 and DP2 were used to complete survey processing at OSI's home office.

B.2.2.3 Methods Used to Achieve Object Detection and Accuracy Requirements

By means of "multibeam" technology and through beam forming techniques, The Klein 5000 side scan sonar generates 5 beams per ping improving greatly upon the resolution capability of "single beam" side scan units. Single beam SSS units require speeds of 5 knots or less to ensure bottom coverage and object detection at the sonar range scales employed during Project OPR-K339-KR-12. However, the Klein 5000, with its multibeam functionality and heightened resolution ensures full bottom coverage at survey speeds up to 10 knots. The *R/V Ferrel* survey speed never exceeded 9 knots during side scan acquisition. Careful review of side scan sonar imagery throughout the course of data acquisition and processing phases regularly confirmed that the vessel speed and side scan sonar ping rate allowed for ensonification of a seafloor feature at a density in excess of that required in the HSSDM.

B.2.2.4 Methods Used to Verify Swath Coverage

Line spacing was planned such that there was ample overlap between adjacent lines from each single 100 % coverage. Side scan lines run at range scales of 50 m and 75 m had a coverage overlap of 20 meters, and side scan lines run at a range scale of 100 m had a coverage overlap of 30 meters. Given that the Autopilot maintained line steering within 2 meters of the planned line and the towfish was flown at a height as not to diminish the scanning range, full swath coverage was achieved without trouble on the majority of mainscheme lines. Gaps in side scan coverage that occurred when the vessel steered off line to avoid oil platforms or divers in the water were subsequently filled with side scan development lines.

The 100 and 200 percent side scan coverage mosaics were updated daily and reviewed for gaps or poor quality data that would require fill-in lines or re-runs of the mainscheme line.

B.2.2.5 Criteria Used for Contact Selection

The criteria used to select contacts was based on the guidance provided in the HSSDM Section 6.3.2 Significant Contacts, which defines a contact as significant based on its shadow height in different depth ranges. The HSSDM significant contact specifications are summarized in Table 7.

**Table 7**
**Significant Contact Selection Criteria**

| Surrounding Depth or Area | Significant Contact Height |
|---|---|
| 0 – 20 meters | 1 meter |
| > 20 meters | 10% of surrounding depth |

During field operations OSI used a more conservative approach when selecting contacts, to make certain that significant features would not be overlooked for further investigation or correlation in the MBES record. All contacts with a minimum shadow length of 0.25 meters were selected; however, contacts that had an estimated height below 0.8 meters were classified as a “contact with insignificant ht.” Contacts with estimated heights above 0.8 meters, irrespective of survey depth, were considered potentially significant and possibly requiring further investigation. OSI’s side scan contact selection and classification criteria are summarized in Table 8.

**Table 8**
**OSI Side Scan Contact Selection and Classification**

| Contact Height | | Action | Contact Type |
|---|---|---|---|
| ≥ 0.8 m | Significant | Create Contact | Obstruction/Rock/Wreck/Unknown |
| 0.25 m to 0.8 m | Insignificant | Create Contact | Contact with Insignificant Height |
| < 0.25 | Insignificant | Disregard | N/A |

There was an abundance of fish encountered within the survey area, represented in the side scan record as individual fish and as schools. Fish contacts were created when the fish schools, singular swimmers or an occasional dolphin created detectable shadows in the side scan record. Singular fish presented themselves in the record most often as hard returns with long detached shadows. Sometimes the fish reflections were evident in the water column, which also created shadows in the SSS record. Fish contacts had the potential to be actual features; therefore, all fish contacts were correlated with the second 100% side scan coverage and with the MBES record. The presence of fish contacts in the HIPS display window was also helpful during editing of bathymetry as an indicator to the hydrographer to anticipate noisy data. Fish contacts were not assigned heights.

Most side scan contacts were symbolized as point features; however, sections of exposed pipelines were digitized as linear contacts, as well. At times contacts without a shadow were selected if there was a noteworthy shape or size to the item, despite its insubstantial relief.

B.2.2.6 Compression Methods Used for Reviewing Imagery

The CARIS Side Scan Editor "Skip" option for compression was used while reviewing imagery. The Skip option selects pixels for display at regular intervals across track. The computer monitors used for data processing were high resolution (1920 x 1080), and the full width of the screen was utilized while reviewing the side scan waterfall. Therefore, the data compression effects were minimized.

B.2.3 Sound Speed

B.2.3.1 Sound Speed Profiles

Preliminary data processing occurred simultaneously with data acquisition. Therefore at regular intervals throughout a survey day, raw MVP sound speed profile files were copied across the network to a Preprocess folder located on the Processing Computer as they became available. The Acquisition computer's directory and log were reviewed to verify file names and size and to remove any aborted casts from preprocess prior to converting the data to SVP files. All casts successfully copied from the acquisition computer were entered into the survey processing log, which was used to track the addition of each cast to the concatenated SVP file.

The ASCII CALC files logged with each MVP cast were processed using NOAA's Velocwin software. The BROOKE-OCEAN MVP Automatic mode was used to convert one or more CALC files and append them to a CARIS HIPS SVP file, referred to as the "CARIS HIPS Accumulating SVP File" in Velocwin. All individual MVP casts, attributed with position, date and time of cast, were concatenated to a survey level SVP file (ex: H12425_Master.svp) for use in sound speed correction of survey lines in CARIS HIPS.

During the Load SVP step in the HIPS Batch Editor, the Master.SVP file was chosen and the Edit option was selected to open the CARIS SVP Editor. All new casts that had been appended to the SVP file were reviewed and the Extended Depth modified as needed.

The CARIS Profile selection method used to apply sound speed correction was the "Nearest in distance within time" option, with 1 hour chosen as the time increment. The Master.SVP file was opened as a Background File in CARIS HIPS to verify that the cast positions all fell within the survey area.

The frequent CTD and MVP comparison casts (at least weekly) acquired during the "UTC midnight" changeover were processed in Velocwin to generate ZZQ files used to compare the sound speed profiles with the "Weekly DQA" tool. The CTD comparison casts were not appended to the CARIS SVP file used for sounding correction. A listing of DQA results is included in DR Separate II.

B.2.3.2 Surface Sound Speed

Frequent comparisons were also made between the surface sound speed of the stationary MVP (and CTD cast) and the surface sound speed recorded by the SBE37 at the time of the cast. The surface DQA comparisons were accomplished using Velocwin's "Daily DQA" tool.

B.2.4 Horizontal and Vertical Control

B.2.4.1 Horizontal Control

The POS MV data logged during MBES calibration testing were post processed in POSPac MMS to calculate SBET solutions. The navigation from the SBET solutions were applied to the patch test survey lines to achieve higher accuracy positioning of the discrete objects used to determine the angular biases of the MBES transducer, prior to processing the lines with CARIS' Calibration Tool.

B.2.4.2 Vertical Control

Predicted, Preliminary and Verified tides were downloaded from the CO-OPS SOAP web services website and were re-formatted as TID files to be used in CARIS HIPS tide correction.

The preliminary tidal zoning file (ZDF) that was provided by CO-OPS with the OPR-K339-KR-12 Tides Statement of Work was used when applying the tide correctors from the Port Fourchon, PORTS station (8762075) in CARIS HIPS. The time and height corrections in the zoning file were used to extrapolate the water level measured at the tide gauge to each discrete tide zone. The zoned tide correctors were then applied to the soundings.

B.2.5 Feature Verification

Contacts were exported daily from HIPS and SIPS to an ascii text file, which was imported into a CARIS Notebook edit layer (HOB). The lead hydrographer would identify the contacts that required additional investigation from the contact HOB file. An item investigation HOB layer was created which included the positions of all side scan contacts and Outstanding soundings to be developed with additional MBES. The Investigation HOB layer was exported to an S57 (000) file which could be opened as a background layer in HYPACK SURVEY during acquisition of development lines.

The item investigation and development lines were converted and processed in CARIS HIPS following the bathymetry processing procedures outlined above. The investigation lines were then filtered to 45 degrees on the port and starboard sides to ensure that a high density sounding set of near nadir beams was acquired. The development lines were processed immediately following their acquisition while the vessel was still in the vicinity of the investigation item, such that if additional near nadir coverage was required to obtain a least depth the vessel would be at the ready.

CUBE surfaces with a grid resolution of 0.5 meters or 1 meter (dependent on the surrounding depth) were created over the investigated features. The density layers were reviewed to verify that the Object Detection Coverage requirement of 5 soundings per node was met. Least depths were designated on all verified features and significant contacts.

All contacts were visually correlated between 100% and 200% coverages in the CARIS Map window and in CARIS Notebook. The current version of CARIS HIPS and SIPS, 7.1, does not allow the user to query contact attribution entered in Side Scan Editor in the Display Window. Therefore, a temporary hob file was generated in CARIS Notebook that included all contact positions and attribution (e.g. contact id, height, hydrographer remarks) with contacts classified as Cartographic Symbols. When opened in CARIS HIPS, the intermediary contact HOB file allowed the hydrographer to query the attributes associated with the side scan contacts to assist in data processing.

Correlated contacts were evaluated with respect to BASE surfaces, charted information, and designated soundings. All significant contacts (or contact pairs) were evaluated in full density sounding subsets to ensure that there was adequate SWMB coverage.

Contacts, contact images and designated soundings were exported from CARIS HIPS and SIPS. These data were processed with a custom OSI correlation macro in MS Excel to produce a contact listing in spreadsheet form as specified in Section 8.3.2 of the HSSDM. The macro displayed contact images and remarks, calculated contact and designated sounding relationships (i.e. distances, depths), updated processing flags/remarks and associated contact/sounding pairs (Figure 8). Unique contact ID’s were created from line-profile-range data. The contact listing spreadsheet is attributed with NAD83 positions and can be imported into a GIS.

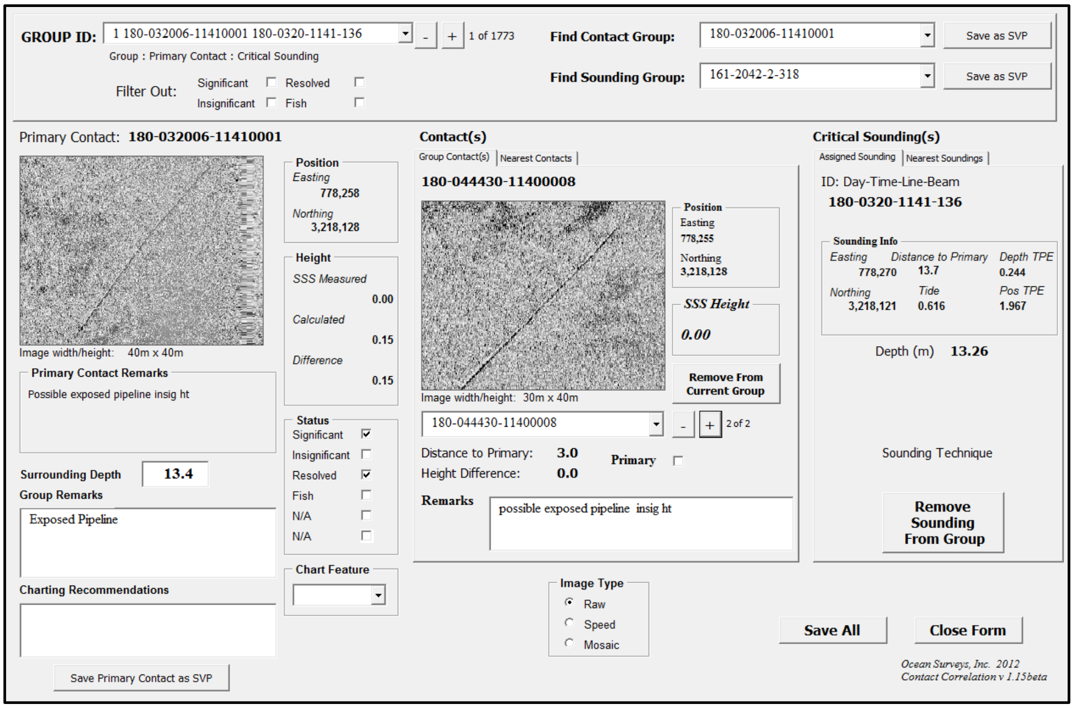



Figure 8. MS Excel contact correlation macro.

A Final Feature File (FFF) in S57 000 format was created in CARIS Notebook beginning with the “Assigned” features from the OCS provided Composite Source File (CSF) as its base. The FFF includes new survey features, updated and disproved charted features provided in the composite source file, and Meta-Objects and is in the WGS84 datum.

New or Updated features’ depths (VALSOU – value of sounding) and positions were imported into Notebook from designated least depth soundings selected in CARIS HIPS and SIPS. Bottom samples were included as attributed SBDARE (Seabed Area) point objects.

Descriptive information pertinent to each feature was entered in the IHO S57 attribute fields and the NOAA extended attribute fields as specified in Section 8.2 and Appendix 8: Feature Attribution of the HSSDM. The following attributes were updated for each item in the FFF:

- SORDAT (Source Date) – Final day of survey. New or verified features only.
- SORIND (Source Indicator) – Survey registry number, ex: US,US,graph,H12425. New or verified features only.
- descrp (Description) – New, Update, Delete, Retain
- prmsec (Primary/Secondary) – New or verified features were marked as Primary.
- remrks (Remarks) – Processing remarks including survey techniques, feature classification (i.e. obstruction, rock, platform), and correlating AWOIS number if applicable.
- recomd (Recommendations) – Hydrographer’s charting recommendations.

- sftype (Special Feature Type) – Only updated for ATON, AWOIS and/or DTON items.
- images (Images) – Contact images, CARIS screen grabs or chartlets included in the media folder.
- userid (Unique ID) – Unique Designated Sounding ID for new obstructions.

The mandatory S57 attribution for each S57 object class was updated as specified in Section 8.2 of the HSSDM. The required attributes vary with S57 object class (i.e. OBSTRN, OFSPLF, SBDARE), but may include:

- WATLEV (Water Level Effect) – updated for OBSTRN features
- VALSOU (Value of Sounding) – updated for OBSTRN features
- CATOBS (Category of Obstruction) – updated for OBSTRN features (when applicable)
- TECSOU (Technique of Sounding Measurement)
- QUASOU (Quality of Sounding Measurement)
- NATSUR (Nature of Surface) – updated for SBDARE features
- NATQUA (Nature of Surface, Qualifying terms) – updated for SBDARE features
- COLOUR (Color) – updated for SBDARE features

The required S-57 Meta-Object, M_COVR(Coverage) was also included in each survey's FFF.000 file, with the required attributes updated as specified in Section 8.2 of the HSSDM.

Within the S-57 Features data directory, four additional Notebook HOB files were submitted with the required deliverables to assist the Atlantic Hydrographic Branch (AHB) with contact and designated sounding review. Three of the additional HOB files divide the contacts into subsets of significant contact feature, insignificant contact features and fish features. The fourth additional HOB file includes all designated soundings on insignificant features that were not included in the final feature file. All contacts and designated soundings were import into Notebook as the $CSYMB object class. Tables 9–11 list the S-57 and NOAA Extended Attributes as utilized for the additional Notebook HOB Files.

**Table 9**
**Insignificant and Significant Contacts HOB File Attribute Mapping**

| Notebook Attribute | Value |
|---|---|
| cnthgt (contact height) | Contact height measured in slant range corrected SSS imagery |
| images (Images) | Contact image from SSS imagery |
| INFORM (Information) | Unique Designated Sounding ID |
| keywrd (Keyword) | Significant or Insignificant |
| obsdpt (Observed depth) | Corrected Least Depth (m) |
| prkyid (Primary Key ID) | Correlating Contact(s) Unique ID |
| remrks (Remarks) | Processing Remarks |
| SORDAT | Survey Date |
| SORIND | Survey Reference – registry ID |
| userid (Unique ID) | Unique Contact Number |

**Table 10**
**Fish Contacts HOB File Attribute Mapping**

| Notebook Attribute | Value |
|---|---|
| images (Images) | Contact image from SSS imagery |
| keywrd (Keyword) | Fish |
| remrks (Remarks) | Processing Remarks |
| SORDAT | Survey Date |
| SORIND | Survey Reference – registry ID |
| userid (Unique ID) | Unique Contact Number |

**Table 11**
**Insignificant Designated Soundings HOB File Attribute Mapping**

| Notebook Attribute | Value |
|---|---|
| images (Images) | Primary Contact image from SSS imagery |
| keywrd (Keyword) | Insignificant Feature |
| obsdpt (Observed depth) | Corrected Least Depth (m) |
| prkyid (Primary Key ID) | Primary Correlating Contact Unique ID |
| remrks (Remarks) | Primary Contact Processing Remarks |
| SORDAT | Survey Date |
| SORIND | Survey Reference – registry ID |
| userid (Unique ID) | Unique Designated Sounding ID |

### B.2.6 Bottom Samples

Bottom sample positions were imported into CARIS Notebook from the HYPACK target file into the Final Feature File. The bottom samples were classified as SBDARE (Seabed area) objects and attributed as instructed in Sections 7.1 and 8.2 of the HSSDM. The full bottom sample description was entered into the Remarks attribute field. The photo names of each bottom sample were entered into the Images attribute field.

## B.3 Quality Management

The majority of cross line sounding data were acquired with the Reson 7101 MBES system at the start of acquisition, prior to collection of mainscheme coverage. The planned cross line mileage was 10% of the planned mainscheme mileage, slightly more than the 8% of mainscheme mileage required in the HSSDM for Set Line Spacing coverage. Cross lines and mainscheme lines intersect at angles greater than 45 degrees. Soundings from mainscheme lines and from the cross lines were compared daily throughout survey operations in the preliminary CUBE surfaces and in CARIS HIPS Subset Editor. The cross line comparison served as a check that the system offsets and biases were entered correctly and to verify the accuracy of the sounding correctors (i.e. tide, sound speed, trueheave).

Statistical quality control information was generated by comparing the beams of each cross line to each finalized CUBE Surface. Cross line evaluations are performed with respect to IHO Order 1a uncertainty specifications with the CARIS QC Report Utility, and are presented in Separate II of the Survey DRs.

Detailed line queries were utilized periodically throughout data processing to be certain all necessary processes were completed and the right corrector files were applied to all the lines. The line queries were also used to calculate line mileage and were compared to processing logs to verify line names and be certain that no aborted lines were included in the final data products.

The standard deviation, depth and uncertainty layers were reviewed to identify possible systematic errors related to sound speed, tide, trueheave correction or to errors in system alignment.

Sound speed profiles were plotted by day to visualize the variation over time and space (Figure 9). Rapid increases or decreases in sound speed in the top 5 meters of the water column generally correlated with higher error in the sounding position, as evidenced by a “frown” effect across the MBES swath. Surface sound speed logged in the raw HYPACK files was extracted and plotted for every line. High deviation and rapid changes in the surface sound speed over a line, was also an indicator of increased sound speed error in sounding correction, which was most severe in the other beams (Figure 10). Lines that exhibited high variability in the surface sound speed were reviewed in the CUBE surface layers and in Subset Editor for excessive sound speed error. CARIS beam filters were used on lines that exhibited larger than acceptable uncertainty in the outer beams due to increased error in sound speed data.

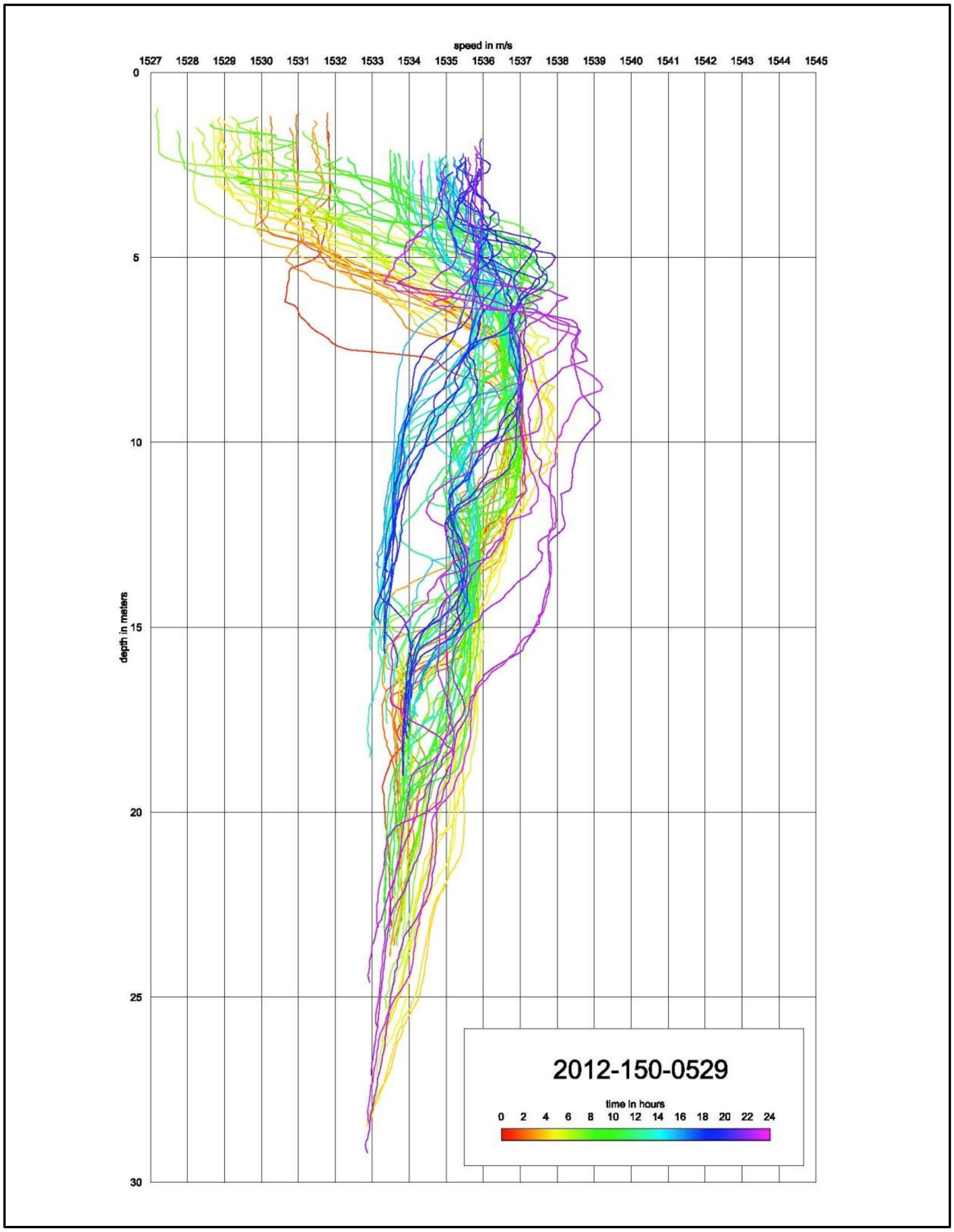



Figure 9. Plot of sound speed casts for May 29, 2012 (DN 150).

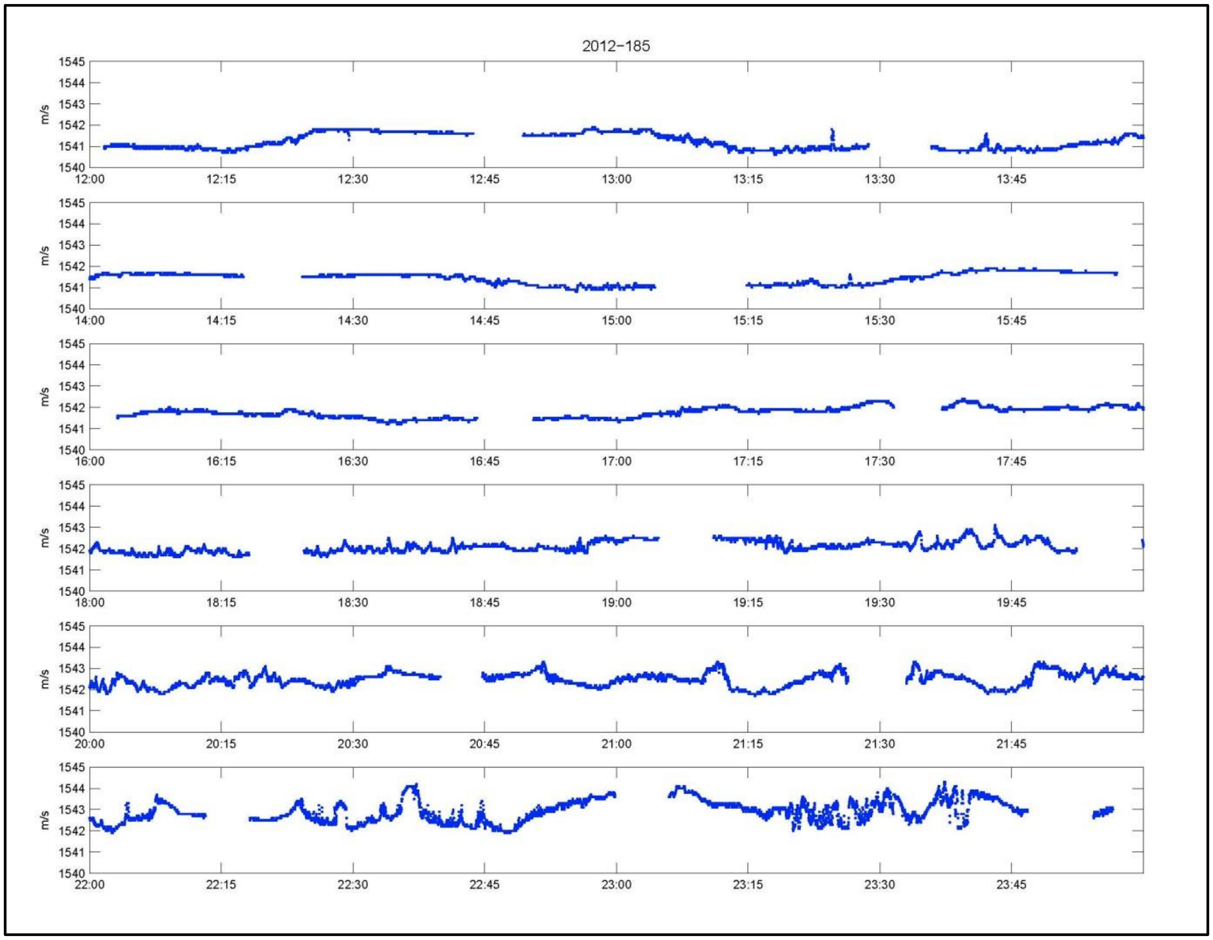



Figure 10. Surface sound speed plot by survey line for July 5, 2012 (DN 185).

The TPU values for final BASE surface depths were evaluated with the CARIS BASE surface QC Report Utility with respect to IHO Order 1a uncertainty specifications.

Junction comparisons between current and prior hydrographic surveys were accomplished using the CARIS HIPS difference surface function.

## B.4 Uncertainty and Error Management

Estimates for the uncertainty of all measurements associated with sounding collection, were gathered from either reported manufacturer system accuracy or from statistics calculated from multiple measurements of the value in question.

Error is defined as the difference between a measured value and the true, or accepted, value. Since the true sounding value is not known ahead of time, an accurate error value cannot be reported with confidence. Uncertainty, not error, is the chosen parameter to quantify sounding accuracy such that it can be reported in terms of an interval of confidence around the measured value. The uncertainty associated with a measurement is reported as the standard deviation (σ), or the root mean square deviation, of the value from the mean.

The combined uncertainty value per sounding, or the Total Propagated Uncertainty (TPU), was calculated using CARIS HIPS. Standard deviation values for vessel offsets, motion, draft and alignment measurements were entered into the vessel HVF "TPE values" section at the 1-sigma level. The HVF uncertainty values along with uncertainties associated with tide and sound speed were used in combination with the sonar model in the DeviceModels.xml file to assign a total horizontal uncertainty (THU) and total vertical uncertainty (TVU) for every sounding.

B.4.1 Total Propagated Uncertainty (TPU)

Tables 12 lists the standard deviation and uncertainty estimates used for all measurements incorporated into the TPU estimates for the Reson 7101 and the Reson 7125 echo soundings.

**Table 12**
**Reson 7101 and 7125 Uncertainty Estimates**

| **Uncertainty Values Included in CARIS HVF Files & Compute TPU Fields** | | | |
|---|---|---|---|
| Heading Measurement σ (deg) | 0.02 | XYZ Offset Measurement σ (m) | 0.015 |
| Heave % Amplitude | 5.00 | Vessel Speed Measurement σ (m/s) | 0.03 |
| Heave Measurement σ (m) | 0.05 | Loading Measurement σ (m) | 0.037 |
| Roll Measurement σ (deg) | 0.02 | Draft Measurement σ (m) | 0.015 |
| Pitch Measurement σ (deg) | 0.02 | Delta Draft Measurement σ (m) | 0.019 |
| Navigation Measurement σ (m) | 1.00 | MRU Align StdDev Gyro (deg) | 0.10 |
| Transducer Timing σ (sec) | 0.01 | MRU Align StdDev Roll/Pitch (deg) | 0.10 |
| Navigation Timing σ (sec) | 0.01 | | |
| Gyro Timing σ (sec) | 0.01 | Tide Measurement σ (m) | 0.01 |
| Heave Timing σ (sec) | 0.01 | Tide Zoning Vertical Uncertainty (m) | 0.10 |
| Pitch Timing σ (sec) | 0.01 | Sound Speed Error Measured (m/s) | 1.00 |
| Roll Timing σ (sec) | 0.01 | Sound Speed Error Surface (m/s) | 1.00 |

The POS MV 320 manufacturer recommended uncertainty values for the heading, heave, roll, pitch and timing measurements were entered in the HVFs.

The standard deviation value for the XYZ Offset and static draft measurements was calculated from distances acquired with the coarsest tool used to verify vessel offsets, the steel tape.

Standard deviation for the loading measurement was calculated from the measure down values acquired on the port and starboard sides during the daily changeover.

The uncertainty for the delta draft was established by calculating two standard deviations of the residuals between the fitted regression curve and the observed squat values. The settlement curve is included in DAPR Appendix I.

The MRU Alignment standard deviation values were calculated from the bias values estimated by multiple hydrographers who had individually processed the patch test data.

The combined tide measurement and zoning uncertainty was provided by CO-OPS in the Tides SOW.

A sound speed measurement uncertainty of 1 m/s was used in the TPU model since casts were taken every 15 minutes or less, a value recommended in Tables 4-9 Uncertainty values for use in CARIS with vessels equipped WITH an attitude sensor from Appendix 4 of the FPM. The surface sound speed uncertainty, 1 m/s, a conservative number per the FPM, was estimated from the surface speed of sound variability measured with the SBE 37.

# C. CORRECTIONS TO ECHO SOUNDINGS

## C.1 Vessel Configuration and Offsets

### C.1.1 Description of Correctors

Vessel configuration parameters and offsets are measures of the location of the integrated survey systems in respect to an established vessel Reference Point (RP) that serves as XYZ point 0, 0, 0 within the vessel's reference frame. The RP on the *R/V Ferrel* was the phase center or "bulls eye" of the POS MV IMU. The measured offsets included the distance between the transducer phase center to the RP, the distances between the GPS antenna phase centers and the RP, and the distance from the top of the side scan sheave and the RP.

### C.1.2 Methods and Procedures

As mentioned in prior sections, a total station was used to complete a full survey of the *R/V Ferrel* in 2010. The POS MV IMU was mounted on a permanent plate close to the vessel's center of rotation. Two permanent benchmarks located on the mid-deck of the *R/V Ferrel* were established in reference to IMU phase center, the RP. The total station was then used to measure the offsets from these benchmarks to the POS MV GPS port and starboard antenna mounts, the Trimble 750 GPS antenna mount, the top of the side scan sheave and the port/starboard draft measurement points. When the multibeam pole mount was fully deployed, the total station was used to establish another survey bench mark on the top side of the transducer pole clamp.

For the 2012 project, the offsets established in 2010 were verified with a steel tape measure on May 24, 2012 (DN 144). The vertical offsets measured from the antenna mounts to the phase center of the GPS antennas were added to the Z-values established with the total station. The vertical offset between the bench mark on the top of the transducer pole clamp and the transducer phase center (TX) was measured with a steel tape.

For both the Reson 7101 and 7125 deployments, the transducer is located directly below the transducer pole clamp bench mark allowing for an unobstructed measurement path.

IMU and antenna offsets and mounting angles, relative to the vessel frame and a vessel reference position (RP), were measured with precise optical survey methods in 2010. The IMU and transducer mounting hardware were co aligned in 2010 employing a gyrocompass while the survey vessel was in dry dock.

During the current (2012) vessel mobilization a new set of POS-MV GPS antenna masts were employed. The difference in height between the new masts and those used during the 2010 survey was known and this difference was applied to the POS-MV setup file using the MV POSView controller software. The relative position of the new antenna masts with respect to the vessel frame and RP remained unchanged. The primary GPS antenna position, with respect to the IMU and RP, was established, as mentioned above, using precise optical survey methods. This offset was confirmed in 2010 using the MV POSView controller calibration procedure. During the current (2012) partial ship survey a gyrocompass was again employed to confirm the angular alignment of the IMU and transducer mounting hardware.

### C.1.3 Vessel Offset Correctors

Instrument offsets input to the CARIS vessel configuration files are included in Tables 13-15 below.

**Table 13**
***R/V Ferrel* Sensor Offsets (see Figure 12)**

| ***R/V Ferrel* Offsets via Topcon Total Station Survey or Measured Relative to Permanent Shipboard Benchmarks. Offsets are relative to Reference Point (RP) or Waterline** | **Forward Positive (m)** | **Starboard Positive (m)** | **Up Positive w.r.t RP (m)** | **Up Positive w.r.t. waterline (m)** |
|---|---|---|---|---|
| RP IMU Center 0,0,0 | 0.000 | 0.000 | 0.000 | -0.840 |
| GPS POS Antenna Phase Center Port | 12.029 | -2.377 | 11.267 | 10.427 |
| GPS POS Antenna Phase Center Starboard | 12.064 | 2.427 | 11.262 | 10.422 |
| Comparison GPS Antenna Phase Center | 15.383 | 2.110 | 11.047 | 10.207 |
| 7101 Transducer Phase Center | 1.476 | 5.260 | -1.757 | -2.597 |
| 7125 Transducer Phase Center | 1.634 | 5.250 | -2.007 | -2.847 |
| Top Of Sheave (Cable at top of sheave) | -18.550 | 2.040 | 4.080 | 3.240 |
| Starboard Side Draft Measurement Point | 2.858 | 4.710 | 2.065 | 1.225 |
| Port Side Draft Measurement Point | 2.832 | -4.708 | 2.083 | 1.243 |

**Table 14**
**Reson 7101 CARIS Vessel File's Transducer Offsets (RP to Tx)**

| **Tx Offsets** | **IMU/Navigation to Transducer (m)** |
|---|---|
| X Phase Center | 5.260 |
| Y Phase Center | 1.476 |
| Z Phase Center | 1.757 |

**Table 15**
**Reson 7125 CARIS Vessel File's Transducer Offsets (RP to Tx)**

| **Tx Offsets** | **IMU/Navigation to Transducer (m)** |
|---|---|
| X Phase Center | 5.250 |
| Y Phase Center | 1.634 |
| Z Phase Center | 2.007 |

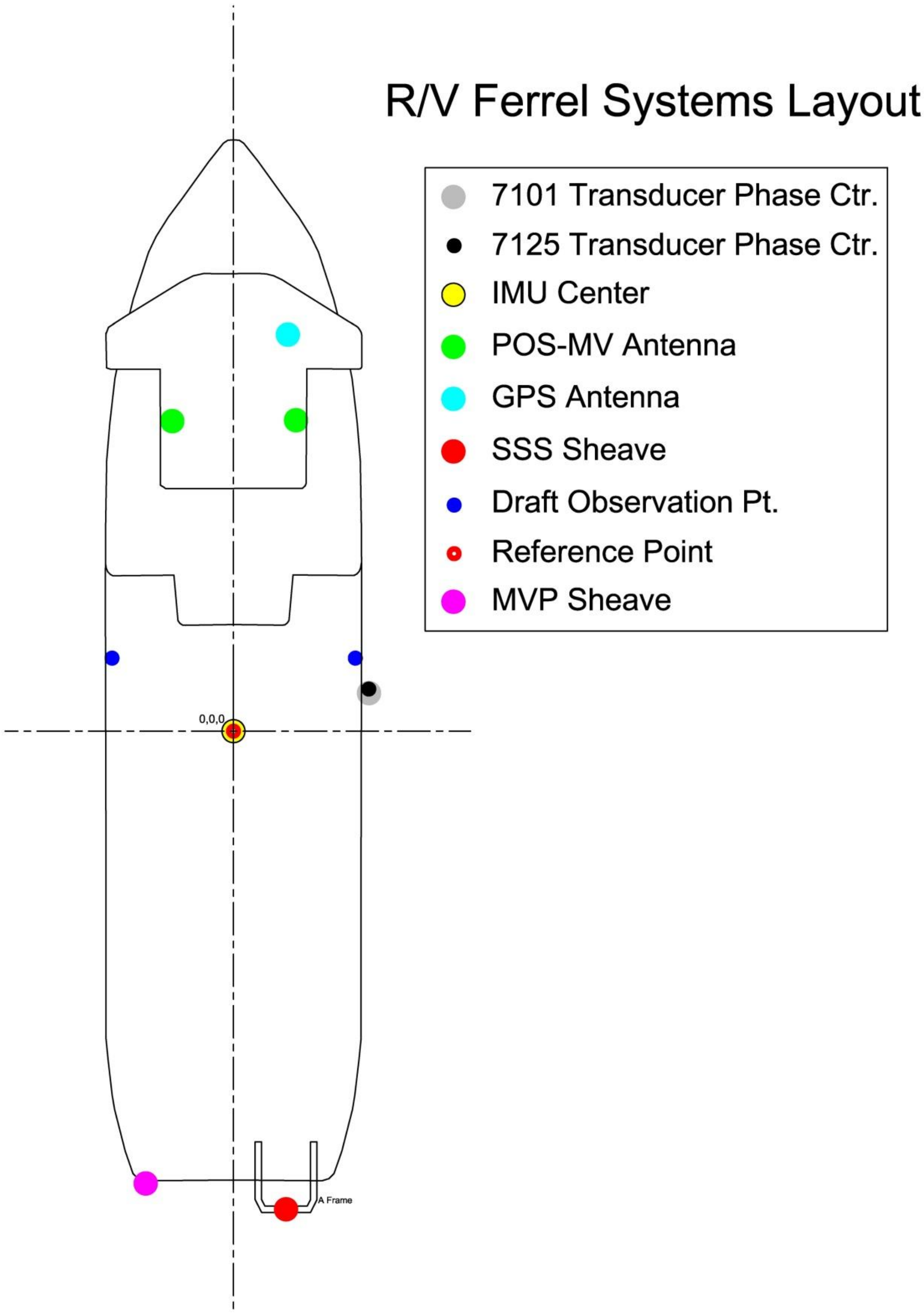



Figure 11. *R/V Ferrel* systems layout.

C.1.4 Layback

Side scan sonar fish positioning was accomplished real time employing Chesapeake Technology's SonarWiz 5. The software was configured to calculate fish position using Pythagoras Theorem (refined via tow fish depth input). The origin for fish position calculations was the top of the cable counter sheave which is related to the vessel RP (within the SonarWiz 5 software) via X,Y, Z offsets. Field testing prior to mobilization of this and other OSI projects employing the SonarWiz software for tow fish positioning indicated that a catenary scalar value of 1.0 was appropriate. As mentioned above, cable-out values were derived from a calibrated cable counter sheave whose accuracy was confirmed frequently throughout the course of each survey day. Side scan sonar target positioning accuracy was verified prior to commencement of survey operations by comparing the position of an oil rig leg (derived with multibeam) to the position of the same leg as viewed in the CARIS SIPS waterfall window. Accuracy testing results are presented in Table 5 of DAPR Appendix II.

C.2 Static and Dynamic Draft

C.2.1 Static Draft

C.2.1.1 Description of Correctors

Static draft is the vertical distance of the echosounder transducer below the water line and is added to the observed soundings during data processing in CARIS HIPS. The vertical offset between the transducer phase center and the RP was entered into the HVF Swath 1, Z-value field. A vertical offset to account for the distance from the RP to the water surface was updated nearly once a day into the Waterline Height field in the HVF. The Z-value and the waterline corrector added together equaled the static draft of the echosounder transducer phase center.

C.2.1.2 Methods and Procedures

Direct measurements of the water surface relative to port side and starboard side benchmarks employing a fiberglass stadia rod were taken at the start of survey (May 25, 2012, DN 145), at the fuel dock before and after fueling, and daily offshore, when conditions were calm. The waterline height above the RP was determined by averaging the differences obtained from subtracting the measured distances from the water surface to the benchmarks from the known vertical offsets between the RP and the benchmarks. Vessel attitude was accounted for as the final measured waterline height value is an average of the port and starboard measured values.

A Hazen water level gauge was also installed within the transducer mount pole to monitor the change in static draft due to changes in vessel loading. The Hazen tide gauge pressure sensor was installed at a fixed elevation within the transducer pole. The transducer mounting flange at the bottom of the transducer pole was fitted with a small diameter copper orifice making the transducer pole, in effect, a stilling well. The Hazen gauge depth below the water surface was calibrated prior to the start of survey in Amelia, LA to determine its vertical offset in reference to the RP. When the vessel was at a full stop for the daily "UTC midnight" changeover, the Hazen gauge water level data were logged for approximately 15 minutes using HYPACK Survey. The water level values were extracted from the raw HYPACK file and averaged to obtain the depth of the Hazen gauge sensor below the water line. The waterline height was calculated by subtracting the vertical offset between the Hazen gauge sensor and the RP from the Hazen gauge average depth.

The Hazen water level gauge was replaced with a HOBO water level data logger on June 8, 2012 due to problems with the Hazen gauge's RF data link. The HOBO gauge was operated in the same manner as the Hazen gauge; however, it was deployed and removed daily to the base of the stilling well in order to upload the water level data from the sensor. The HOBO gauge was calibrated at the fueling dock prior to its operation offshore to determine the vertical offset between the RP and the HOBO gauge depth. The HOBO water level data were corrected for atmospheric pressure and water density. The waterline height was calculated by subtracting the vertical offset between the water level sensor and the RP from the average water level measured with the HOBO gauge. The HOBO gauge was used for the remainder of survey operations.

The waterline height measurement was calculated nearly daily using the Hazen or Hobo tide gauge method and the measure down values were acquired when sea conditions allowed. The waterline height measurement was corrected to the vessel reference point and recorded in the acquisition log. Waterline height values calculated from physical measurement, "measure downs," or the Hazen/HOBO gauge data, were time stamped and entered into the CARIS vessel configuration file.

In CARIS HIPS, the time stamped waterline height correctors were added to the Z-value vertical offset between the RP and the transducer phase center to obtain the echosounder static draft.

### C.2.2 Dynamic Draft

#### C.2.2.1 Description of Correctors

Dynamic draft correctors account for the vertical displacement of the transducer when a vessel is underway in relation to its position at rest.

#### C.2.2.2 Methods and Procedures

Dynamic draft was measured on May 26, 2012 (DN 146), with the *R/V Ferrel* configured for data acquisition with an average loading weight and vessel trim.

The dynamic draft calibration test lines were acquired in water with a nominal depth of 10 m, with wave height of 1 foot or less. Data were acquired along pre-determined tracklines approximately 500 m long at regular intervals of speed, beginning with the engines in "clutch" and increasing by 100 RPMs until the maximum vessel survey speed was reached. A reciprocal line pair was acquired at each speed. Tidal variations were accounted for by recording a "drift line" with the vessel at rest at the beginning and end of each line run at speed. Lines, at speed or at rest, were only logged after the vessel speed leveled out or stabilized to a static state. POSPac data were acquired for the duration of the dynamic draft calibration testing, with the file logged at least 5 minutes before and after data acquisition.

The POSPac files logged during the dynamic draft calibration were processed in Applanix's POSPac MMS software to obtain an SBET solution. Speed and ellipsoid heights were extracted from the SBET solution for each line. Dynamic draft values estimating the difference in ellipsoid heights between the vessel at each RPM/speed and the vessel at rest were determined by averaging the results for each RPM pair. A polynomial regression curve was fit to the observed dynamic draft data and the final dynamic draft table was derived using the regression curve equation.

C.2.2.3 Dynamic Draft Correctors

**Table 16**
***R/V Ferrel* Dynamic Draft Correctors**

| Dynamic Draft Correctors | | |
|---|---|---|
| **Speed** | | **Dynamic Draft** |
| **M/S** | **Knots** | **Meters** |
| 0.000 | 0.0 | 0.000 |
| 1.029 | 2.0 | 0.016 |
| 1.286 | 2.5 | 0.018 |
| 1.543 | 3.0 | 0.022 |
| 1.801 | 3.5 | 0.025 |
| 2.058 | 4.0 | 0.026 |
| 2.315 | 4.5 | 0.029 |
| 2.572 | 5.0 | 0.034 |
| 2.829 | 5.5 | 0.039 |
| 3.087 | 6.0 | 0.044 |
| 3.344 | 6.5 | 0.051 |
| 3.601 | 7.0 | 0.060 |
| 3.858 | 7.5 | 0.069 |
| 4.116 | 8.0 | 0.080 |
| 4.373 | 8.5 | 0.093 |

## C.3 System Alignment

### C.3.1 Description of Correctors

A multibeam sonar calibration was completed to determine residual navigation timing error and angle biases in roll, pitch, and heading in the echosounder transducer alignment.

### C.3.2 Methods and Procedures

Prior to commencement of survey operations, a sensor alignment or patch test was performed for each MBES system utilized for data acquisition. The initial patch test for the Reson 7101 MBES system was performed on May 26, 2012 (DN 147). The initial patch test for the Reson 7125 MBES system was performed on June 14 and 15, 2012 (DNs 166 and 167). The patch tests were conducted in order to determine biases in roll, pitch, heading and navigation timing. Data were acquired in accordance with HSSDM April 2012 Section 5.2.4.1, using a discrete feature rather than a slope to calculate the bias values due to the flat nature of the survey site. Initial patch test calibrations were accomplished employing RTK GPS positioning and water level determination. Final patch test calibrations were accomplished with post-processed kinematic (PPK) GPS positioning and verified tide correctors from the Port Fourchon, LA tide gauge.

Each set of patch test lines was run multiple times to ensure system repeatability. Patch test biases were determined in the following order: navigation timing error (latency), pitch, roll, and heading. The CARIS HIPS Calibration Tool (Figure 12) was primarily used to determine offset values. However, all patch test values were verified with the HYPACK HYSWEEP patch test routine (Figure 13).

For each parameter, multiple processing iterations were performed by multiple hydrographers. The final offset values for each vessel file (HVF) are an average of the CARIS-derived values. The final applied values, entered into the respective CARIS vessel files, are shown in Tables 17 and 18. The patch tests results were of high quality and repeatability.

Patch tests were also acquired at the conclusion of survey operations for both the Reson 7101 and Reson 7125. The bias values calculated from the end of survey patch tests verified the values determined with the initial patch tests.

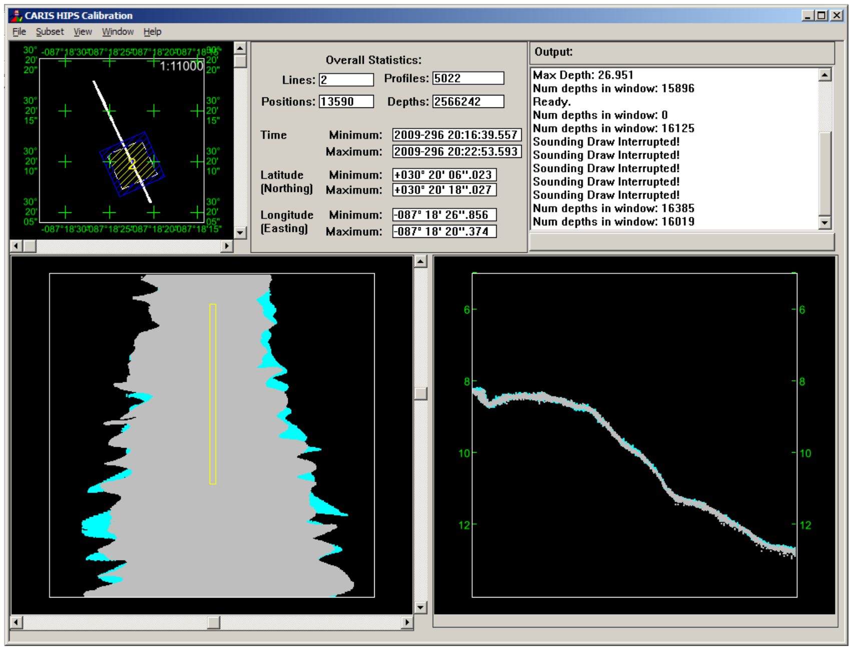



Figure 12. CARIS HIPS Calibration Tool.

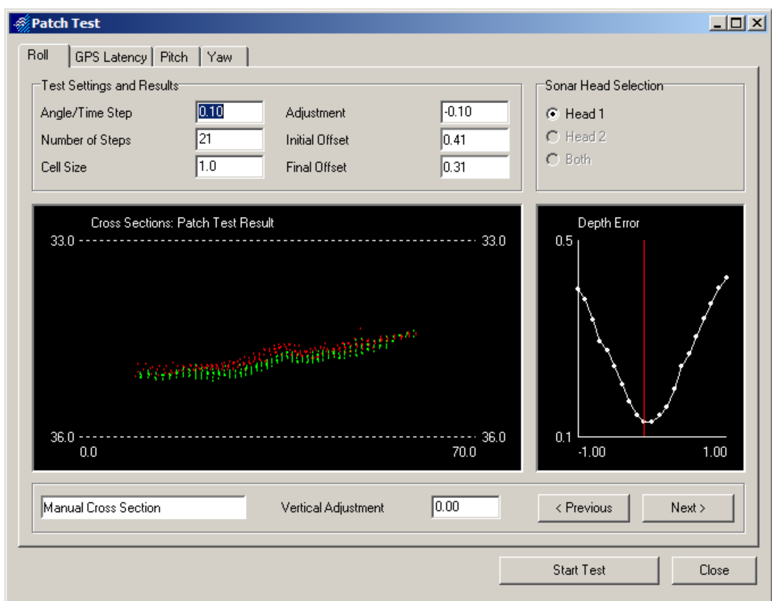



Figure 13. HYPACK HYSWEEP Patch Test Utility.

A performance surface was created on May 26, 2012 (DN 147) from a high density, near nadir sounding set collected with the Reson 7101. Ten MBES lines were acquired over a flat section of seafloor, and processed in CARIS HIPS with the patch test bias values for timing, pitch, roll and yaw entered into the HVF. A port and starboard beam filter of 45 degrees was applied to the performance surface lines and a 1 m x 1 m Uncertainty Surface was generated from the processed soundings. Two performance check lines that were run perpendicular across the center of the surface were processed in CARIS HIPS as well; however, no beam filter was applied. The CARIS HIPS QC Report Utility was used to compare the beams of each performance check line to the performance surface to verify system accuracy.

Additional performance check lines were acquired over the performance surface site periodically throughout survey operations with the Reson 7101 and Reson 7125 systems, and then compared to the performance surface in CARIS HIPS. Performance test results are summarized in Table 6 of DAPR Appendix II.

### C.3.3 System Alignment Correctors

**Table 17**
**Initial *7101* Patch Test Alignment Correctors**

| **CARIS Patch Test Results** | |
|---|---|
| Latency | 0.00 sec |
| Pitch | 0.24 deg |
| Roll | 0.09 deg |
| Yaw (heading) | -0.19 deg |

**Table 18**
**Initial *7125* Patch Test Alignment Correctors**

| **CARIS Patch Test Results** | |
|---|---|
| Latency | 0.00 sec |
| Pitch | 0.14 deg |
| Roll | -0.16 deg |
| Yaw (heading) | 0.20 deg |

## C.4 Positioning and Attitude

### C.4.1 Description of Correctors

DGPS correctors received from the USCG are used to improve positioning accuracy over operation in stand-alone GPS mode. Attitude corrections measured at the vessel RP are applied to soundings to correct for vessel motion.

C.4.2 Methods and Procedures

An Applanix POS MV 320 V.4 was employed for motion, heading, and position determination. Manufacturer's stated accuracy and resolution values are tabulated below in Table 19.

**Table 19**
**POS MV Specifications**

| **POS MV 320 V.4 Manufacturer's Specifications** | | |
|---|---|---|
| **Parameter** | **Accuracy** | **Resolution** |
| Roll | 0.02° | 0.01° |
| Pitch | 0.02° | 0.01° |
| Heave | 5 cm or 5% of wave height | 0.01m |
| Heading | 0.02° | 0.01° |

Prior to calibration of the POS MV, lever arm distances, mounting angles and the separation distance between the port and starboard GPS antennas were entered in the controller software. The heading accuracy threshold was set to 0.5 degrees. A GAMS calibration was run after the heading accuracy had dropped below the 0.5 degrees threshold, keeping a straight course until the calibration was completed. See DAPR Appendix III, Positioning and Attitude System Reports for additional information on the POS MV configuration and calibration.

C.5 Tides and Water Levels

C.5.1 Description of Correctors

Tide correctors are applied to reduce the soundings to the Mean Lower Low Water (MLLW) datum.

C.5.2 Methods and Procedures

The water level station at Port Fourchon, LA (876-2075), is the reference station for predicted, preliminary observed and verified tides for all hydrography for this project. The time and range ratio correctors for applicable zones were applied to all tide correctors in CARIS HIPS during the preliminary and final processing phases of this project. Predicted and preliminary observed zoned tides were applied to sounding data for preliminary processing. Verified tide data were downloaded from the NOAA CO-OPS Internet page and applied with final zoning for all final soundings and BASE surfaces. Water levels used for DTON submissions are specified in the reports.

## C.6 Sound Speed

Observed depth is a function of the speed of sound in the water column, such that depth is equivalent to the sound speed multiplied by the travel time of the sound pulse from transmit to receive divided by 2. Sound speed is not a constant and varies temporally and spatially, affected by changes in temperature, salinity and depth. Sound speed profiles are acquired to model the speed of sound versus depth within a survey site. Improper sound speed correction can result in inaccurate depth values and sounding positions. The sound speed correctors from the profiles are applied to soundings to override the assumed sound speed value used during acquisition and to calculate the depth using the actual sound speed measured in the survey site for a defined space and time.

### C.6.1 Sound Speed Profiles

The sound speed profiles used to correct the echo soundings were acquired with an ODIM MVP-30 equipped with two sensors; a sensor that measured sound speed directly at 10 Hz during its descent through the water column and a pressure sensor for profile depth measurement. The MVP sensors (sound speed and depth) were calibrated on April 30, 2012 and May 2, 2012. The calibration reports are included in DAPR Appendix IV, Sound Speed Sensor Report and in Separate II of the survey DRs.

Sound speed profile correctors were applied in CARIS HIPS using the Sound Velocity Correction process, which employs a ray tracing algorithm to simulate refraction. The Nearest in Distance within Time profile selection method was used to determine which cast was applied to the soundings. This method was selected to limit the effects of spatial and temporal variation in sound speed.

### C.6.2 Surface Sound Speed

Surface sound speed correctors were sent directly to the Reson 7101 and 7125 TPUs in real time to facilitate beam steering in equidistant mode and roll stabilization, a feature used throughout the survey. The SBE 37 sensor was calibrated by the manufacturer in April 2012.

## D. APPROVAL SHEET

# LETTER OF APPROVAL

# REGISTRY NOS. H12425, H12426, H12427, AND H12428

This report and the accompanying data are respectfully submitted.

Field operations contributing to the accomplishment of Surveys H12425, H12426, H12427, and H12428 were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and associated data have been closely reviewed and are considered complete and adequate as per the Statement of Work.

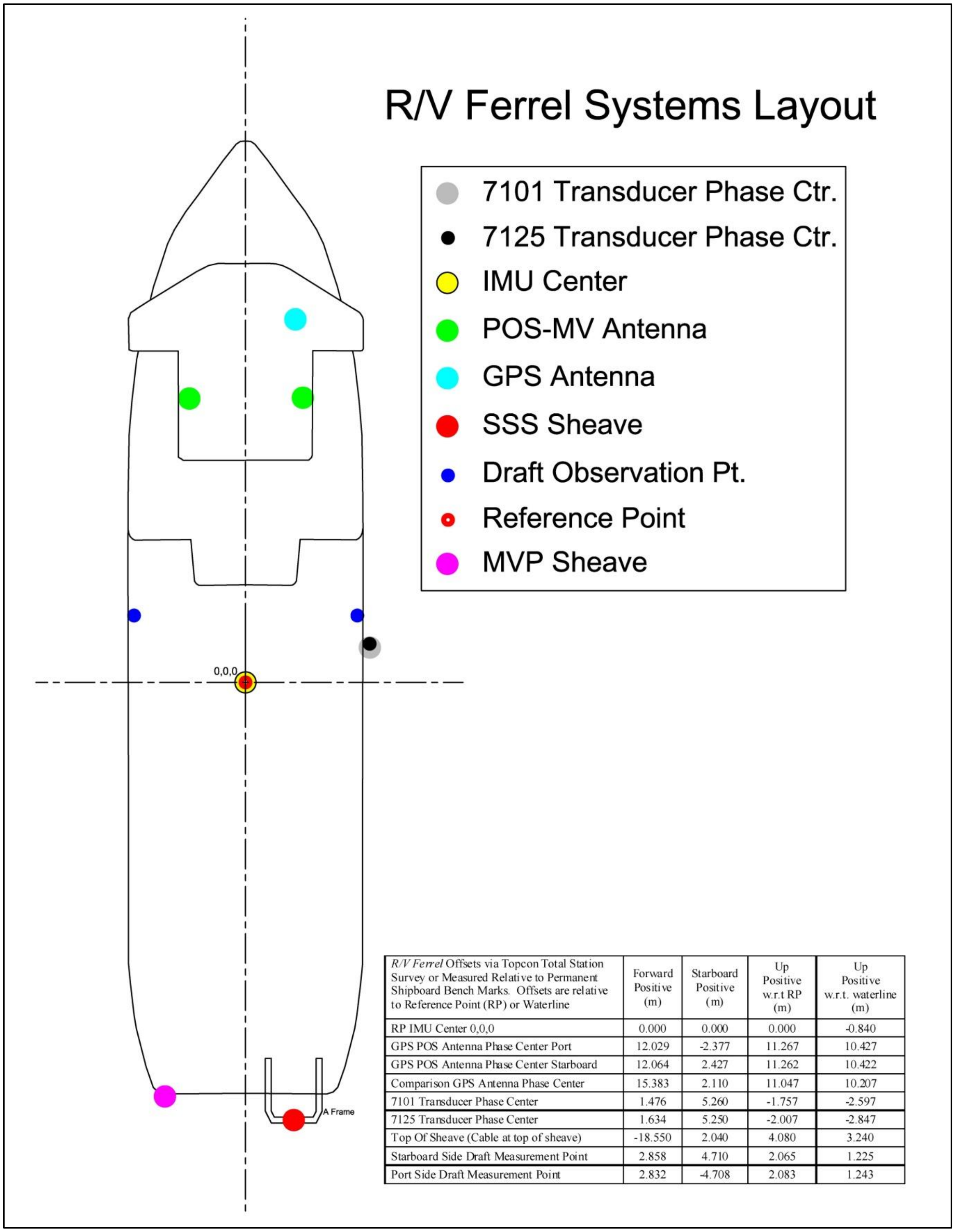
George Reynolds

Digitally signed by George G. Reynolds
DN: cn=George G. Reynolds, o=Ocean Surveys, Inc., ou, email=ggr@oceansurveys.com, c=US
Date: 2012.11.27 08:07:37 -05'00'

George G. Reynolds
Ocean Surveys, Inc.
Chief of Party
November 27, 2012

# DAPR Appendix I

# Vessel Reports




| *R/V Ferrel* Offsets via Topcon Total Station Survey or Measured Relative to Permanent Shipboard Bench Marks. Offsets are relative to Reference Point (RP) or Waterline | Forward Positive (m) | Starboard Positive (m) | Up Positive w.r.t RP (m) | Up Positive w.r.t. waterline (m) |
|---|---|---|---|---|
| RP IMU Center 0,0,0 | 0.000 | 0.000 | 0.000 | -0.840 |
| GPS POS Antenna Phase Center Port | 12.029 | -2.377 | 11.267 | 10.427 |
| GPS POS Antenna Phase Center Starboard | 12.064 | 2.427 | 11.262 | 10.422 |
| Comparison GPS Antenna Phase Center | 15.383 | 2.110 | 11.047 | 10.207 |
| 7101 Transducer Phase Center | 1.476 | 5.260 | -1.757 | -2.597 |
| 7125 Transducer Phase Center | 1.634 | 5.250 | -2.007 | -2.847 |
| Top Of Sheave (Cable at top of sheave) | -18.550 | 2.040 | 4.080 | 3.240 |
| Starboard Side Draft Measurement Point | 2.858 | 4.710 | 2.065 | 1.225 |
| Port Side Draft Measurement Point | 2.832 | -4.708 | 2.083 | 1.243 |

Figure 1: *R/V Ferrel* vessel offsets.

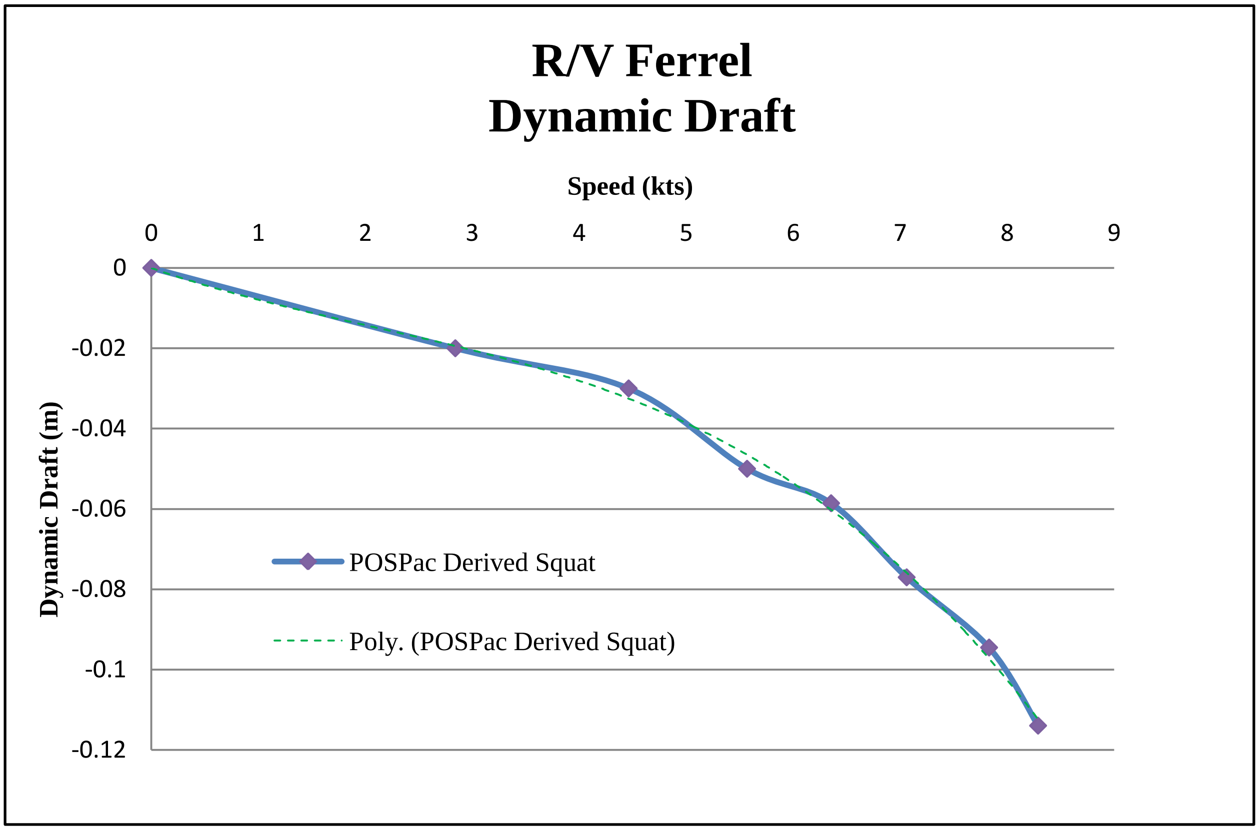



Figure 2. Plot of dynamic draft values derived from the averaged difference in ellipsoid height logged in the POSPac data between the vessel at speed and at rest. A regression curve, shown in green, was fit to the data. The resultant polynomial equation was used to calculate the final values entered into the dynamic draft table in the *R/V Ferrel's* vessel configuration files.

**Table 1**

**POSPac-derived Dynamic Draft Table**

| | **RPM** | **Static** | **680 – 1 Engine** | **680 – 2 Engines** | **800** | **900** | **1000** | **1100** | **1200** |
|---|---|---|---|---|---|---|---|---|---|
| **Speed** | **Knots** | 0 | 2.842 | 4.462 | 5.569 | 6.355 | 7.061 | 7.832 | 8.290 |
| | **m/s** | 0 | 1.462 | 2.296 | 2.865 | 3.269 | 3.633 | 4.029 | 4.265 |
| **Dynamic Draft** | **Meters** | 0 | -0.020 | -0.030 | -0.050 | -0.059 | -0.077 | -0.094 | -0.114 |

# DAPR Appendix II

# Echosounder Reports

## Table 1

## Echosounder System Accuracy Test (Bar Check - Confidence Check)

| Date | Lat, Long | Sounding System Models | Bar Depth (m) | MBES Depth (m) | Spot Depth (m) | MBES Depth (m) | Comments |
|---|---|---|---|---|---|---|---|
| 5/24/12 | 29-41-06.97 N, 91-05-59.93 W | Lead Line, Reson 7101 | 3.28 | 3.28 | 5.51 | 5.50 | Start of survey bar check at Amelia dock. Water surface flat calm. No corrections necessary. |
| 5/26/12 | 29-07-16.76 N, 90-12-30.04 W | Lead Line, Reson 7101 | 5.00 | 5.00 | 7.92 | 7.93 | At Fourchon Dock. |
| 6/2/12 | 29-07-19.09 N, 90-00-47.01 W | Lead Line, Reson 7101 | 8.21<br>13.21 | 8.21<br>13.21 | 14.17 | 14.15 | Offshore |
| 6/8/12 | 29-07-16.73 N, 90-12-29.99 W | Lead Line, Reson 7101 | 5.00<br>7.00 | 5.01<br>7.00 | 8.04<br>8.05<br>8.03 | 8.01<br>8.02<br>8.04 | At Fourchon Dock. |
| 6/11/12 | 29-07-04.35 N, 90-12-24.41 W | Lead Line, Reson 7101 | 5.00 | 5.01 | 5.79 | 5.77 | At Fourchon Dock. |
| 6/15/12 | 29-01-21.30 N, 90-08-19.68 W | Lead Line, Reson 7101 | 8.30<br>13.30 | 8.30<br>13.30 | | | Last bar check using 7101 (offshore) |
| 6/15/12 | 29-07-04.57 N, 90-12-23.87 W | Lead Line, Reson 7125 | 5.00<br>5.50<br>6.00 | 5.00<br>5.50<br>6.00 | 6.23 | 6.23 | First bar check using 7125<br>At Fourchon Dock. |
| 6/21/12 | 29-07-04.82 N, 90-12-22.78 W | Lead Line, Reson 7125 | 5.00<br>6.00 | 5.00<br>6.00 | 6.42 | 6.40 | At Fourchon Dock |
| 6/28/12 | 29-07-04.28 N, 90-12-24.51 W | Lead Line, Reson 7125 | 5.00 | 5.01 | 5.96 | 5.96 | At Fourchon Dock |
| 7/5/12 | 29-10-01.46 N, 89-47-12.72 W | Lead Line, Reson 7125 | 8.26<br>13.26 | 8.26<br>13.26 | 17.61 | 17.62 | Offshore |
| 7/9/12 | 29-07-16.28 N, 90-12-29.85 W | Lead Line, Reson 7125 | 5.00<br>6.00<br>7.00 | 5.01<br>6.01<br>7.01 | 8.01 | 7.98 | At Fourchon Dock. Soft bottom. |

# Table 2

## Lead Line Accuracy Confirmation

| | | |
|---|---|---|
| **Lead Line Identification Number:** M1 | | |
| **Date of Calibration:** 5-24-2012 | | |
| **Method of Calibration:** Steel tape | | |
| **Location:** Amelia, Louisiana | | |
| **Lead Line Unit of Measure:** Meters | | |
| **Graduated Marking (a)** | **Calibration Measurement (b)** | **Lead Line Corrector (c = b - a)** |
| 5 | 5.00 | 0.00 |
| 10 | 10.00 | 0.00 |
| 15 | 15.00 | 0.00 |
| 20 | 20.00 | 0.00 |
| 25 | 25.00 | 0.00 |

**Table 3**

**Reson Seabat 7101 Patch Test Results**

| **TEST INFORMATION** |
|---|
| **Test Date(s) / DN(s):** 05-26-12/DN 147<br>**Wind / Seas / Sky:** ENE 5-10 kts; seas < 2 ft<br>**Locality:** Gulf of Mexico<br>**Sub-Locality:** South of Caminada Pass<br>**Bottom Type:** muddy<br>**Approximate Average Water Depth:** 20 meters |
| **TEST RESULTS** |
| **Navigation Timing Error:** 0.0 seconds<br>**Pitch Timing Error:** 0.0 seconds<br>**Roll Timing Error:** 0.0 seconds<br>**Pitch Bias:** 0.24 degrees<br>**Roll Bias:** 0.09 degrees<br>**Heading Bias:** -0.19 degrees<br>**Resulting CARIS HIPS HVF File Names:** FERREL_7101_511_ED_Mainscheme.hvf, FERREL_7101_511_ED_Crosslines.hvf, FERREL_7101_511_ED_Developments.hvf |

**Table 4**

**Reson Seabat 7101 Patch Test Lines**

| Line Number | Average Heading (degrees) | Average Speed (knots) | Comments |
|---|---|---|---|
| 2012FE1470551_2 | 32 | 7.6 | Pitch/Roll (with 0601_2) |
| 2012FE1470601_2 | 211 | 8.4 | Pitch/Roll (with 0551_2) |
| 2012FE1470608_1 | 32 | 7.6 | Pitch/Roll (with 0618_1)<br>Yaw (with 0624_3) |
| 2012FE1470618_1 | 211 | 8.3 | Pitch/Roll (with 0608_1)<br>Yaw (with 0633_3) |
| 2012FE1470624_3 | 32 | 7.6 | Yaw (with 0608_1) |
| 2012FE1470633_3 | 211 | 8.3 | Yaw (with 0618_1) |
| 2012FE1470639_2 | 31 | 7.6 | Latency (with 0735_2) |
| 2012FE1470659_2 | 210 | 8.3 | Latency (with 0727_2) |
| 2012FE1470707_3 | 32 | 7.8 | Yaw (with 0717_1) |
| 2012FE1470717_1 | 31 | 7.7 | Yaw (with 0707_3) |
| 2012FE1470727_2 | 210 | 5.5 | Latency (with 0659_2) |
| 2012FE1470735_2 | 30 | 4.7 | Latency (with 0639_2) |

**Table 5**

**Reson Seabat 7125 Patch Test Results**

| |
|---|
| **TEST INFORMATION** |
| **Test Date(s) / DN(s):** 06-14-12/DN 166 and 06-15-12/DN 167<br>**Wind / Seas / Sky:** Winds ENE 12 kts, seas 1-2 ft<br>**Locality:** Gulf of Mexico<br>**Sub-Locality:** South of Caminada Pass<br>**Bottom Type:** muddy<br>**Approximate Average Water Depth:** 20 meters |
| **TEST RESULTS** |
| **Navigation Timing Error:** 0.0 seconds<br>**Pitch Timing Error:** 0.0 seconds<br>**Roll Timing Error:** 0.0 seconds<br>**Pitch Bias:** 0.14 degrees<br>**Roll Bias:** -0.16 degrees<br>**Heading Bias:** 0.20 degrees<br>**Resulting CARIS HIPS HVF File Names:** FERREL_7125_Mainscheme.hvf, FERREL_7125_Crosslines.hvf, FERREL_7125_Developments.hvf |

**Table 6**

**Reson Seabat 7125 Patch Test Lines**

| Line Number | Average Heading (degrees) | Average Speed (knots) | Comments |
|---|---|---|---|
| 2012FE1671459_1 | 31 | 8.6 | Roll (with 1510_1)<br>Yaw (with 1535_3) |
| 2012FE1671510_1 | 211 | 7.8 | Roll (with 1459_1)<br>Yaw (with 1543_3) |
| 2012FE1671519_2 | 31 | 8.6 | Pitch/Roll (with 1527_2)<br>Latency (with 1602_2) |
| 2012FE1671527_2 | 211 | 7.8 | Pitch/Roll (with 1519_2)<br>Latency (with 1613_2) |
| 2012FE1671535_3 | 31 | 8.6 | Roll (with 1543_3)<br>Yaw (with 1459_1) |
| 2012FE1671543_3 | 211 | 7.8 | Roll (with 1535_3)<br>Yaw (with 1510_1) |
| 2012FE1671602_2 | 31 | 5.9 | Pitch/Roll (with 1613_2)<br>Latency (with 1519_2) |
| 2012FE1671613_2 | 211 | 4.9 | Pitch/Roll (with 1602_2)<br>Latency (with 1527_2) |

**Table 7**

**Klein 5000 Target Positioning Accuracy Confirmation**

| **TEST INFORMATION** |
|---|
| **Test Date(s) / DN(s):** 05-26-12/DN 147 and 05-27-12/DN148 |
| **Wind / Seas / Sky:** ENE 5-10 kts; seas < 2 ft |
| **Locality:** Gulf of Mexico |
| **Sub-Locality:** South of Caminada Pass |
| **Description of Bathymetry:** flat |
| **Bottom Type:** muddy |
| **Approximate Water Depth:** 15 meters |
| **Description of Target:** northwest corner of the base of an oil production platform |
| **Target Position:** 196557.648 E, 3218267.041 N |
| **Description of Positioning Method:** Towfish layback calculated in Chesapeake |
| **Estimated Target Position Error:** 2.2 meters |
| **Approximate Survey Speed:** 4 m/s |
| **Approximate Towfish Altitude:** 9 meters |
| **TEST RESULTS** |
| **Number of Passes on Target:** six (6)<br>**Successful Target Detections:** six (6)<br>**Mean Detected Position:** 196558.10 E, 3218266.81 N<br>**Distance from Mean Position to True Position:** 0.51 meters<br>**Approximate 95% Confidence Radius:** 0.68 meters |

**Table 8**

**Performance Surface Test Results**

| Performance Test | Reson 7101 DN 147 | Reson 7101 DN 149 | Reson 7101 DN 165 | Reson 7125 DN 167 | Reson 7125 DN 191 |
|---|---|---|---|---|---|
| ***** | -0.009 – 0.038 meters | -0.017 – 0.041 meters | -0.002 – 0.048 meters | -0.001 – 0.067 meters | 0.019 – 0.073 meters |
| ****** | 0.021 – 0.03 meters | 0.010 – 0.022 meters | 0.012 – 0.033 meters | 0.012 – 0.030 meters | 0.049 – 0.068 meters |
| **IHO Special Order** | 100 % | 100 % | 100 % | 100 % | 100 % |
| **IHO Order 1a** | 100 % | 100 % | 100 % | 100 % | 100 % |

(*) min/max of the mean differences between each individual beam from the performance check line v. the 1-meter performance surface.

(**) min/max of the standard deviation of the mean differences between each individual beam from the performance check line v. the 1-meter performance surface.

# DAPR Appendix III

# Positioning and Attitude System Reports

# Table 1

## Tabulation of Navigation System Performance Checks

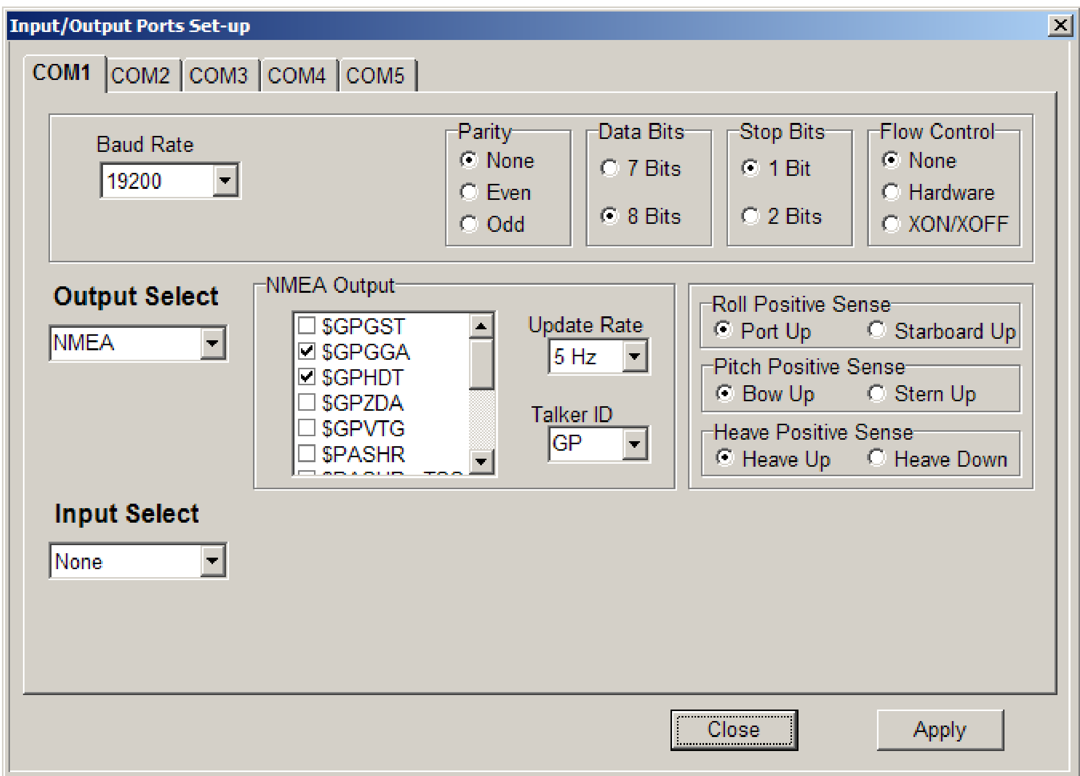
| Date | Time UTC | Nav. Check Point | DGPS Beacon | Observed Easting UTM 16N, NAD83 (meters) | Observed Northing UTM 16N, NAD83 (meters) | Calculated Distance Steering Point to Nav. Check Point (meters) | Tape Measure Steering Point to Nav. Check Point (meters) | Difference Calculated/ Tape Measured (meters) |
|---|---|---|---|---|---|---|---|---|
| May 26, 2012 (147) | 13:28 | JWS 5 | English Turn, LA | 187,820.3 | 3,225,581.6 | 10.15 | 10.40 | 0.25 |
| June 8, 2012 (167) | 13:00 | JWS 3 | English Turn, LA | 187,787.5 | 3,225,683.7 | 18.28 | 18.50 | 0.22 |
| June 15, 2012 (167) | 11:55 | JWS 3 | English Turn, LA | 187,791.3 | 3,225,669.3 | 8.69 | 9.39 | 0.70 |
| June 21, 2012 (173) | 11:28 | JWS 3 | English Turn, LA | 187,791.2 | 3,225,670.7 | 9.19 | 9.80 | 0.61 |
| June 28, 2012 (180) | 7:05 | JWS 9 | English Turn, LA | 187,873.8 | 3,225,415.9 | 10.35 | 10.97 | 0.62 |
| July 9, 2012 (191) | 10:36 | JWS 3 | English Turn, LA | 187,792.9 | 3,225,669.2 | 10.11 | 9.66 | 0.45 |
| July 9, 2012 (191) | 10:47 | JWS 3 | Eglin, FL | 187,791.3 | 3,225,669.9 | 8.88 | 9.63 | 0.75 |

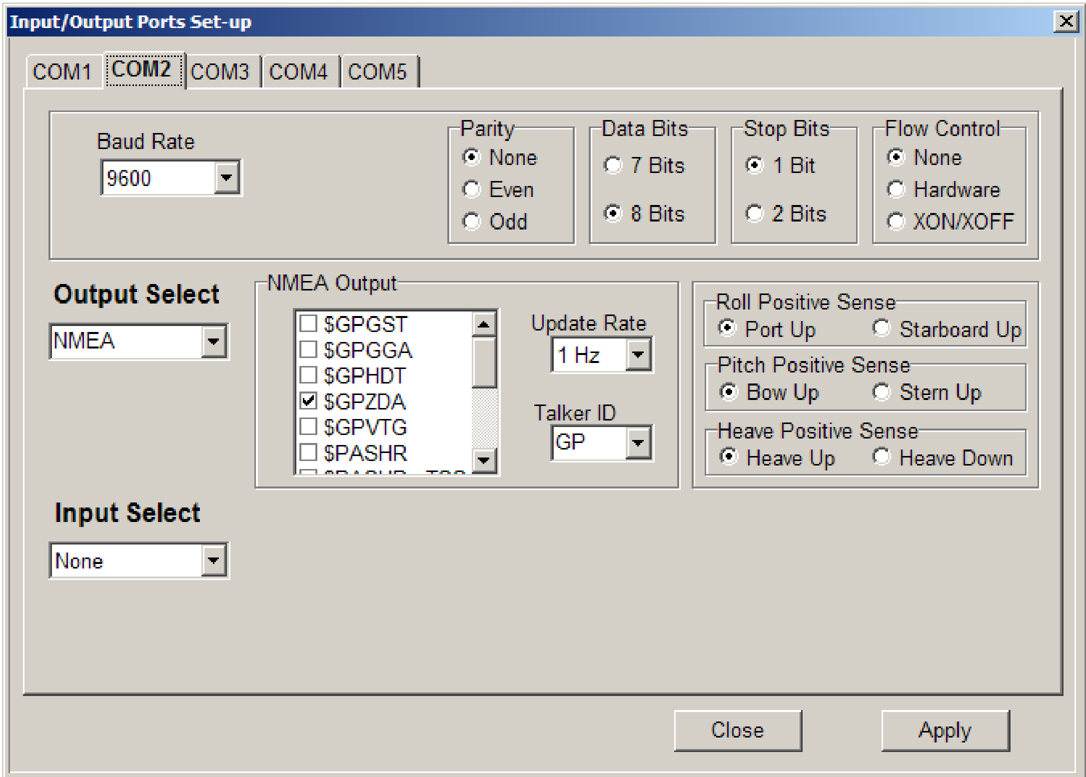
**Table 2**

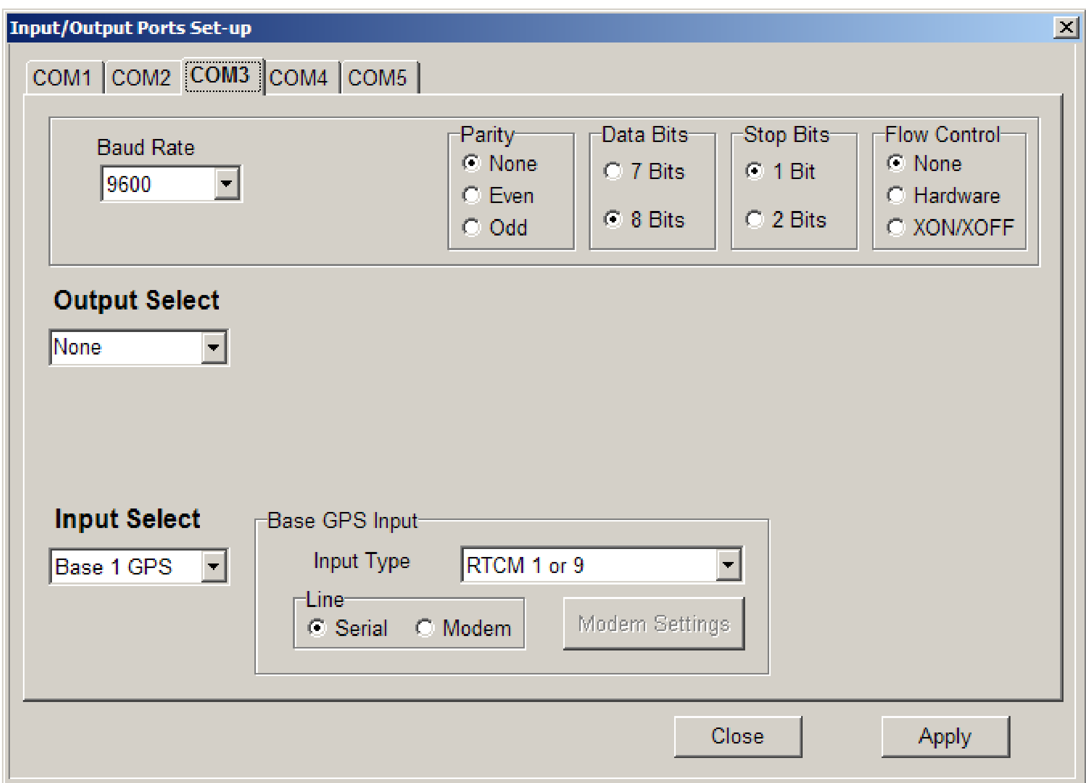
**POS/MV Calibration**

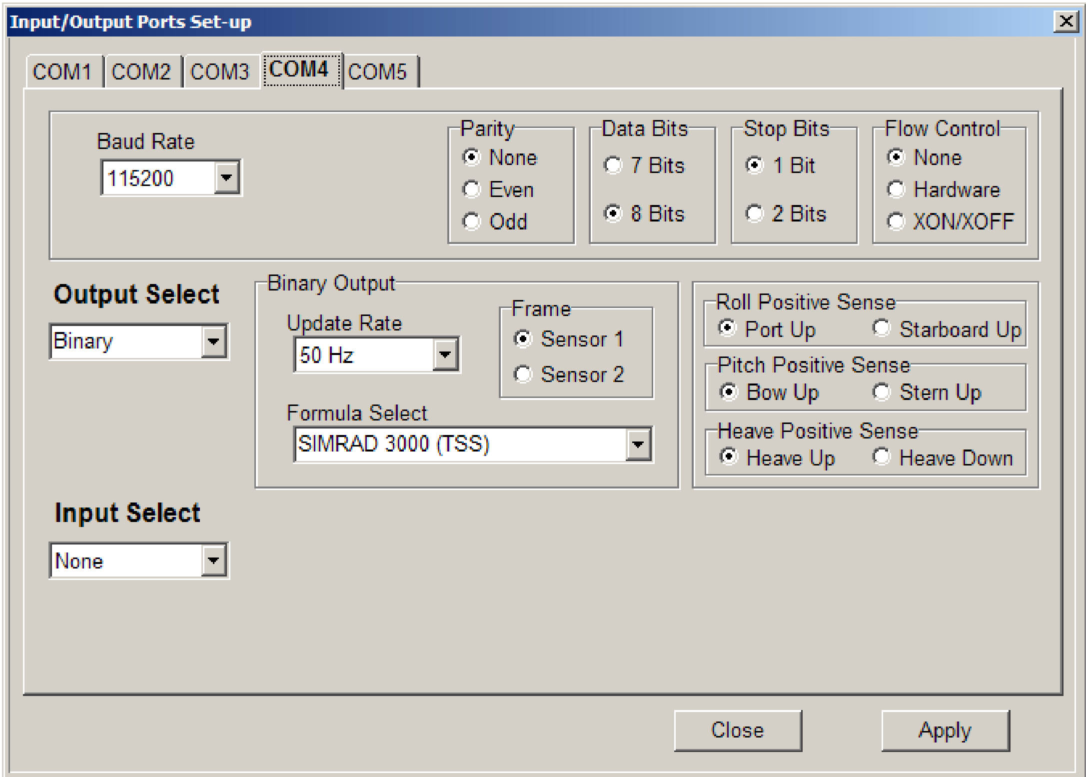
| **POS/MV Calibration Test Date:** May 25, 2012 (DN 145) | | | |
|---|---|---|---|
| **GAMS Parameter Setup** | | | |
| | | Baseline Vector | |
| Two Antenna Separation (m) | **4.805** | X Component (m) | **-0.015** |
| Heading Calibration Threshold | **0.500** | Y Component (m) | **-4.805** |
| Heading Correction | **0.000** | Z Component (m) | **0.017** |

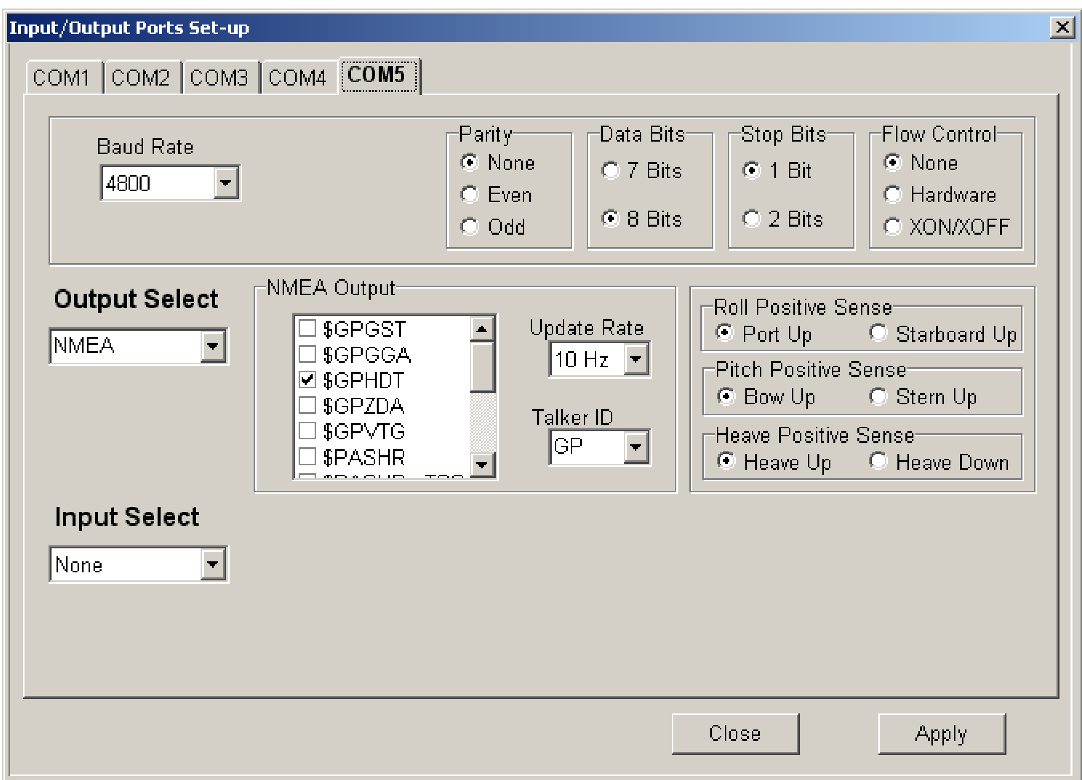
**POS/MV Settings and Configuration**




Input/Output Ports Set-up
COM1
COM2
COM3
COM4
COM5
Baud Rate
9600
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
NMEA
NMEA Output
$GPGST
$GPGGA
$GPHDT
$GPZDA
$GPVTG
$PASHR
Update Rate
1 Hz
Talker ID
GP
Roll Positive Sense
Port Up
Starboard Up
Pitch Positive Sense
Bow Up
Stern Up
Heave Positive Sense
Heave Up
Heave Down
Input Select
None
Close
Apply


Input/Output Ports Set-up
COM1
COM2
COM3
COM4
COM5
Baud Rate
9600
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
None
Input Select
Base 1 GPS
Base GPS Input
Input Type
RTCM 1 or 9
Line
Serial
Modem
Modem Settings
Close
Apply


Input/Output Ports Set-up
COM1
COM2
COM3
COM4
COM5
Baud Rate
115200
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
Binary
Binary Output
Update Rate
50 Hz
Frame
Sensor 1
Sensor 2
Formula Select
SIMRAD 3000 (TSS)
Roll Positive Sense
Port Up
Starboard Up
Pitch Positive Sense
Bow Up
Stern Up
Heave Positive Sense
Heave Up
Heave Down
Input Select
None
Close
Apply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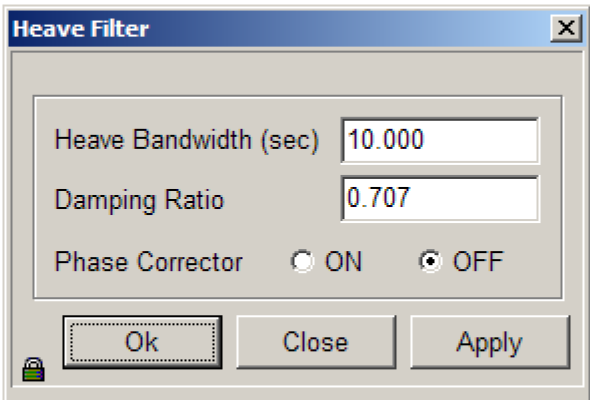
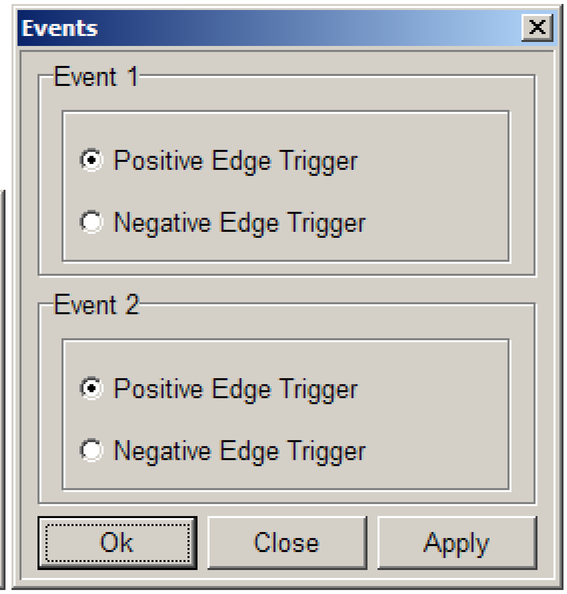
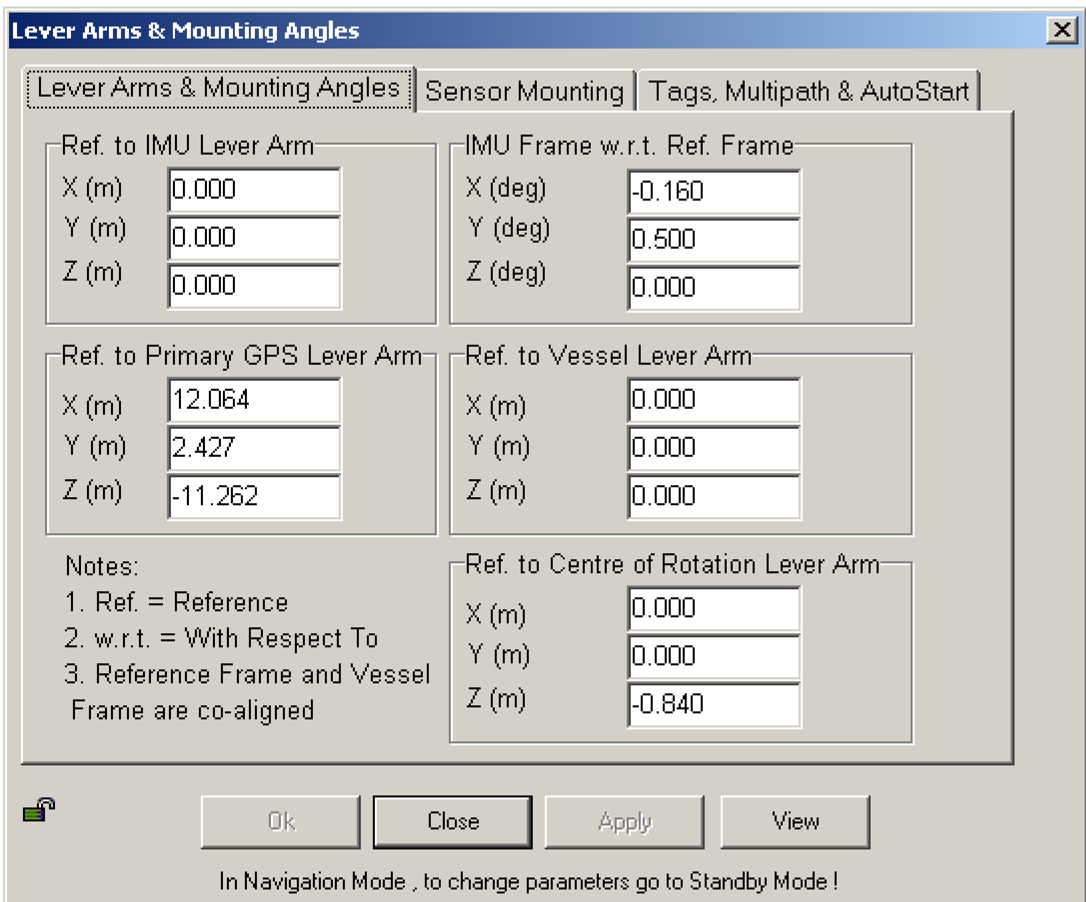
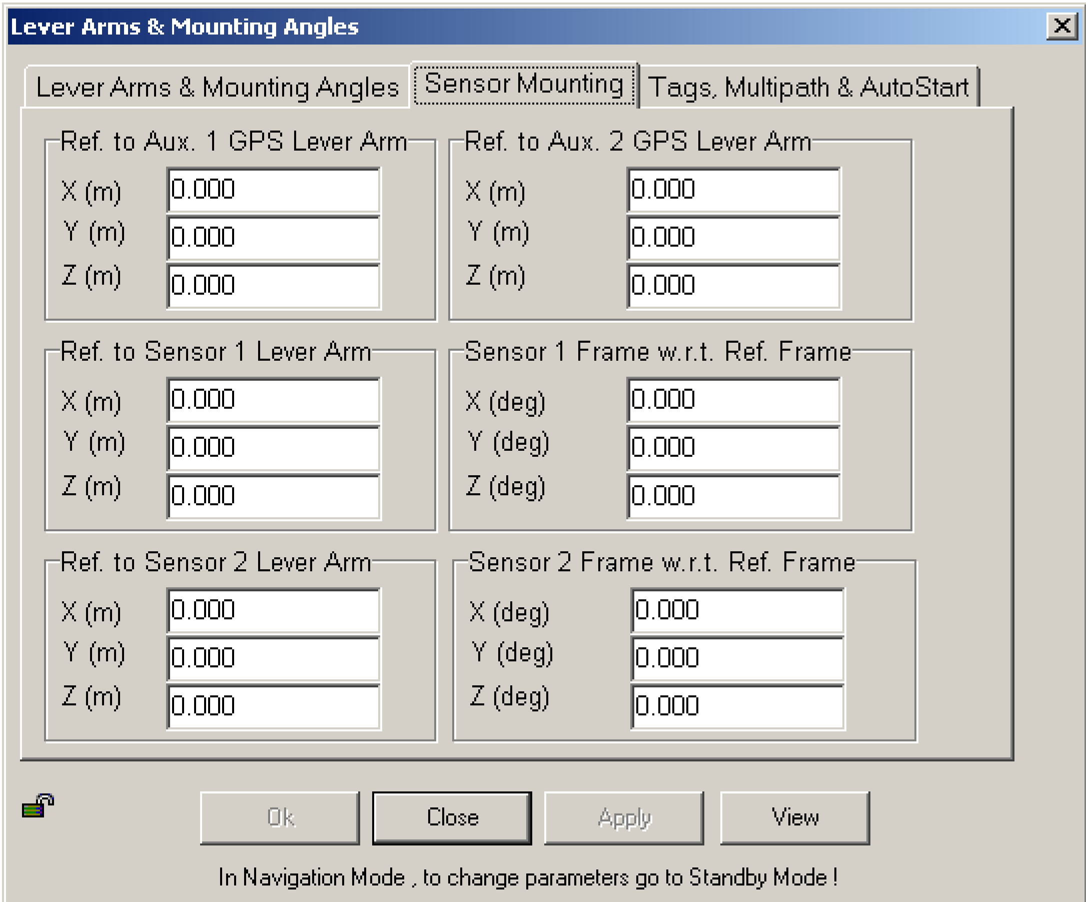
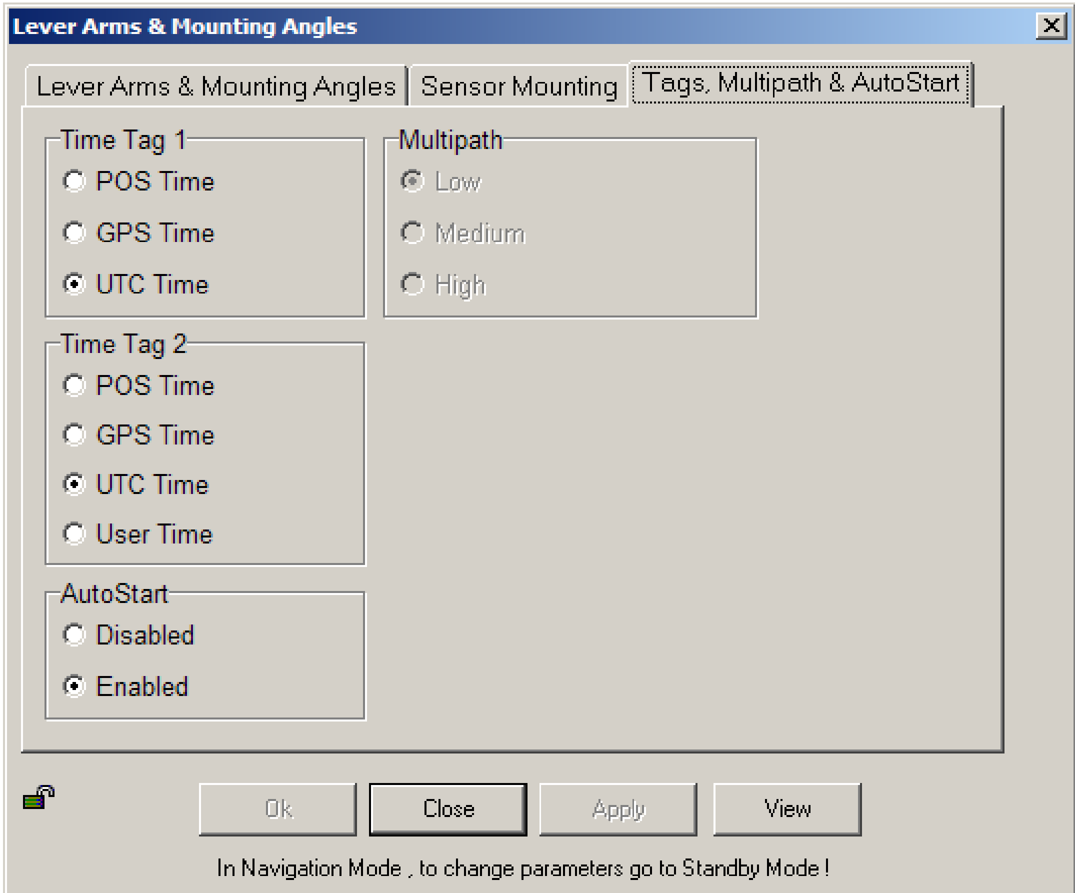
COM2
COM3
COM4
COM5
Baud Rate
4800
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
NMEA
NMEA Output
$GPGST
$GPGGA
$GPHDT
$GPZDA
$GPVTG
$PASHR
Update Rate
10 Hz
Talker ID
GP
Roll Positive Sense
Port Up
Starboard Up
Pitch Positive Sense
Bow Up
Stern Up
Heave Positive Sense
Heave Up
Heave Down
Input Select
None
Close
Apply

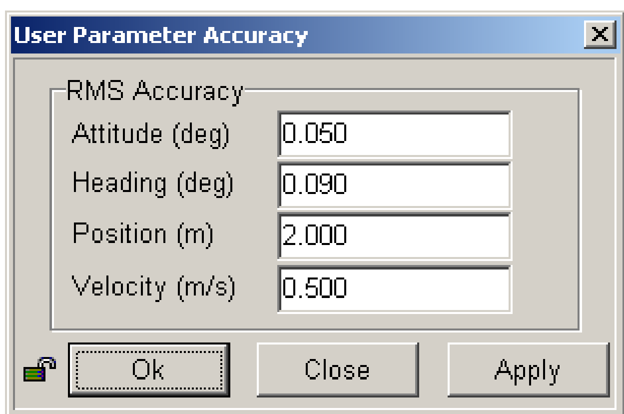

Heave Filter
Heave Bandwidth (sec) 10.000
Damping Ratio 0.707
Phase Corrector ON OFF
Ok
Close
Apply

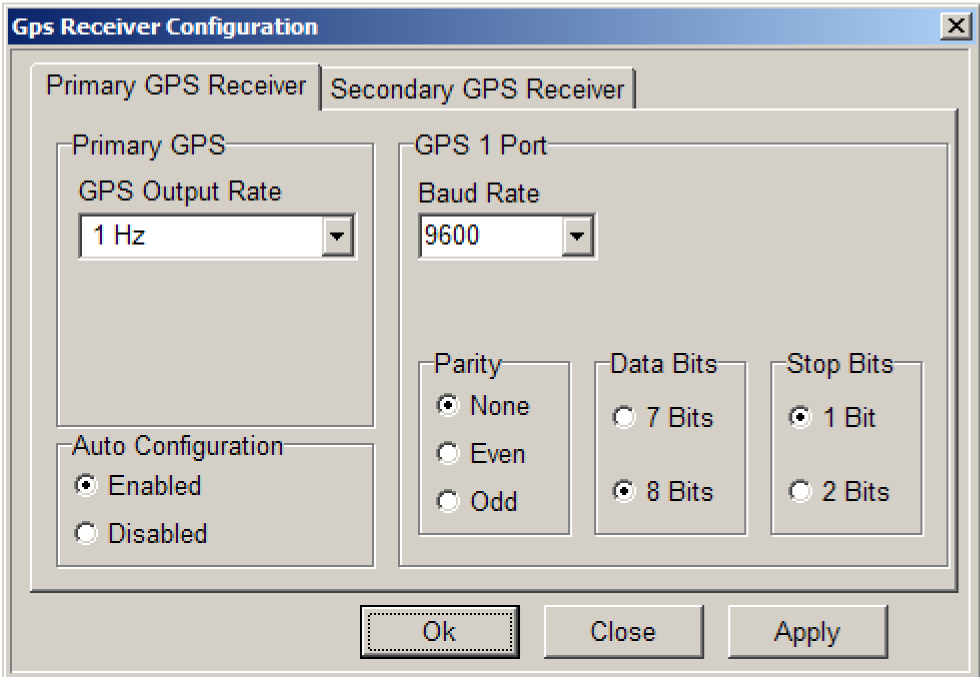

Events
Event 1
Positive Edge Trigger
Negative Edge Trigger
Event 2
Positive Edge Trigger
Negative Edge Trigger
Ok
Close
Apply

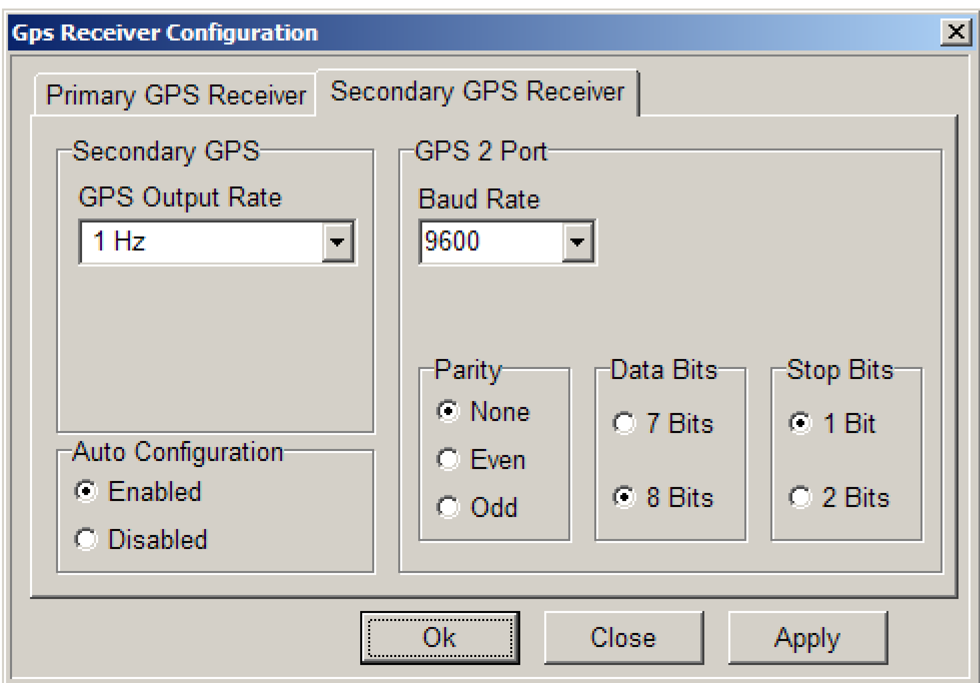

Lever Arms & Mounting Angles
Lever Arms & Mounting Angles
Sensor Mounting
Tags, Multipath & AutoStart
Ref. to IMU Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
IMU Frame w.r.t. Ref. Frame
X (deg) -0.160
Y (deg) 0.500
Z (deg) 0.000
Ref. to Primary GPS Lever Arm
X (m) 12.064
Y (m) 2.427
Z (m) -11.262
Ref. to Vessel Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Notes:
1. Ref. = Reference
2. w.r.t. = With Respect To
3. Reference Frame and Vessel Frame are co-aligned
Ref. to Centre of Rotation Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) -0.840
Ok
Close
Apply
View
In Navigation Mode , to change parameters go to Standby Mode !


Lever Arms & Mounting Angles
Lever Arms & Mounting Angles
Sensor Mounting
Tags, Multipath & AutoStart
Ref. to Aux. 1 GPS Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Ref. to Aux. 2 GPS Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Ref. to Sensor 1 Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Sensor 1 Frame w.r.t. Ref. Frame
X (deg) 0.000
Y (deg) 0.000
Z (deg) 0.000
Ref. to Sensor 2 Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Sensor 2 Frame w.r.t. Ref. Frame
X (deg) 0.000
Y (deg) 0.000
Z (deg) 0.000
Ok
Close
Apply
View
In Navigation Mode , to change parameters go to Standby Mode !


Lever Arms & Mounting Angles
Lever Arms & Mounting Angles
Sensor Mounting
Tags, Multipath & AutoStart
Time Tag 1
POS Time
GPS Time
UTC Time
Multipath
Low
Medium
High
Time Tag 2
POS Time
GPS Time
UTC Time
User Time
AutoStart
Disabled
Enabled
Ok
Close
Apply
View
In Navigation Mode , to change parameters go to Standby Mode !


User Parameter Accuracy
RMS Accuracy
Attitude (deg) 0.050
Heading (deg) 0.090
Position (m) 2.000
Velocity (m/s) 0.500
Ok
Close
Apply


Gps Receiver Configuration
Primary GPS Receiver
Secondary GPS Receiver
Primary GPS
GPS Output Rate
1 Hz
GPS 1 Port
Baud Rate
9600
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Auto Configuration
Enabled
Disabled
Ok
Close
Apply


Gps Receiver Configuration
Primary GPS Receiver
Secondary GPS Receiver
Secondary GPS
GPS Output Rate
1 Hz
GPS 2 Port
Baud Rate
9600
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Auto Configuration
Enabled
Disabled
Ok
Close
Apply

# DAPR Appendix IV

# Sound Speed Sensor Reports

AML OCEANOGRAPHIC
Xchange your old ideas

Certificate of Calibration

| | |
|---|---|
| Customer: | Ocean Surveys, Inc. |
| Asset Serial Number: | 201525 |
| Asset Product Type: | SV•Xchange™ Calibrated Sensor |
| Calibration Type: | Sound Velocity |
| Calibration Range: | 1375 to 1625 m/s |
| Calibration RMS Error: | .024 |
| Calibration ID: | 201525 999999 201525 020512 120815 |
| Installed On: | |

| | | | |
|---|---|---|---|
| Coefficient A: | 0.000000E+0 | Coefficient G: | 0.000000E+0 |
| Coefficient B: | 0.000000E+0 | Coefficient H: | 0.000000E+0 |
| Coefficient C: | 2.817833E-7 | Coefficient I: | 0.000000E+0 |
| Coefficient D: | 1.947918E-7 | Coefficient J: | 0.000000E+0 |
| Coefficient E: | -1.799007E-5 | Coefficient K: | 0.000000E+0 |
| Coefficient F: | 1.953159E-7 | Coefficient L: | 0.000000E+0 |
| | | Coefficient M: | 0.000000E+0 |

Calibration Date (dd/mm/yyyy): 2/5/2012

Certified By:

AML Oceanographic

Robert Haydock
President, AML Oceanographic

AML Oceanographic certifies that the asset described above has been calibrated or recalibrated with equipment referenced to traceable standards. Please note that Xchange™ sensor-heads may be installed on assets other than the one listed above; this calibration certificate will still be valid when used on other such assets. If this instrument or sensor has been recalibrated, please be sure to update your records. Please also ensure that you update the instrument's coefficient values in any post-processing software that you use, if necessary. Older generation instruments may require configuration files, which are available for download at our Customer Centre at www.AMLoceanographic.com/support

AML Oceanographic
2071 Malaview Avenue, Sidney B.C. V8L 5X6 CANADA
T: +1-250-656-0771 F: +1-250-655-3655 Email: service@AMLoceanographic.com

Figure 1. Certificate of Calibration for the MVP SV Exchange Sensor SN# 201525.

AML OCEANOGRAPHIC
Xchange your old ideas

## Certificate of Calibration

| | |
|---|---|
| Customer: | Ocean Surveys, Inc. |
| Asset Serial Number: | 007777 |
| Asset Product Type: | Micro SVTP, Fixed Sensors, for Brooke MVP - |
| Calibration Type: | Pressure |
| Calibration Range: | 200 dBar |
| Calibration RMS Error: | .0138 |
| Calibration ID: | 007777 999999 0AX944 300412 145920 |
| Installed On: | |

| | | | |
|---|---|---|---|
| Coefficient A: | 7.330229E+3 | Coefficient G: | -6.331045E-11 |
| Coefficient B: | -4.822223E-1 | Coefficient H: | 4.160645E-16 |
| Coefficient C: | 1.058696E-5 | Coefficient I: | -1.901994E-6 |
| Coefficient D: | -7.819008E-11 | Coefficient J: | 1.260470E-10 |
| Coefficient E: | -4.808270E-2 | Coefficient K: | -2.784541E-15 |
| Coefficient F: | 3.180526E-6 | Coefficient L: | 2.050530E-20 |
| | | Coefficient M: | 0.000000E+0 |

Calibration Date (dd/mm/yyyy): 30/4/2012

Certified By:

Robert Haydock
President, AML Oceanographic

AML Oceanographic certifies that the asset described above has been calibrated or recalibrated with equipment referenced to traceable standards. Please note that Xchange™ sensor-heads may be installed on assets other than the one listed above; this calibration certificate will still be valid when used on other such assets. If this instrument or sensor has been recalibrated, please be sure to update your records. Please also ensure that you update the instrument's coefficient values in any post-processing software that you use, if necessary. Older generation instruments may require configuration files, which are available for download at our Customer Centre at www.AMLoceanographic.com/support

AML Oceanographic
2071 Malaview Avenue, Sidney B.C. V8L 5X6 CANADA
T: +1-250-656-0771 F: +1-250-655-3655 Email: service@AMLoceanographic.com

Figure 2. Certificate of Calibration for the MVP Micro SVTP Pressure Sensor SN# 007777.

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Certificate of Calibration

| | |
|---|---|
| Customer: | Ocean Surveys, Inc. |
| Asset Serial Number: | 201527 |
| Asset Product Type: | SV•Xchange™ Calibrated Sensor |
| Calibration Type: | Sound Velocity |
| Calibration Range: | 1375 to 1625 m/s |
| Calibration RMS Error: | .007 |
| Calibration ID: | 201527 999999 201527 020512 121954 |
| Installed On: | 007777 |

| | | | |
|---|---|---|---|
| Coefficient A: | 0.000000E+0 | Coefficient G: | 0.000000E+0 |
| Coefficient B: | 0.000000E+0 | Coefficient H: | 0.000000E+0 |
| Coefficient C: | -1.314329E-7 | Coefficient I: | 0.000000E+0 |
| Coefficient D: | 1.949081E-7 | Coefficient J: | 0.000000E+0 |
| Coefficient E: | -1.812342E-5 | Coefficient K: | 0.000000E+0 |
| Coefficient F: | 1.953382E-7 | Coefficient L: | 0.000000E+0 |
| | | Coefficient M: | 0.000000E+0 |

Calibration Date (dd/mm/yyyy): 2/5/2012

Certified By:

AML Oceanographic

Robert Haydock
President, AML Oceanographic

AML Oceanographic certifies that the asset described above has been calibrated or recalibrated with equipment referenced to traceable standards. Please note that Xchange™ sensor-heads may be installed on assets other than the one listed above; this calibration certificate will still be valid when used on other such assets. If this instrument or sensor has been recalibrated, please be sure to update your records. Please also ensure that you update the instrument's coefficient values in any post-processing software that you use, if necessary. Older generation instruments may require configuration files, which are available for download at our Customer Centre at www.AMLoceanographic.com/support

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Figure 3. Certificate of Calibration for the MVP SV Exchange Sensor SN# 201527.

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## Certificate of Calibration

| | |
|---|---|
| Customer: | Ocean Surveys, Inc. |
| Asset Serial Number: | 007786 |
| Asset Product Type: | Micro SVTP, Fixed Sensors, for Brooke MVP - |
| Calibration Type: | Pressure |
| Calibration Range: | 200 dBar |
| Calibration RMS Error: | .0078 |
| Calibration ID: | 007786 999999 D00026 300412 164958 |
| Installed On: | |

| | | | |
|---|---|---|---|
| Coefficient A: | -2.546368E+1 | Coefficient G: | 0.000000E+0 |
| Coefficient B: | 0.000000E+0 | Coefficient H: | 0.000000E+0 |
| Coefficient C: | 0.000000E+0 | Coefficient I: | -4.698300E-11 |
| Coefficient D: | 0.000000E+0 | Coefficient J: | 0.000000E+0 |
| Coefficient E: | 3.795613E-3 | Coefficient K: | 0.000000E+0 |
| Coefficient F: | 0.000000E+0 | Coefficient L: | 0.000000E+0 |
| | | Coefficient M: | -1.057742E-15 |

Calibration Date (dd/mm/yyyy): 30/4/2012

Certified By:

AML Oceanographic

Robert Haydock
President, AML Oceanographic

AML Oceanographic certifies that the asset described above has been calibrated or recalibrated with equipment referenced to traceable standards. Please note that Xchange™ sensor-heads may be installed on assets other than the one listed above; this calibration certificate will still be valid when used on other such assets. If this instrument or sensor has been recalibrated, please be sure to update your records. Please also ensure that you update the instrument's coefficient values in any post-processing software that you use, if necessary. Older generation instruments may require configuration files, which are available for download at our Customer Centre at www.AMLoceanographic.com/support

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2071 Malaview Avenue, Sidney B.C. V8L 5X6 CANADA
T: +1-250-656-0771 F: +1-250-655-3655 Email: service@AMLoceanographic.com

Figure 4. Certificate of Calibration for the MVP Micro SVTP Pressure Sensor SN# 007786.

**SBE SEA-BIRD ELECTRONICS, INC.**
13431 NE 20th Street Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

## Conductivity Calibration Report

| | | | |
|---|---|---|---|
| **Customer:** | Ocean Surveys, Inc. | | |
| **Job Number:** | 68727 | **Date of Report:** | 4/25/2012 |
| **Model Number:** | SBE 37SI | **Serial Number:** | 37SI51378-6372 |

*Conductivity sensors are normally calibrated 'as received', without cleaning or adjustments, allowing a determination of sensor drift. If the calibration identifies a problem or indicates cell cleaning is necessary, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.*

*An 'as received' calibration certificate is provided, listing the coefficients used to convert sensor frequency to conductivity. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'slope' allows small corrections for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair or cleaning apply only to subsequent data.*

**'AS RECEIVED CALIBRATION'** ☑ Performed ☐ Not Performed

Date: 4/25/2012 Drift since last cal: +0.00010 **PSU/month***

Comments:

**'CALIBRATION AFTER CLEANING & REPLATINIZING'** ☐ Performed ☑ Not Performed

Date: Drift since Last cal: **PSU/month***

Comments:

**Measured at 3.0 S/m*

*Cell cleaning and electrode replatinizing tend to 'reset' the conductivity sensor to its original condition. Lack of drift in post-cleaning-calibration indicates geometric stability of the cell and electrical stability of the sensor circuit.*

Figure 5. Conductivity Calibration Report for the Sea-Bird SBE 37 SN# 6372.

SBE SEA-BIRD ELECTRONICS, INC.
13431 NE 20th St. Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

## Temperature Calibration Report

| | | | |
|---|---|---|---|
| Customer: | Ocean Surveys, Inc. | | |
| Job Number: | 68727 | Date of Report: | 4/25/2012 |
| Model Number: | SBE 37SI | Serial Number: | 37SI51378-6372 |

*Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.*

*An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.*

**'AS RECEIVED CALIBRATION'** ☑ Performed ☐ Not Performed

Date: 4/25/2012 Drift since last cal: -0.00023 Degrees Celsius/year

**Comments:**

**'CALIBRATION AFTER REPAIR'** ☐ Performed ☑ Not Performed

Date: Drift since Last cal: Degrees Celsius/year

**Comments:**

Figure 6. Temperature Calibration Report for the Sea-Bird SBE 37 SN# 6372.

**Sea-Bird Electronics, Inc.**
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 6372
CALIBRATION DATE: 25-Apr-12

SBE 37 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -9.508970e-001
h = 1.338595e-001
i = -4.117841e-004
j = 4.865841e-005

CPcor = -9.5700e-008
CTcor = 3.2500e-006
WBOTC = 0.0000e+000

| BATH TEMP (ITS-90) | BATH SAL (PSU) | BATH COND (Siemens/m) | INST FREQ (Hz) | INST COND (Siemens/m) | RESIDUAL (Siemens/m) |
|---|---|---|---|---|---|
| 22.0000 | 0.0000 | 0.00000 | 2672.80 | 0.00000 | 0.00000 |
| 1.0000 | 34.9210 | 2.98406 | 5438.12 | 2.98407 | 0.00001 |
| 4.5000 | 34.9009 | 3.29192 | 5646.29 | 3.29191 | -0.00001 |
| 15.0000 | 34.8583 | 4.27622 | 6264.75 | 4.27619 | -0.00003 |
| 18.5000 | 34.8493 | 4.62227 | 6467.83 | 4.62229 | 0.00001 |
| 24.0000 | 34.8397 | 5.18172 | 6782.89 | 5.18174 | 0.00002 |
| 29.0000 | 34.8348 | 5.70501 | 7064.44 | 5.70501 | 0.00000 |
| 32.5000 | 34.8327 | 6.07853 | 7258.48 | 6.07852 | -0.00001 |

f = INST FREQ * sqrt(1.0 + WBOTC * t) / 1000.0

Conductivity = $(g + hf^2 + if^3 + jf^4) / (1 + \delta t + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; $\delta$ = CTcor; $\varepsilon$ = CPcor;

Residual = instrument conductivity - bath conductivity

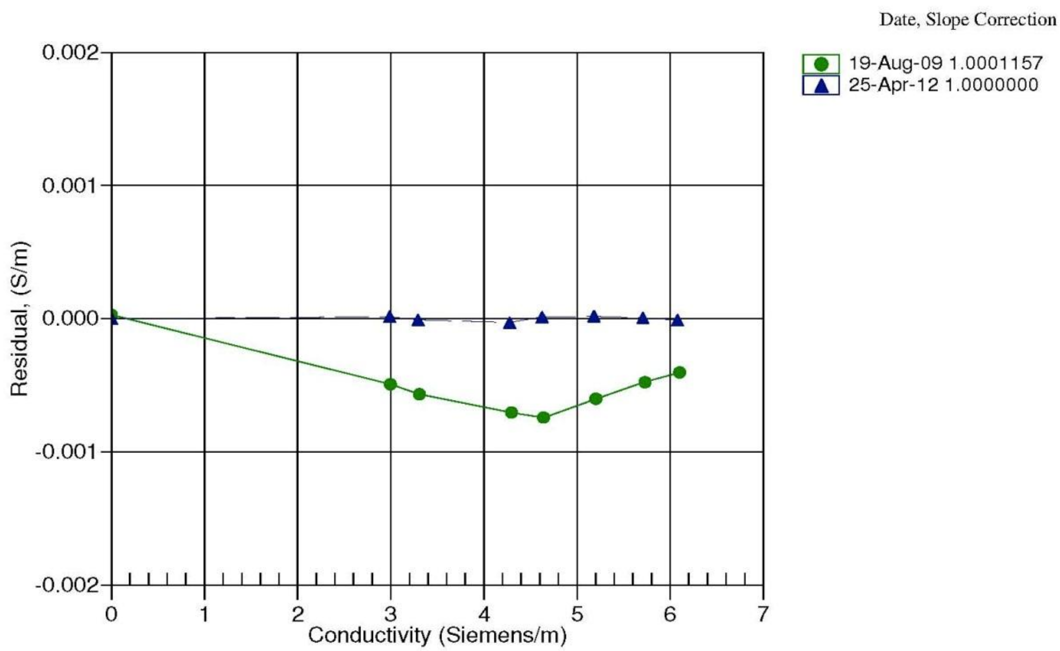


Figure 7. Conductivity Calibration Data for the Sea-Bird SBE 37 SN# 6372.

**Sea-Bird Electronics, Inc.**
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 6372
CALIBRATION DATE: 25-Apr-12

SBE 37 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

a0 = 6.002304e-005
a1 = 2.688034e-004
a2 = -2.035669e-006
a3 = 1.400071e-007

| BATH TEMP (ITS-90) | INSTRUMENT OUTPUT | INST TEMP (ITS-90) | RESIDUAL (ITS-90) |
|---|---|---|---|
| 1.0000 | 693388.7 | 1.0000 | 0.0000 |
| 4.5000 | 591544.1 | 4.5000 | -0.0000 |
| 15.0000 | 374620.0 | 15.0000 | 0.0000 |
| 18.5000 | 323729.1 | 18.5000 | 0.0000 |
| 24.0000 | 258906.9 | 24.0000 | 0.0000 |
| 29.0000 | 212612.5 | 28.9999 | -0.0001 |
| 32.5000 | 185844.1 | 32.5000 | 0.0000 |

Temperature ITS-90 = $1/\{a0 + a1[ln(n)] + a2[ln^2(n)] + a3[ln^3(n)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature

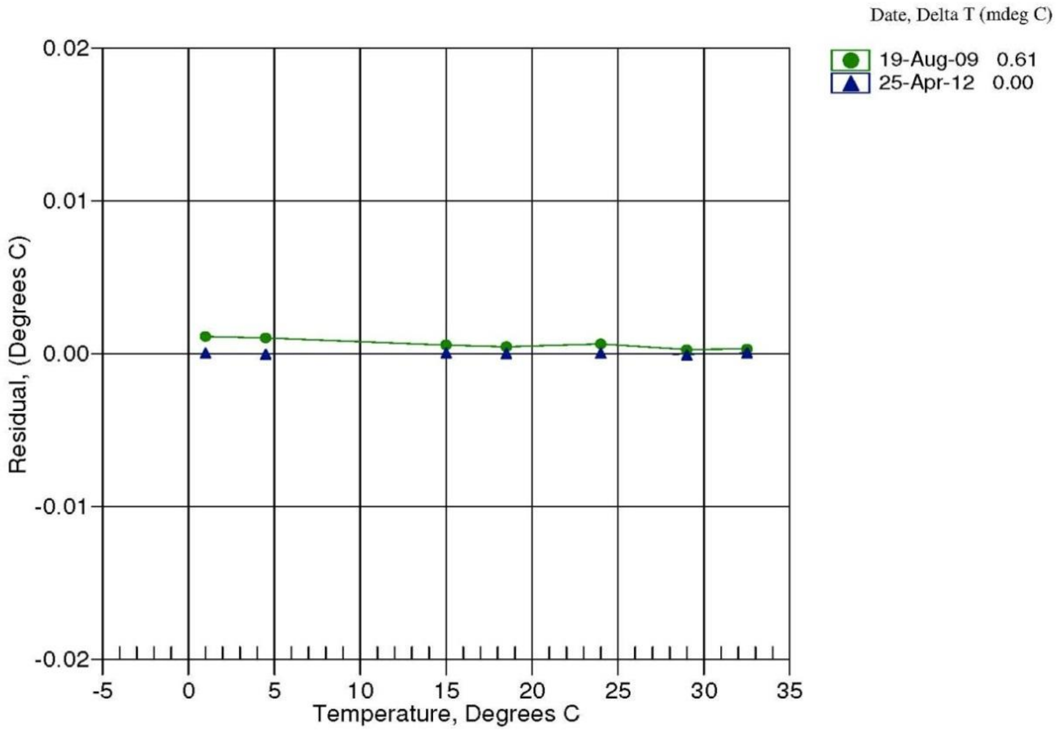


Figure 8. Temperature Calibration Data for the Sea-Bird SBE 37 SN# 6372.

**SBE SEA-BIRD ELECTRONICS, INC.**
13431 NE 20th Street Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

## Conductivity Calibration Report

| | | | |
|---|---|---|---|
| Customer: | Ocean Surveys, Inc. | | |
| Job Number: | 68727 | Date of Report: | 5/17/2012 |
| Model Number: | SBE 37SI | Serial Number: | 37SI57268-7531 |

*Conductivity sensors are normally calibrated 'as received', without cleaning or adjustments, allowing a determination of sensor drift. If the calibration identifies a problem or indicates cell cleaning is necessary, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.*

*An 'as received' calibration certificate is provided, listing the coefficients used to convert sensor frequency to conductivity. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'slope' allows small corrections for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair or cleaning apply only to subsequent data.*

**'AS RECEIVED CALIBRATION'** ☑ Performed ☐ Not Performed

Date: 4/21/2012 Drift since last cal: -0.00230 PSU/month*

Comments:

**'CALIBRATION AFTER CLEANING & REPLATINIZING'** ☑ Performed ☐ Not Performed

Date: 5/16/2012 Drift since 29 Jan 10 +0.00040 PSU/month*

Comments:

***Measured at 3.0 S/m**

*Cell cleaning and electrode replatinizing tend to 'reset' the conductivity sensor to its original condition. Lack of drift in post-cleaning-calibration indicates geometric stability of the cell and electrical stability of the sensor circuit.*

Figure 9. Conductivity Calibration Report for the Sea-Bird SBE 37 SN# 7531.

SBE **SEA-BIRD ELECTRONICS, INC.**
13431 NE 20th St. Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

## *Temperature Calibration Report*

| | | | |
|---|---|---|---|
| **Customer:** | Ocean Surveys, Inc. | | |
| **Job Number:** | 68727 | **Date of Report:** | 5/17/2012 |
| **Model Number:** | SBE 37SI | **Serial Number:** | 37SI57268-7531 |

*Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.*

*An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.*

**'AS RECEIVED CALIBRATION'** ☑ Performed ☐ Not Performed

Date: 4/21/2012 Drift since last cal: -0.00051 Degrees Celsius/year

**Comments:**

**'FINAL CALIBRATION'** ☑ Performed ☐ Not Performed

Date: 5/16/2012 Drift since 29 Jan 10 -0.00044 Degrees Celsius/year

**Comments:**

Figure 10. Temperature Calibration Report for the Sea-Bird SBE 37 SN# 7531.

## Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 7531
CALIBRATION DATE: 16-May-12

SBE 37 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -1.039123e+000        CPcor = -9.5700e-008
h =  1.381928e-001        CTcor =  3.2500e-006
i = -2.106958e-004        WBOTC =  1.2141e-007
j =  3.327088e-005
```

| BATH TEMP (ITS-90) | BATH SAL (PSU) | BATH COND (Siemens/m) | INST FREQ (Hz) | INST COND (Siemens/m) | RESIDUAL (Siemens/m) |
|---|---|---|---|---|---|
| 22.0000 | 0.0000 | 0.00000 | 2745.40 | 0.00000 | 0.00000 |
| 1.0000 | 34.9572 | 2.98686 | 5400.78 | 2.98685 | -0.00001 |
| 4.5000 | 34.9368 | 3.29497 | 5603.04 | 3.29499 | 0.00002 |
| 15.0000 | 34.8935 | 4.28008 | 6204.83 | 4.28007 | -0.00001 |
| 18.5000 | 34.8836 | 4.62633 | 6402.67 | 4.62632 | -0.00001 |
| 24.0000 | 34.8721 | 5.18601 | 6709.85 | 5.18601 | 0.00001 |
| 29.0000 | 34.8634 | 5.70916 | 6984.47 | 5.70918 | 0.00002 |
| 32.5000 | 34.8549 | 6.08196 | 7173.54 | 6.08195 | -0.00001 |

f = INST FREQ * sqrt(1.0 + WBOTC * t) / 1000.0

Conductivity = $(g + hf^2 + if^3 + jf^4) / (1 + \delta t + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; $\delta$ = CTcor; $\varepsilon$ = CPcor;

Residual = instrument conductivity - bath conductivity

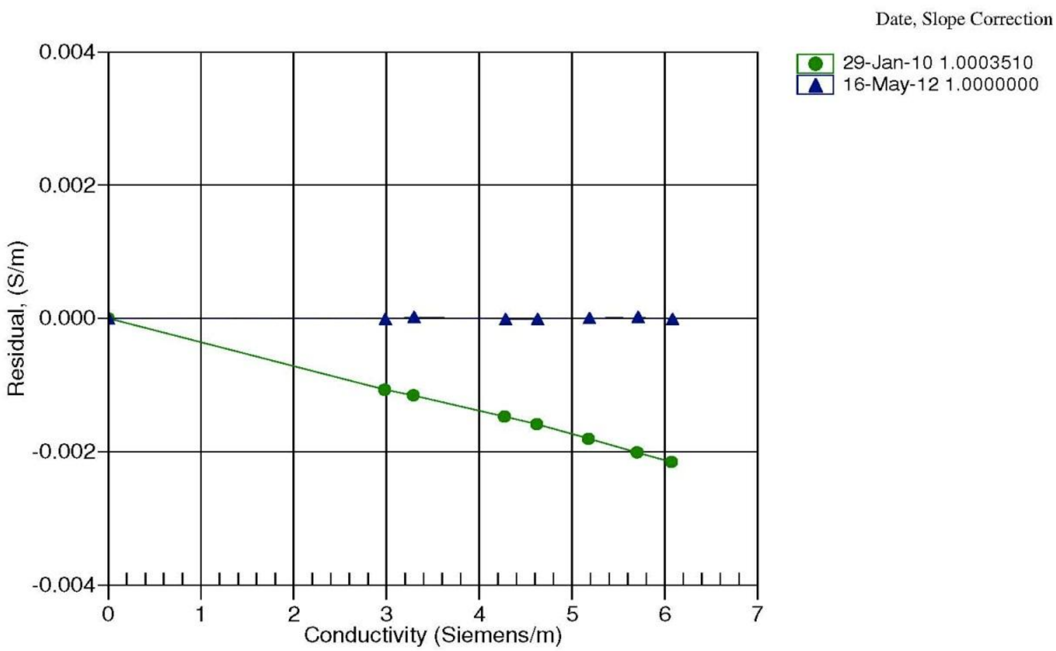


Figure 11. Conductivity Calibration Data for the Sea-Bird SBE 37 SN# 7531.

**Sea-Bird Electronics, Inc.**
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 7531
CALIBRATION DATE: 16-May-12

SBE 37 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
a0 = -5.737543e-005
a1 = 2.990251e-004
a2 = -3.990460e-006
a3 = 1.886397e-007

| BATH TEMP (ITS-90) | INSTRUMENT OUTPUT | INST TEMP (ITS-90) | RESIDUAL (ITS-90) |
|---|---|---|---|
| 1.0000 | 577249.5 | 1.0000 | 0.0000 |
| 4.5000 | 493200.0 | 4.4999 | -0.0001 |
| 15.0000 | 313740.2 | 15.0001 | 0.0001 |
| 18.5000 | 271530.0 | 18.4999 | -0.0001 |
| 24.0000 | 217675.8 | 24.0000 | 0.0000 |
| 29.0000 | 179144.2 | 29.0000 | -0.0000 |
| 32.5000 | 156831.3 | 32.5000 | 0.0000 |

Temperature ITS-90 = $1/\{a0 + a1[ln(n)] + a2[ln^2(n)] + a3[ln^3(n)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature

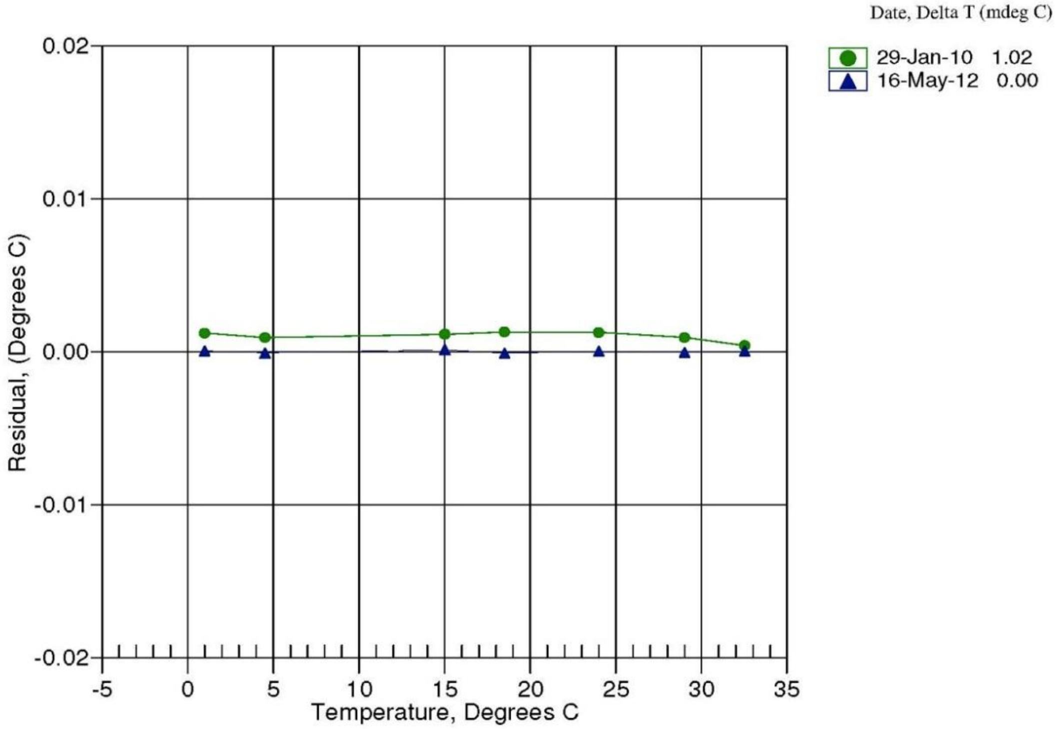


Figure 12. Temperature Calibration Data for the Sea-Bird SBE 37 SN# 7531.