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-K354-KR-17
Time Frame:	August - October 2017

LOCALITY

State:	Louisiana
General Locality:	Gulf of Mexico
Sub-locality:	Louisiana Coast

2017

CHIEF OF PARTY

George G. Reynolds

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Date:

NOAA FORM 77-28 (11-72) U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION	REGISTRY NUMBERS:
HYDROGRAPHIC TITLE SHEET	H13040, H13041 H13042, H13043

State:	**Louisiana**
General Locality:	**Gulf of Mexico**
Sub-Locality:	**Louisiana Coast**
Scale:	**1:40,000**
Date of Survey:	**August 3 to October 12, 2017**
Instructions Dated:	**June 21, 2017**
Project No.:	**OPR-K354-KR-17**
Vessels:	**R/V Ocean Explorer- Official Number 905425** **R/V Osprey – CT Registration CT7934BC**
Chief of Party:	**George G. Reynolds**
Surveyed By:	**Ocean Surveys, Inc.**
Soundings by:	**Multibeam Echosounder**
Imagery by:	**Side Scan Sonar, Multibeam Echosounder Backscatter**
Verification by:	**Atlantic Hydrographic Branch**
Soundings Acquired in:	**Meters at MLLW**
H-Cell Compilation Units:	

Remarks: The purpose of this project is to provide contemporary surveys to update National Ocean Service (NOS) nautical charting products. All times are recorded in UTC. Data recorded and presented relative to UTM Zone 15 North.

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Old Saybrook, CT 06475

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APPENDICES

A. EQUIPMENT

A.1 Survey Vessels

The survey was conducted employing two vessels. Much of the relatively deep reaches of the study area were surveyed using the *R/V Ocean Explorer* (Figure 1). A smaller vessel, the *R/V Osprey* (Figure 2), surveyed relatively shallow reaches of the study area as well as certain “deep” water areas. For the sake of clarity, especially as concerns the field data file naming convention, two distinct abbreviations were employed. Specifically, files generated on the *R/V Ocean Explorer* include “OE” in the name and files generated on the *R/V Osprey* include “SB” which is meant to indicate “small boat” files.

A.1.1 *R/V Ocean Explorer –“OE”*

R/V Ocean Explorer, O.N. 905425, is an 18-meter aluminum vessel, with a 5.1-meter beam and nominally 2-meter draft. *R/V Ocean Explorer* is powered by two 1,000 HP Iveco diesel engines.

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

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

1. Survey system control modules (processors) and computer systems were installed at purpose-built work stations in the main cabin of the vessel.

2. A measured and indexed Inertial Measurement Unit (IMU) mounting plate was installed on the vessel's fore-aft (roll) centerline at the approximate pitch center of rotation. The POS MV IMU was installed on this plate which resides approximately 0.5 meters below the plane of the vessel waterline.
3. A retractable multibeam transducer pole, constructed of thick-wall aluminum pipe, was attached to the starboard side of the vessel at the approximate pitch centerline. The pole was attached at two points: a substantial, positive locking swivel near the deck of the vessel and a "receiver plate" at the chine of the vessel. The transducer pole is forced, by means of a block and tackle system using non-stretch rope and a hand-crank winch, 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 a termination flange configured with a small copper orifice. This configuration allowed the transducer pole to be used as a stilling well.
4. To support "fixed mount" side scan sonar (SSS) operations a substantial, custom fabricated, SSS mounting bracket was affixed to the forward side of the multibeam transducer pole (described above). The fixed mount SSS bracket was installed approximately 0.4 meters above the multibeam transducer which was at the bottom of the transducer pole. Due to relatively shallow water depths no towed SSS imagery was acquired.
5. A moving vessel profiler (MVP) was installed on the port quarter of the vessel.

A full survey of the *R/V Ocean Explorer* was conducted on May 6, 2015 by OSI during which reference points (permanent shipboard benchmarks) were established onboard the vessel 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 blocked on land. Offsets measured during the 2015 total station survey were confirmed during the 2017 vessel mobilization employing a steel tape measure.

The multibeam transducer pole is capable of variable draft settings. During the 2017 vessel mobilization the initial transducer phase center-to-RP value was established relative to shipboard benchmarks employing a steel tape measure. The relative distance between transducer phase center and vessel RP did not change during the survey. Survey offsets and estimated measurement accuracies were incorporated into the CARIS vessel configuration file.

Major data acquisition system components that were employed on the *R/V Ocean Explorer* during the project are summarized in Table 1 below. A brief description of the equipment also follows.

A.1.2 *R/V Osprey –"SB"*

R/V Osprey, CT Registration CT7934BC, is a 7.9-meter fiberglass vessel, with a 2.6-meter beam and nominally 0.6-meter draft. *R/V Osprey* is powered by two 150 HP Yamaha outboard engines.

Figure 2. *R/V Osprey* configured for hydrographic survey operations.

The *R/V Osprey* was also modified to support hydrographic survey operations by OSI. The following summarizes the major adaptations and/or custom survey support hardware installed on the *R/V Osprey*:

1. Survey system control modules (processors) and computer systems were installed at purpose-built work stations in the main cabin of the vessel.
2. A measured and indexed Inertial Measurement Unit (IMU) mounting plate was installed on the vessel's fore-aft (roll) centerline at the approximate pitch center of rotation. The POS MV IMU was installed on this plate which resides approximately 0.03 meters above the plane of the vessel waterline.
3. A retractable multibeam transducer pole, constructed of thick-wall stainless steel pipe, was attached to the starboard side of the vessel at the approximate pitch centerline. The pole was attached at two points: a substantial, positive locking swivel on the gunwale of the vessel and a "stiff arm" protruding from aluminum H-beam integrated into the roof of the vessel. When deployed, the top of the transducer pole is bolted to a point on the stiff arm attachment point and clamped tight at the gunwale swivel point thereby eliminating pole movement. This configuration allows for repeatable deployment of the transducer during data acquisition and ease of retrieval for transit.

4. To support "fixed mount" side scan sonar (SSS) operations a substantial, custom fabricated, SSS mounting bracket was affixed to the starboard quarter of the vessel. Due to relatively shallow water depths no towed SSS imagery was acquired.

A full survey of the *R/V Osprey* was conducted on July 27, 2017 by OSI during which reference points (permanent shipboard benchmarks) were established onboard the vessel to define a fixed reference frame, vessel reference point (RP), a draft measurement location, 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 blocked on its transport trailer. Offsets measured during the 2017 total station survey were later confirmed employing a steel tape measure.

The multibeam transducer pole is capable of variable draft settings. During the 2017 vessel mobilization the initial transducer phase center-to-RP value was established relative to shipboard benchmarks employing a steel tape measure. The relative distance between transducer phase center and vessel RP did not change during the survey. Survey offsets and estimated measurement accuracies were incorporated into the CARIS vessel configuration file.

Major data acquisition system components that were employed on the *R/V Osprey* during the project are summarized in Table 2 below. A brief description of the equipment also follows.

Table 1
***R/V Ocean Explorer* "OE" Acquisition Equipment**

System	Data	Manufacturer	Model/ Version No.	Firmware/Software Ver.	Serial Number (s)
Side Scan Sonar Towfish (fixed-mount)	Imagery/Contacts	EdgeTech	4125	N/A	46118
Side Scan Sonar Processor	Imagery/Contacts	EdgeTech	4125P	4125D V. 36.0.1.120	46921
Multibeam Echosounder Processor	Soundings	Reson	7125 SV2	SV2 SP4 7K 6,0,0,6	18342213063
Multibeam Echosounder Transducer	Soundings	Reson	7125 SV2	N/A	Proj. 4712049 Rec. 0213063
Surface Sound Speed	Sound Speed	AML	Micro-X w/ SV- Exchange	N/A	MicroX 10315 SV-X 201525
Moving Vessel Profiler (MVP)	Sound Speed	ODIM	MVP30	MVP Controller 2.43	10646
MVP Sound Speed Profile Sensors (2)	Sound Speed	AML Oceanographic	Micro SVPT SV-Xchange & Pressure/Temp Sensor	N/A	SV-X-203108 PT-7786 SV-X-201527 PT-7777
Sound Speed Profiler	QC Comparison Sound Speed	AML Oceanographic	Base-X SV-Xchange P-Xchange	4.15	Base X-25016 SV-X 201521 P-X 303077
Navigation, Vessel Attitude & Heading	Position, Attitude, Heading	Applanix/ Trimble	POS MV 320 V.4	HW 1.1-7 SW 05.03	TPU 3352 IMU 497
Navigation	Position (comparison)	Trimble	MS750	1.58	220209271
U.S.C.G. Differential Beacon Receivers (2)	DGPS correctors	Trimble	ProBeacon	3	0220096149 0220181937
Land Survey GPS	RTK GPS Base Station	Trimble	5700	V3.01	220332818
Water Level Gauge	Static Draft	GE/Druck	PDCR-830	N/A	363764
Lead Line	Bar Check	OSI	Lead Disk	N/A	2010B
Steel Tape Measure	Static Draft	BMI	Ergoline 100	N/A	N/A
Autopilot	Vessel Steering	Simrad	AP50	V1R4	20212221 DA1711

Table 2
***R/V Osprey* "SB" Acquisition Equipment**

System	Data	Manufacturer	Model/ Version No.	Firmware/Software Ver.	Serial Number (s)
Side Scan Sonar Towfish (fixed-mount)	Imagery/Contacts	EdgeTech	4125	N/A	53387
Side Scan Sonar Processor	Imagery/Contacts	EdgeTech	4125P	4125D V. 36.0.1.120	53276
Multibeam Echosounder Processor	Soundings	Reson	8125	8125-2.10-A50F	39337
Multibeam Echosounder Transducer	Soundings	Reson	8125	8125-1.08-9E98	1008298
Surface Sound Speed	Sound Speed	Sea-Bird Electronics	SBE-37	N/A	6372
Sound Speed Profiler	Primary Sound Speed	AML Oceanographic	Base-X SV-Xchange P-Xchange	4.15	Base X-25028 SV-X 203524 P-X 304351
Sound Speed Profiler	QC Comparison Sound Speed (shared with OE)	AML Oceanographic	Base-X SV-Xchange P-Xchange	4.15	Base X-25016 SV-X 201521 P-X 303077
Navigation, Vessel Attitude & Heading	Position, Attitude, Heading	Applanix/ Trimble	POS MV 320 V.5	HW 1.2-10 SW 07.92	TPU 6415 IMU 861
U.S.C.G. Differential Beacon Receiver	DGPS correctors for POS MV	Leica	MX 52R	N/A	2531
Navigation with integrated DGPS Receiver	Position (comparison)	Trimble	DSM 232	1.71	220246318
Lead Line	Bar Check	OSI	Lead Disk	N/A	OSI 50-2
Steel Tape Measure	Static Draft	BMI	Ergoline 100	N/A	N/A

A.2 Echo Sounding Equipment

A.2.1 Side Scan Sonar System

A.2.1.1 EdgeTech 4125

The fixed-mount or "pole mount" SSS system on each vessel was an EdgeTech 4125 dual-frequency CHIRP system operating at a nominal frequency of 600 kHz. The second frequency, 1,600 kHz, was not enabled during this survey. This sonar was operated at the 50 m range scale only. The system consists of a portable Topside Processing Unit (TPU) and sonar towfish. The towfish was equipped with an optional telemetry package that allowed for towfish-TPU communication via a coaxial cable connection. The towfish was equipped with standard sensors for pitch, roll, heading, and depth (pressure). However, given that the respective systems were fixed-mounted, none of these sensor data were used during data processing. The TPU connected to the SSS acquisition computer through a dedicated Ethernet cable. In the case of the *R/V Ocean Explorer* a 4125 SSS positioning verification test was performed in the vicinity of the vessel's home port on July 17, 2017 (DN 198). In the case of the *R/V Osprey* a 4125 SSS positioning verification test was performed in the vicinity of the survey area on August 24, 2017 (DN 236). The respective tests are documented in the DAPR Appendix II: Echosounder Reports. On each vessel positioning accuracy was verified during the course of the survey by observation of coincidental adjacent and/or reciprocal data.

Figure 3. Pole-mounted EdgeTech 4125 SSS transducer as configured on the *R/V Ocean Explorer* for Project OPR-K354-KR-17. The AML Micro X surface sound speed sensor is located within the multibeam bow fairing. Note that the SSS transducer module (pointing down in this photo) is separated from the electronics module which is secured parallel to the forward side of the transducer pole. A Reson 7125 transducer is mounted to the bottom of the pole in this photo.

Figure 4. Pole-mounted EdgeTech 4125 SSS transducer as configured on the *R/V Osprey* for Project OPR-K354-KR-17. In this photo the SSS is resting in its transit cradle.

A.2.2 Multibeam Echosounders

Two types of multibeam echosounders were employed on this project. The *R/V Ocean Explorer* was equipped with a Reson SeaBat 7125 SV2 while the *R/V Osprey* was equipped with a Reson SeaBat 8125. A description of each sonar follows.

A.2.2.1 Reson SeaBat 7125 SV2

The SeaBat 7125 SV2 is a dual-frequency Multibeam Echosounder (MBES) System with operational frequencies of 200 kHz or 400 kHz. For Project OPR-K354-KR-17, the echosounder's 400 kHz capability was employed. At this frequency and at the beam spacing basis chosen for this project, the 7125 system is able to illuminate 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 with numerous beam density and swath angle combinations. The 512-equidistant beam configuration was used for Project OPR-K354-KR-17. For this project the swath width was maintained at either 130° or 140° based on site conditions and/or area-specific necessity. The manufacturer's stated depth resolution is 6 mm. This sonar system, as employed, 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.

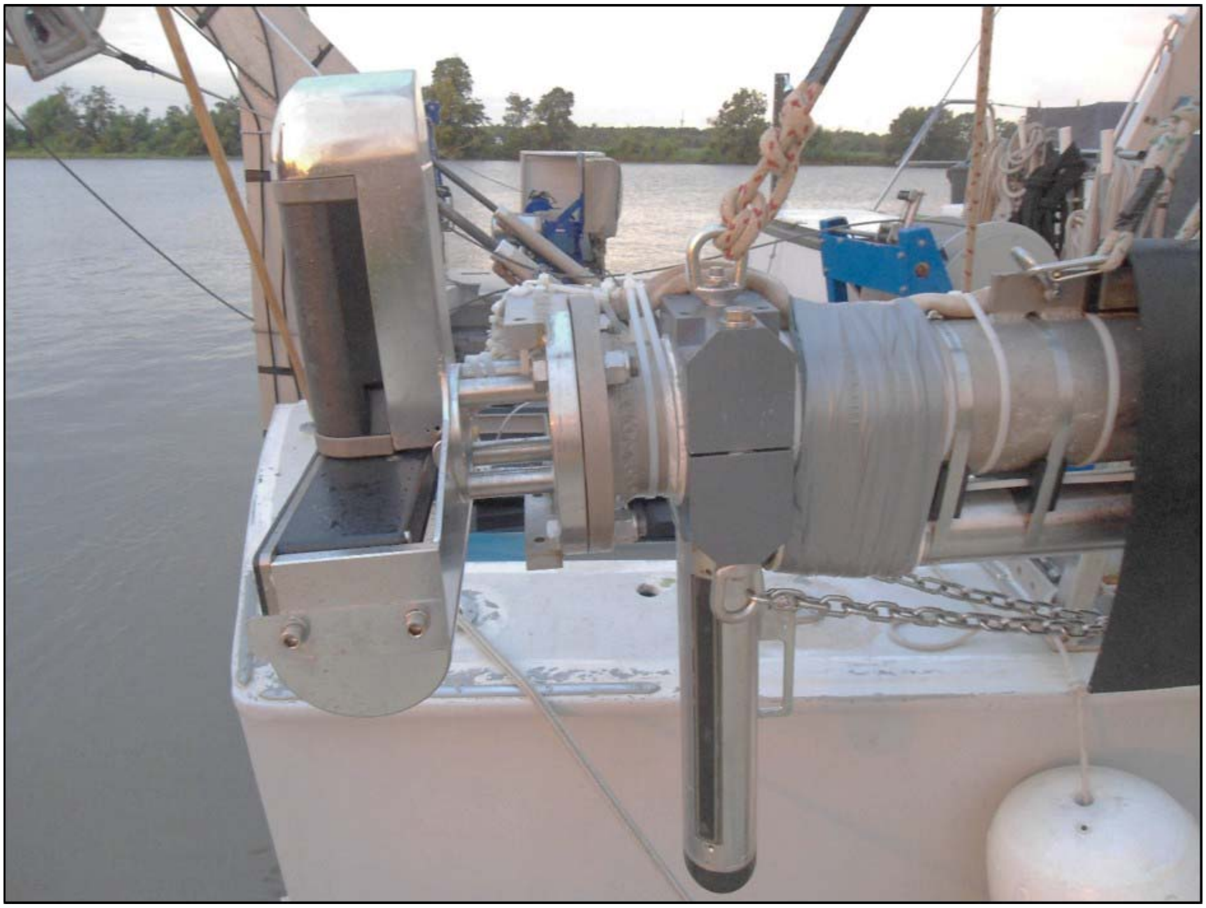


Figure 5. Pole-mounted Reson 7125 transducer as configured on the *R/V Ocean Explorer* for Project OPR-K354-KR-17.

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 2015 full static survey with values confirmed prior to the 2017 survey.

A.2.2.2 Reson SeaBat 8125

The SeaBat 8125 is a 455 kHz Multibeam Echosounder (MBES) that measures the relative water depths across a swath oriented perpendicular to the vessel's track. The ensonified swath propagates out 120º in the across-track axis and 1º in the along-track axis. The system forms 240 equiangular beams within this swath, each having an across-track angle of 0.5º. The SeaBat 8125 has a maximum ping rate of 30 Hz (range dependent) with backscatter (Snippets) enabled. Snippets was enabled during this survey. The manufacturers stated depth resolution is 6 mm and the system is designed to comply with International Hydrographic Organization (IHO) standards to measure seafloor depths to a maximum range of 150 meters. Digital data were output through an Ethernet port and displayed real-time on the system's monitor.

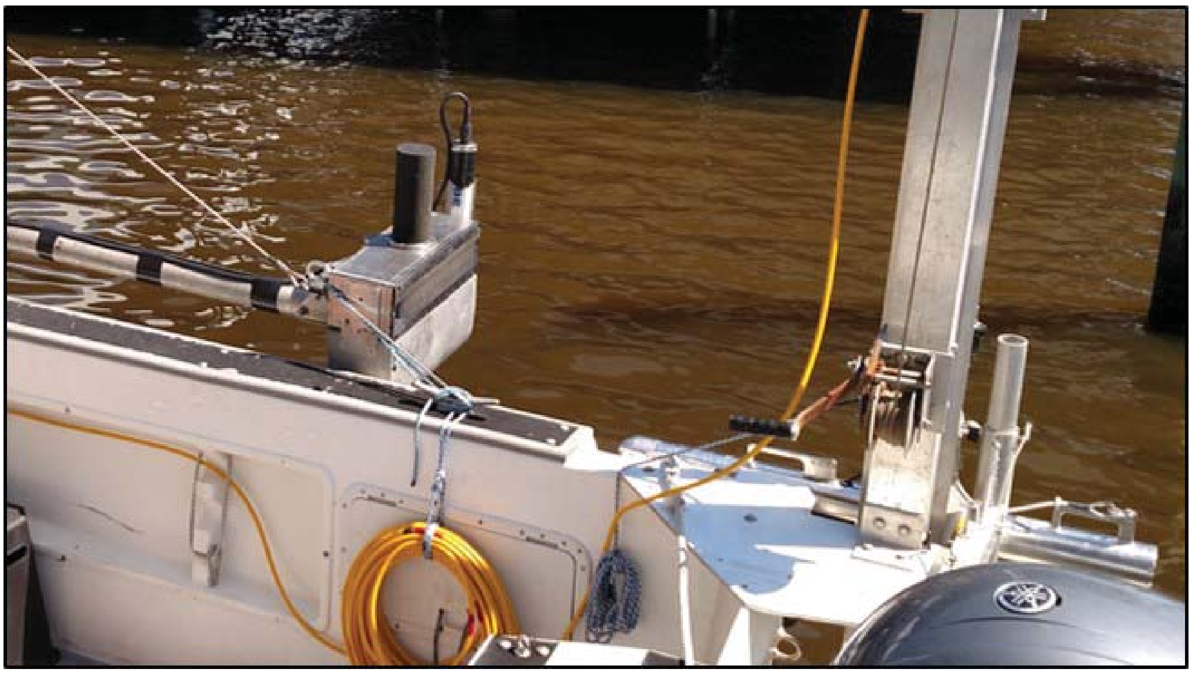


Figure 6. Pole-mounted Reson 8125 transducer (with custom bow faring) as configured on the *R/V Osprey* for Project OPR-K354-KR-17. Note the Sea-Bird SBE37 surface sound speed sensor attached to the outboard side of the multibeam transducer. Also note the pole mounted SSS deployment post and aft end of EdgeTech 4125 SSS fish on the right side of this image.

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 *R/V Osprey* July 27, 2017 full static survey.

A.3 Manual Sounding Equipment

A.3.1 Lead Line

The lead lines were constructed by OSI utilizing 9 kilogram, 0.3-meter round lead disks attached to stainless steel cables with permanent index markers established at measured 1-meter intervals.

The lead lines were calibrated prior to survey operations for each vessel using a steel tape measure to verify index mark accuracy. The lead line calibrations were accomplished on July 15, 2017 (DN 196) and July 20, 2017 (DN 201) for the *R/V Ocean Explorer* and *R/V Osprey* respectively (see DAPR Appendix II for results).

A.4 Positioning and Attitude Equipment

A.4.1 Applanix POS MV

An Applanix POS MV 320 V.4 or POS MV 320 V.5 system was installed on the respective 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. Per manufacturer's literature there are two navigation algorithms incorporated into the system, namely a tightly coupled and a 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 an antenna baseline ≥ 2 meters) when blended with the inertial navigation solution. The system uses this heading information 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.

For the *R/V Ocean Explorer*, IMU and antenna offsets, relative to the vessel frame and a vessel RP, were measured during the 2015 full static survey (values confirmed prior to the 2017 survey). For the *R/V Osprey*, IMU these parameters were measured during the 2017 full static survey. For each vessel an Applanix-specified GAMS calibration procedure was conducted during mobilization and prior to acquisition of any of the calibration data of record. In the case of the *R/V Ocean Explorer* the GAMS calibration was conducted on July 17, 2017 (DN 198). In the case of the *R/V Osprey* the GAMS calibration was conducted on August 23, 2017 (DN235).

A.4.2 DGPS

In the case of the *R/V Ocean Explorer* individual Trimble Pro Beacon DGPS beacon receivers were manually tuned to one of the two local USCG differential beacon stations and interfaced, as signal quality dictated, to the POS MV. Onboard the *R/V Ocean Explorer*, on one occasion, the primary DGPS corrector source, English Turn, LA become unusable due to station maintenance or nearshore weather (assumed). In this case the secondary DGPS signal (Angleton, TX) was utilized for a short period.

In the case of the *R/V Osprey* the POS MV was supplied with DGPS correctors from the English Turn, LA beacon via a Leica MX 52R. In no case during the survey was the English Turn, LA signal unusable.

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

On both vessels a secondary GPS was setup in parallel to the POS MV and was used to trigger “position integrity alarms” within HYPACK. The secondary GPS system consists of an integrated GPS and DGPS receiver and operated in DGPS mode. Each vessel’s secondary DGPS system was manually configured to tune to the second closest USCG differential beacon (Angleton, TX).

A.5 Sound Speed Equipment

Onboard the *R/V Ocean Explorer* the surface sound speed sensor, the sound speed comparison profiler, and the undulating sound speed profiler (ODIM MVP) were all fitted with AML Oceanographic sensors which were manufacturer calibrated prior to survey data acquisition. Onboard the *R/V Osprey* the surface sound speed sensor, a Sea-Bird Electronics SBE-37 and the sound speed profiler, an AML Oceanographic instrument, were also manufacturer calibrated prior to survey data acquisition. Copies of the calibration sheets are included in DAPR Appendix IV. The two survey vessels shared a single AML Base-X sound speed profiler which was used periodically for sound speed profile comparisons. Sensors on this "comparison" instrument were manufacturer calibrated prior to use on the project.

A.5.1 Sound Speed Profiles

A.5.1.1 Sound Speed Profiler *R/V Ocean Explorer*: ODIM MVP30

The MVP30 was the primary sound speed profiler employed on the *R/V Ocean Explorer* during this survey. 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"), an electro-mechanical 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 10 Hz. During data acquisition on the *R/V Ocean Explorer* "MVP casts" were performed at approximately 15-minute intervals.

Figure 7. ODIM MVP30 as mounted on the port quarter of the *R/V Ocean Explorer*.

A.5.1.2 Sound Speed Profiler *R/V Osprey*: AML Oceanographic Base-X

An AML Oceanographic Base-X sound speed profiler was the primary sound speed profiler employed on the *R/V Osprey* during this survey. As mentioned above a second AML Base-X logging profiler, shared between both vessels, was employed to acquire comparison cast data for sound speed confidence checks. Sound speed confidence checks were performed periodically during the course of the survey. This instrument collects high-precision direct sound speed and pressure measurements. Each of the instruments employed on this project was configured to take measurements at a rate of 5 Hz. These data were stored internally and downloaded via a serial connection using the field logging computer. Throughout the course of data acquisition on the *R/V Osprey* "AML casts" were performed at an interval of approximately 1-2 hours.

As mentioned above sound speed data from a secondary AML Base-X was used for comparison casts. In practice the secondary AML Base-X was physically attached to either the MVP freefall fish or the primary AML Base-X (vessel dependent) and the paired sensors deployed to the deepest practical depth while both instruments logged data. Data from both instruments were compared employing utilities within NOAA's Velocwin program.

A.5.2 Surface Sound Speed *R/V Ocean Explorer*: AML Micro-X

The AML Micro-X is a high-accuracy sound speed sensor capable of measuring and transmitting sound speed data directly to the MBES via a manufacturer-supplied data cable. The Micro-X, mounted within the bow faring of the MBES transducer, transmitted real-time surface sound speed data to the Reson 7125 multibeam system and the HYPACK acquisition computer via the Reson interface. The Micro-X, like the AML SVPT and Base-X sensors discussed above, uses a sound speed "exchange" sensor.

A.5.3 Surface Sound Speed *R/V Osprey*: Sea-Bird Electronics SBE-37

The SBE-37 is a conductivity/temperature sensor capable of calculating sound speed values in real time and transmitting these data directly to the SeaBat 8125 TPU via a manufacturer-supplied data cable. The SBE37 was mounted directly to the starboard side of the SeaBat 8125 transducer. The data output from the SBE37 were also sent directly into HYPACK SURVEY, so the real-time surface parameters (temperature, salinity, and sound speed) could be monitored and logged.

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 of each vessel was verified by means of a physical measurement to temporary horizontal control/navigation checkpoints located at each vessel's base of operation. Each checkpoint was established using a Trimble 5700 GPS system configured with a Trimble Zephyr Geodetic antenna.

A.6.2 Pressure Gauge: GE/Druck Water Level Gauge

Onboard the *R/V Ocean Explorer* data from a GE/Druck pressure sensor were used to calculate vessel static draft values while the vessel was offshore. The water level system consists of a vented pressure transducer connected to a top-side voltage converter. The system transmits a serial "depth" string to the HYPACK logging computer. The pressure transducer was installed well below the waterline at a fixed elevation within the multibeam transducer pole. As mentioned earlier, the otherwise sealed base of the multibeam pole was configured with a small copper orifice, in effect making the transducer pole a stilling well. The physical offset between the sensor "depth" and vessel draft was established dockside during a series of physical draft measurements versus sensor value observations (static dockside calibration).

During offshore operations on the *R/V Ocean Explorer*, sensor data were logged once a day (when practical) when the vessel was at full stop. The system was configured to record a water level at a rate of 20 Hz. Water level readings were logged to a HYPACK .RAW file for 5-10 minutes while the vessel was at a full stop. The average sensor value for the term of the observation was used for each offshore static draft calculation. Sensor readings were adjusted based on the derived fixed offset value established during the static dockside calibration procedure. This approach allowed the field team to accurately track vessel static draft despite offshore conditions.

Given that the *R/V Osprey* returned to a dock each night, static draft measurements were accomplished before and after survey each day and no electronic means of draft determination were employed.

A.6.3 Steel Tape Measure

A plastic coated steel tape measure was employed throughout the survey on both vessels for various tasks requiring physical measurements. Offset confirmations and manual static draft measurements aboard each vessel were accomplished employing a steel tape measure. Static draft measurements were made relative to permanent shipboard benchmarks which were related to the vessel RP during the full vessel survey.

A.7 Additional Acquisition Equipment

A.7.1 Bottom Sampler

A sediment sampler was employed to obtain seafloor sediment samples within the survey area. A hydraulic pot hauler aboard the *R/V Ocean Explorer* was used to recover the unit. Onboard the *R/V Osprey* a smaller bottom sampler was employed. As such, the unit was recovered by hand.

A.7.2 Auto Pilot

A Simrad AP50 Marine Autopilot was installed on the *R/V Ocean Explorer* and interfaced with HYPACK 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.

While an autopilot was installed onboard the *R/V Osprey* it was not interfaced to HYPACK. This vessel's autopilot was used during transit and, conditions permitting, to aid in line steering in "manual control" mode.

A.8 Computer Hardware and Software

A.8.1 Computer Hardware

Table 3
Computer Hardware

Vessel	Use	Manufacturer	Model	Operating System
R/V Ocean Explorer	MBES/POSPac/SSS Acquisition and Log-Keeping	OSI Custom Build	OSI Custom	Windows 10 64-bit
R/V Ocean Explorer	MVP Acquisition	Hewlett Packard	HP 530	Windows XP
R/V Ocean Explorer	Onboard Data QA/QC	OSI Custom Build	OSI Custom	Windows 10 64-bit
R/V Ocean Explorer	AML Base-X Comparison Cast Download	Dell	D830	Windows XP
R/V Osprey	MBES/POSPac/SSS Acquisition and Log-Keeping	OSI Custom Build	OSI Custom	Windows 10 64-bit
R/V Osprey	Onboard Data QA/QC	Shuttle	XPC SH67H3	Windows 7 64-bit
R/V Osprey	AML Base-X Primary Sound Speed Profiler and Comparison Cast Download	Dell	D830	Windows XP

Onboard both vessels concurrent MBES, POSPac, and SSS acquisition was accomplished on a single computer (per vessel) running HYPACK SURVEY/HYSWEEP SURVEY, Applanix POSView, and EdgeTech Discover software simultaneously. On each vessel this same computer was also used to keep an EXCEL-format acquisition log. Each vessel's "acquisition" computer was a Windows 10 64-bit computer having a MSI Military Class 4 Motherboard, a 3.2 GHz Intel Core i5 quad core processor (i7 on the *R/V Ocean Explorer*), redundant 250 gigabyte (GB) solid-state program drives, redundant 2 terabyte (TB) internal data hard drives, three gigabit network adapters, 16 GB of RAM, dedicated graphics, multiple display monitors, 9 serial ports and multiple USB-3 ports.

A second i5 processor version of the computer build described above was employed on the *R/V Ocean Explore*r as a data review machine. Onboard the *R/V Osprey* the data review machine was a Windows 7 64-bit computer having a 3.57 GHz Intel Core i5 processor, a 1 terabyte (TB) RAID 0 primary solid-state drive (SSD), a 2 TB internal hard drive backup, three gigabit network adapters, and a single high-definition display monitor.

Each of the data review machines was also used as the onboard data backup hub. In practice data were synced across the network after the completion of each trackline and soon after synced to an external 2-GB or 4-GB removable USB-3 drive.

Data processing was completed at the home office using multiple Windows 10 64-bit computers with the following typical hardware specifications: 3.40 GHz Intel Core i7-4930K processor (6-core/12-thread), 120 GB primary SSD, 2 TB RAID 0 (high-performance) SSD data drive, two 2 TB hard drives in RAID 1 (redundant) configuration, 16 GB of RAM, dual graphics cards, and four high-definition displays. The multiple computers shared data over a 10 gigabit local area network.

A.8.2 Computer Software

Computer software utilized during this survey is itemized in Table 4 below.

Table 4
Computer Software

Manufacturer	Application	Version	Version Date
HYPACK	HYPACK SURVEY	17.1.3.0	Jan. 26, 2017
HYPACK	HYSWEEP SURVEY	17.1.11.0	Jan. 25, 2017
EdgeTech	Discover 4125D 8.1	36.0.1.120	Oct. 25, 2016
Teledyne CARIS	HIPS/SIPS	10.2.3	May 23, 2017
Teledyne CARIS	HIPS/SIPS	10.4.0	Oct. 26, 2017
Teledyne CARIS	Notebook	3.1.1	SP1 2011
HYPACK	MBMax64	17.1.9	June 9, 2017
Chesapeake Technology	Sonar Wiz 5	5.1.0.40	Sept 4, 2013
NOAA	NOAA Velocwin	8.92	May 8, 2008
AML Oceanographic	SeaCast	4.2.5	April 12, 2016
Microsoft	Office (Word, Excel) 2016	16.0.6965.2058	June 3, 2016
ODIM Brooke Ocean	MVP Controller	2.430	Jan. 20, 2010
Applanix	MV POS View	7.92	April 9, 2014
Applanix	POSPac MMS	7.1	June 8, 2016
Global Mapper Software LLC	Global Mapper	13.2	June 20, 2012
AutoDesk Inc.	AutoCAD	2004	Feb. 14, 2003
Trimble	Pro Beacon (DOS)	N/A	Sept 12, 1994
Trimble	DSM Utility	0.90	July 7, 2006
Trimble	GPS Configurator	4.10	March 20, 2013
National Geodetic Survey	OPUS	2.3	July 7, 2016
UNH-CCOM/NOAA	HydrOffice QC Tools 2	2.1.2	
NOAA HSTP	XMLDR	18.1 (7665)	Jan 18, 2018

A.8.2.1 HYPACK SURVEY

On both vessels survey vessel trackline control and position fixing were accomplished by using the HYPACK SURVEY data-logging and navigation software package. Vessel position data were output from the POS MV at 25 Hz frequency and transmitted to the navigation computer system, which processed these data in real-time into the desired mapping coordinate system (UTM Zone 15 North, NAD 83). Raw and processed position data were continuously logged onto the computer hard drive, sent to the autopilot (on the *R/V Ocean Explorer* "OE"), and displayed on a video monitor, enabling the vessel's helmsman (and autopilot on the OE) 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 other pertinent survey reference files.

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 MVP or Base-X cast positions, bottom sample locations, and side scan targets of interest. Raw, geographic position data (NAD83 degrees latitude and longitude) were time tagged with UTC time by the POS MV and recorded by HYPACK SURVEY 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 surface sound speed change).

Aboard each vessel HYPACK SURVEY was used to generate real-time SSS positioning which was transmitted to and recorded by the respective instances of Discover SSS software. In the case of pole-mounted 4125 SSS, HYPACK's "Genoffset.dll" was used to calculate SSS fish position. This process is described in more detail in Section C.1.4. Towfish position was recorded in the HYPACK RAW data, and the real-time position was sent to the individual instances of Discover to serve as primary positioning for each vessel's SSS system.

Each vessel's acquisition computer's HYPACK SURVEY program was configured to use GPS UTC time to continuously sync the computer time. Acquisition PCs were synced using the Group 7 message from the POS MV.

A.8.2.2 HYSWEEP SURVEY

On each vessel 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 or 81P respectively and recorded by HYSWEEP 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 HYSWEEP in HSX format line files.

Multibeam backscatter data were recorded via HYSWEEP SURVEY in HYPACK .7K or 81X format respectively.

On each vessel HYSWEEP SURVEY was also configured to display and record a network-streamed instance of the EdgeTech SSS signal. This SSS imagery waterfall, viewed in a

HYSWEEP SURVEY window, was monitored along with the imagery waterfall viewed using the primary SSS acquisition software, EdgeTech's Discover. The HYSWEEP-recorded SSS data were not intended to be a project deliverable. As such the HYSWEEP-recorded SSS data were stripped from the .HSX files (using HYPACK's HSX Utilities module) prior to compilation of the project deliverables.

The HYSWEEP SSS functionality was meant to be a field tool. Use of this tool has at least three benefits including the following: First, by means of the HYSWEEP/SSS interface, upon "starting" a survey line in HYPACK a SSS file was simultaneously "started" in the Discover software. The Discover-recorded file, logged in a separate directory on the acquisition computer, was named by HYPACK with the identical name of the corresponding HYPACK file; the only difference in file name being the extension. Specifically, the Discover-recorded file is given a .JSF extension. This functionality was not only a convenience but also helped to eliminate log entry file name transcribing errors and happened to make file correlation easier during processing.

The second benefit, as mentioned above, is the ability to view a second instance of the SSS waterfall. Often times the HYSWEEP SSS waterfall was setup differently than the Discover waterfall, e.g. color palate and gain. This afforded the field teams an alternate view of a given feature which is sometimes helpful in interpreting the character of the feature.

Finally, HYPACK's standard "double click" targeting functionality also works in the HYSWEEP SSS waterfall. As such, certain features viewed in the HYSWEEP SSS waterfall were "targeted" and displayed on the HYPACK SURVEY map window for future consideration or avoidance.

A.8.2.3 EdgeTech Discover 4125D

Discover is a side scan sonar control and acquisition software that interfaces directly with the EdgeTech SSS systems via a dedicated Ethernet connection. As described above, for each vessel, the software was installed and operated on the primary acquisition computer which also ran HYPACK, Applanix POSView, and EXCEL. The majority of the EdgeTech settings are controlled within this software; these include the specific sensor inputs/outputs, side scan range settings, display gains, color palettes, real-time bottom tracking parameters, file recording characteristics, pressure sensor zero depth calibration (if applicable), altitude alarms, and navigation offsets.

On both vessels Discover received fish position information from the HYPACK SURVEY program via a looped serial connection (HYPACK-out to Discover-in on the same computer). HYPACK SURVEY calculated and transmitted fish position based upon the fixed physical offsets of the EdgeTech 4125 SSS relative to the vessel RP. Given that HYPACK was providing position information to Discover navigation offset settings within Discover were set to zero.

In addition to receiving position, Discover was configured to accept an ancillary time input. A NMEA ZDA message was generated by the POS MV and delivered to Discover over a serial connection. The software used this timing message to sync its time and the EdgeTech 4125 TPU time to UTC.

All SSS scrolling waterfall data displays (Discover and HYSWEEP) were configured to display uncorrected side scan sonar imagery. These displays were arranged on a vertically oriented high-definition IPS (In-plane switching) display. Scrolling imagery was continuously reviewed during collection for data quality, feature detection, and to identify water column noise and/or interference (e.g. fish, boat wakes, refraction, etc.). System and user alarms were monitored to ensure continuous system functionality.

Discover compiled system specific side scan sonar image data along with position records and stored these data in EdgeTech .JSF format. Based on past project experience, OSI has determined that JSF files produce superior imagery in CARIS. Therefore, XTF data were not recorded for this project.

A.8.2.4 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.

All SSS data were converted from raw JSF format line files to HDCS format and processed using CARIS SIPS software.

HIPS/SIPS was also utilized to process MBES and SSS calibration data, which included MBES patch and performance tests, and SSS position confidence tests.

In practice, for both HIPS and SIPS, Version 10.2.3 was used during data conversion and processing during the time of data acquisition. Soon after the period of data acquisition all further conversion and processing was accomplished using Version 10.4.0.

CARIS HIPS/SIPS Version 10.4.0. was employed to create the final MBES coverage surface and SSS mosaic data deliverables.

A process previously accomplished using CARIS Notebook was largely accomplished employing the Feature Editing Module within CARIS HIPS/SIPS 10.2.3. or 10.4.0. However, CARIS Notebook was used sporadically to this end. The Feature Editing Module was used during home office processing to track and organize side scan sonar targets of interest, i.e. significant targets and targets requiring further investigation. Danger to Navigation (DtoN) submittals were compiled and exported in S-57.000 format using the Feature Editing Module or CARIS Notebook. Field investigation assignments were tracked and conveyed to the field team using, among other tools, HOB files created in the Feature Editing Module or CARIS Notebook.

A.8.2.5 CARIS Notebook

As mentioned above CARIS Notebook, a predecessor to CARIS' Feature Editing Module was used sporadically during home office processing for many of the functions described above.

A.8.2.6 HYPACK MBMax

MBMax was used for various shipboard and home office support functions such as patch test data processing and performance test data processing as well as general day-to-day shipboard and home office data QA/QC review. MBMax patch and performance test data processing were accomplished as a QA/QC measure and to validate the CARIS-derived values.

A.8.2.7 Chesapeake Technologies, Inc. (CTI) SonarWiz 5

CTI's SonarWiz was used frequently aboard the survey vessel for various SSS QA/QC functions such as image quality review and positioning accuracy confirmation.

A.8.2.8 NOAA Velocwin

Velocwin was used to convert the MVP sound speed cast data into CARIS SVP format. Along with the AML Oceanographic data processing software, SeaCast, and Microsoft Excel, the Velocwin software was also used for sound speed comparisons performed periodically throughout the course of the survey.

A.8.2.9 AML Oceanographic SeaCast

Onboard the *R/V Osprey* sound speed cast data were acquired using an AML Oceanographic Base-X system. And, as mentioned previously, both vessels shared an AML Base-X system that was used for comparison QA/QC vs. each vessel's primary sound speed profiler. The software used to interface with the Base-X instrumentation is AML's SeaCast software. This software was used to configure the instruments for deployment and to download the raw cast data. Since the data collected during each cast were continuous during deployment (i.e. collected during equalization, and both the down and up cast data), the data had to be processed to create a useable down-cast file. The processing of the raw cast data was accomplished using an OSI-developed Excel workbook.

Routines contained within the customized Excel workbook read in a raw SeaCast exported data file, isolate the down cast, plot the data, and generate, among other things, the corresponding Velocwin-compatible .ZZQ file used in processing a comparison cast with Velocwin.

A.8.2.10 Microsoft Office Word and Excel

MS Word was used for report generation. MS Excel was used for log keeping (acquisition and processing), organization and preparation of field and office tasks, report figure production and statistical data analysis. Excel was also used to reformat sound speed/depth data into the .ZZQ format files for use in Velocwin's sound speed comparison cast utility.

A.8.2.11 ODIM Brooke Ocean MVP Controller

Onboard the *R/V Ocean Explorer* only 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 exported 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 periodically during sound speed comparisons, the MVP fish was allowed to reach near 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 water column, MVP casts.

A.8.2.12 Applanix MV POSView

On both vessels the MV POSView controller software was used to configure and monitor the POS MV navigation and motion systems. IMU parameters (heave, pitch, roll), navigation and GAMS status were monitored continuously at the acquisition stations. Visual alarms were configured to alert the operator in the event that attitude, position, velocity, heading or heave accuracy was degraded.

MV POSView was also used to start and end logging for daily POSPac files which contain True Heave data and are used for various QA/QC analysis.

A.8.2.13 Applanix POSPac MMS Post-Processing Data

POSPac MMS is a post-processing software module, which, given acceptable distance and geometry between the survey vessel and nearby Continuously Operating Reference Stations (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.

POSPac data were acquired during survey operations primarily so the TrueHeave component of the solution was available for application to MBES data.

Inertially Aided Post Processed Kinematic (IAPPK) position and attitude, was not applied to the MBES data as the area of operation did not fall within a network of shore-based CORS stations.

A utility developed by OSI was used to extract high rate position and heading data from the raw POSPac files. Once the 4125 data were converted in CARIS, the lower frequency fixed-mount SSS fish position and heading logged to the JSF file were replaced with the high rate position and heading data extracted from the POSPac files using the Generic Data Parser Tool in CARIS HIPS/SIPS.

A.8.2.14 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.8.2.15 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.8.2.16 Trimble ProBeacon and DSM Utility

The Trimble ProBeacon PC interface program was installed on a utility laptop computer onboard the *R/V Ocean Explorer* 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. Trimble's DSM Utility was used to configure and monitor the DSM232 which was used onboard the *R/V Osprey* as the position comparison DGPS.

A.8.2.17 Trimble GPS Configurator

The Trimble GPS Configurator software was installed on a utility laptop and used to configure the Trimble 5700 Receiver. The software is a menu-driven Windows program that was used to configure the RTK GPS base station (used for pre-survey calibrations). This software is also used to monitor system status and start/stop internal logging the results of which were submitted as RINEX-format files to the National Geodetic Survey's Online Positioning User Service (NGS OPUS).

A.8.2.18 NGS OPUS

The NGS' online OPUS software was used to transform dual-frequency GPS observables, recorded with the Trimble 5700, into what the NGS describes as "high–accuracy National Spatial Reference System coordinates." The resultant coordinates were used as local reference points against which the survey vessel's POS MV DGPS position solution accuracy was verified during port stops throughout the project.

A.8.2.19 HydrOffice QC Tools 2

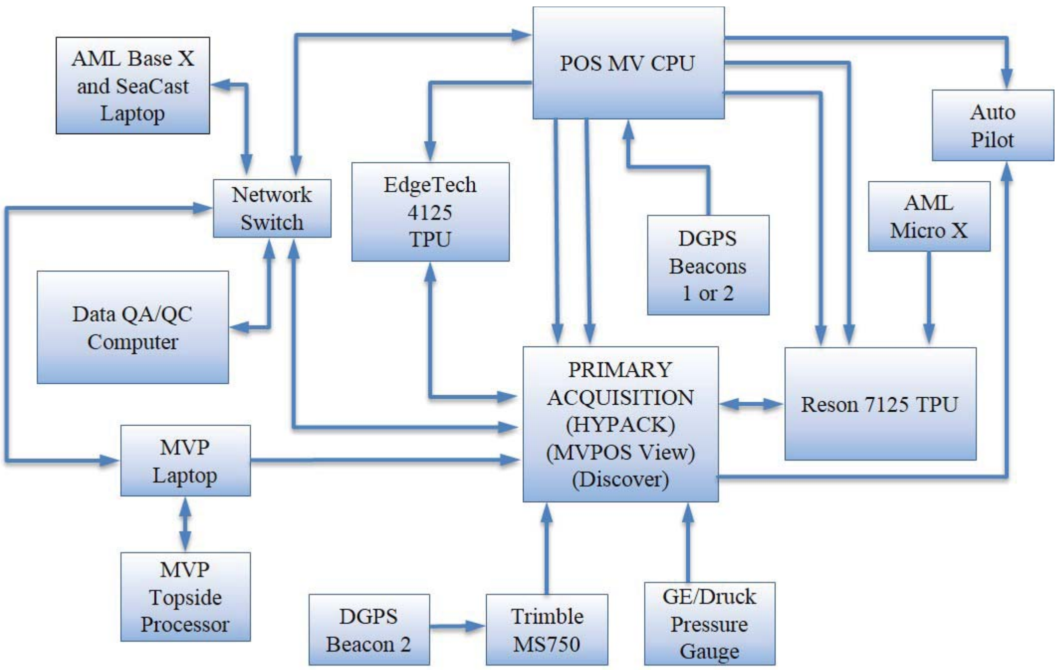
UNH-CCOM/NOAA's HydrOffice QC Tools 2 was used for various surface QC tasks including the following:

- Flier Finder v5 - Scan grids for anomalous grid data "fliers"
- Holiday Finder v4 - Scan grids for empty grid nodes that meet NOAA NOS Hydrographic Survey Specifications and Deliverables (HSSD) definitions of "holidays."
- Grid QA v5 - Compute basic grid statistics to ensure compliance to uncertainty and density requirements.
- Designated Scan v2 - Scan grids to ensure the eligibility of soundings designated.
- Feature Scan v7 - Scan features to ensure proper attribution.
- VALSOU Check v6 - Ensure surveyed features are properly accounted for in the gridded bathymetry.
- Submission Checks v3 - Ensures the required directory structure and completeness of survey deliverables.

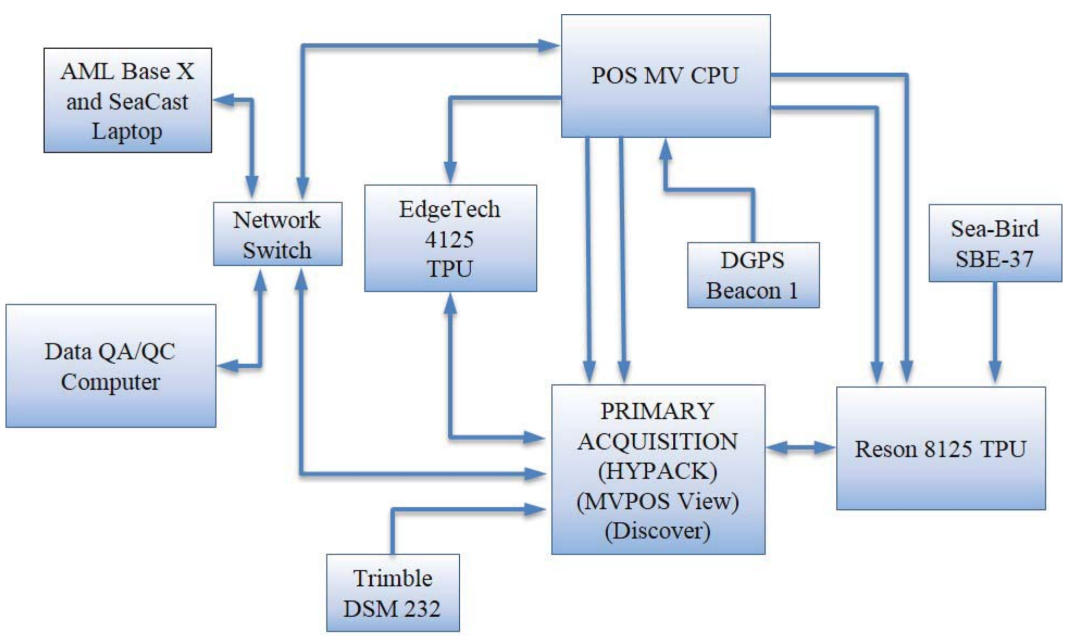
A.8.2.20 NOAA HSTP XmlDR

Used in compilation and printing (to PDF) of project Descriptive Reports.

A.8.2.21 Acquisition System Block Diagram – *R/V Ocean Explorer*



A.8.2.22 Acquisition System Block Diagram – *R/V Osprey*



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 over three years of experience conducting hydrographic surveys. The Chief of Party as well as the lead hydrographer on each vessel are ACSM/NSPS/THSOA "Certified Hydrographers."

Prior to the survey, a review of the current charted data was conducted to identify critical features and areas including platforms, obstructions and wrecks. The Composite Source File (CSF) and Project Reference File (PRF) supplied by NOAA were included in this review.

The Hydrographic Survey Project Instructions called for "Complete Coverage" over much of the survey area. In areas not requiring Complete Coverage, "Set Line Spacing" was called for. In consideration of the Project Instructions, where required, line plans were created to achieve 100% SSS coverage with concurrent MBES. It should be noted that the Project Instructions included a "Towfish Operation Waiver" which permitted SSS towfish height above the bottom of 6-20% of SSS range (as opposed to the traditional 8-20%). The fixed mount SSS on both vessels was operated only at the 50-meter range scale. For most Complete Coverage areas, 100% SSS coverage lines were planned as follows:

- 80-meter line spacing (in anticipated and/or preliminary water depths ≥ 5 meters) resulting in 20 meters of outer range overlap; SSS nadir coverage provided by the MBES

- 40-meter (or less) line spacing (in anticipated and/or preliminary water depths ≤ 5 meters). The 40 meter line plan, which was essentially 80 meter line plan "splits" resulted in substantial outer range overlap where conditions allowed. As in the case above, SSS nadir coverage was provided by the MBES.

- NOAA-assigned and/or survey-generated investigations in assigned "Complete Coverage" *and* "Set Line Spacing" coverage areas were accomplished with 200% SSS coverage on variable spaced line plans which were constructed on a case-by-case basis in consideration of water depth, local conditions, the anticipated or observed character of the feature.

A certain relatively deep reach of the assigned survey area was covered with Compete Coverage MBES in lieu of 100% SSS. In this area SSS was in fact acquired but was not used to demonstrate Complete Coverage.

In certain areas the Project Instructions called for 200 meter "Set Line Spacing" coverage. As such, in these Set Line Spacing areas, SSS was acquired but no attempt was made to achieve a coverage specification.

Data acquisition quality control procedures were established and performed to ensure survey data met requirements specified in the Project Instructions, SOW, and HSSD.

B.1.1 Bathymetry: Multibeam Echosounder (MBES)

Transducer offsets for the Reson 7125 (*R/V Ocean Explorer "OE")* and Reson 8125 (*R/V Osprey* "SB") were measured relative to permanent shipboard benchmarks and to the vessel reference position (RP) using a steel tape measure. The benchmarks were established during the full static surveys of the respective vessels which were completed using standard optical survey equipment and techniques. For both vessels, the transducer mounting orientation as relates to the vessel's fore/aft centerline and the POS MV IMU orientation was set, using a portable, survey grade gyroscopic compass mounted on a square plate.

The *R/V Ocean Explorer*'s transducer orientation was established as follows: soon after the 2015 fixed static survey, once the vessel was launched, the vessel was secured to a fixed dock on a calm day with engines ahead pulling the dock lines taut. At this time the transducer pole was rotated until the heading of the transducer matched the physical heading of the POS MV IMU (via gyrocompass observations). The gyrocompass was passed back and forth multiple times to confirm that the orientation of the IMU matched the orientation of the transducer. At this time index marks were permanently scribed into both the transducer pole and vessel attachment point such that the initial transducer orientation could be reliably repeated if it was necessary to move the transducer pole, e.g. to accommodate a draft change or, in this case, remobilization for a new field season. These permanently scribed index marks were used to accomplish the initial alignment during the 2017 mobilization. A patch test was then used to determine minor residual misalignments between the transducer and the POS MV IMU. As regards the attachment and alignment of the entire transducer mounting system, apart from retracting the pole for transit, once the draft and alignment were set during mobilization no changes were made for the period of the survey. As mentioned earlier, daily roll check patch test results indicated that the multibeam pole was stable for the period of the survey.

The *R/V Osprey*'s transducer orientation was established during the 2017 static survey of this vessel. In general the transducer orientation was accomplished in the same manner as described above for the *R/V Ocean Explorer* except that the *R/V Osprey*'s transducer orientation was accomplished with the vessel on its transport trailer. Concerning the attachment and alignment of the entire transducer mounting system, apart from retracting the pole for transit, once the draft and alignment were set during mobilization no changes were made for the period of the survey. Daily roll check patch test results indicated that the multibeam pole was stable for the period of the survey.

The POS MV IMU "bullseye" or reference point, located on the top of the IMU served as the vessel RP on the *R/V Ocean Explorer*. For the *R/V Osprey*, the X, Y position of the IMU bullseye describes the horizontal coordinates of the RP but the Z component of the RP coordinate is referenced to the IMU mounting plate (bottom of IMU) at the X, Y position of the bullseye. On both vessels the IMU mounting plate and key components of the transducer pole mounting apparatus are permanently installed hardware components of the respective vessels. For detailed information regarding system offsets refer to *Section C* Correction to Echo Soundings.

On the *R/V Ocean Explorer* the Reson 7125 processor was interfaced with the POS MV such that UTC date and time information from the POS MV were used to accurately time stamp the Reson output data string. The Reson 7125 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 "TSS1" message to the Reson TPU allowing for real-time roll stabilization. Surface sound speed measured at the transducer head with the AML Micro-X was output to the Reson 7125 processor to be used in beam-forming. The 7125's "Normal" filter was used for sound speed filtering. Raw sounding data were output from the Reson 7125 TPU to the HYPACK acquisition computer via an Ethernet connection.

On the *R/V Osprey* the Reson 8125 processor was interfaced with the POS MV such that UTC date and time information from the POS MV were used to accurately time stamp the Reson output data string. The Reson 8125 processor received a serial $UTC NMEA timing string from the POS MV. The POS MV also supplied a "TSS1" message to the Reson TPU allowing for use of roll compensated depth gates which were employed sporadically depending on factors such as water depth, bottom type, and water column interference. Real-time roll stabilization is not an option on the Reson 8125. As such, roll correction is accomplished during post processing. Surface sound speed measured at the transducer head with the Sea-Bird SBE-37 was output to the Reson 8125 processor to be used in beam-forming. Raw sounding data were output from the Reson 8125 TPU to the HYPACK acquisition computer via an Ethernet connection.

The POS MV received DGPS correctors from a Trimble ProBeacon (OE) or a Leica MX52R (SB). POS MV position, heading and attitude data strings were output to the respective HYPACK acquisition computers via an Ethernet connection.

For each vessel 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 for the respective vessels.

Prior to the start of data collection on either vessel, in light of physical offsets derived during the respective full static surveys, each vessel's static draft was measured and the transducer draft was confirmed by means of a "bar check" while alongside a 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 respective Reson echosounder as returned from the acoustic target. Aboard each vessel 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. Throughout the course of the survey bar checks were completed periodically on each vessel. All bar checks and spot checks indicate that the respective multibeam sonar systems were performing within expected accuracy limits (DAPR Appendix II).

For the *R/V Ocean Explorer* residual transducer alignment offsets (patch test) and multibeam system performance test were completed on July 17, 2017 (DN 198). The vessel and MBES calibration to establish the dynamic draft correction table (squat test) was performed on July 19, 2017 (DN 200). The July 17, 2017 patch test is the patch test of record for this field season.

On the *R/V Osprey* a preliminary "vessel acceptance" residual transducer alignment offsets (patch test) and multibeam system performance test were completed on August 18, 2017 (DN 230). The vessel and MBES calibration to establish the dynamic draft correction table (squat test) was also performed on this day (DN 230).

In the case of both vessels the tests were performed with the respective POS MVs in RTK GPS mode as a land based RTK GPS base station was established for this purpose. These data were collected nearby the vessel's home port once the vessel was mobilized and physical offsets derived.

After each vessel transited to the project area a second set of vessel-specific patch test and performance test data were acquired. Specifically, on the *R/V Ocean Explorer,* a confirmation patch test was performed adjacent to the survey area (south of the Freshwater Bayou Canal Lock) on August 3, 2017 (DN 215). None of the OE's survey system components were removed during transit to the project area, therefore, as mentioned above, the July 17, 2017 patch test is considered the patch test of record for the *R/V Ocean Explorer*. The initial performance test of record was performed south of the Freshwater Bayou Canal Lock on August 4, 2017 (DN 216). Verification or "close out" patch and performance testing for the *R/V Ocean Explorer* were performed at the completion of the project on October 12, 2017 (DN 285). Close out test results were in keeping with the pre-survey results. This vessel's patch test and performance test results of record are presented in DAPR Appendix II.

Since the *R/V Osprey*'s survey system components were removed from the vessel for transit to the project area, the vessel was reassembled once onsite, and, the initial patch test and performance test of record were performed in southern Vermillion Bay, LA (Southwest Pass) on August 24, 2017 (DN 236). Verification or "close out" patch and performance testing for the *R/V Osprey* were performed at the completion of the project on October 12, 2017 (DN 285). Close out test results were in keeping with the pre-survey results. This Vessel's patch test and performance test results of record are presented in DAPR Appendix II.

Given that each vessel's multibeam transducer was deployed on a retractable pole, in order to maintain confidence that the deployed pole was stable, multiple interim "roll" patch tests were performed throughout the course of the survey. In practice, reciprocal multibeam data were collected on a short set of lines at a convenient time each day and processed onboard to confirm system stability. In cases where the pole was deployed after transit, e.g. after returning to the survey area after a port call, a roll test was conducted immediately prior to data acquisition. Essentially, each vessel recorded at least one interim roll test at least once during each respective day of acquisition. In all cases, results of interim roll testing on both vessels indicated that the respective multibeam pole was stable.

The SeaBat display and user interface of the Reson 7125 or 8125 TPU were used to configure MBES settings, to monitor sounding acquisition, and to adjust system parameters in real time.

On the *R/V Ocean Explorer* the Reson 7125 was operated in equidistant mode using 512 return beams. As mentioned previously the system is capable of operating in equidistant mode with a swath of 140°. However, the swath was reduced to 130° for all project data acquisition due to observed degradation of data quality in the outer beams (beyond 65°) caused primarily by dynamic changes in the sound speed profile. The roll stabilization feature was activated throughout the term of the project.

Aboard the *R/V Osprey* the Reson 8125 was operated in the system's only available mode, equi-angle with 240 return beams spread over a swath of 120°. Roll stabilization is not available for this Reson model.

On both vessels "absolute" depth gates were conservatively employed to reject fliers during mainscheme and crossline data acquisition. Depth gate filters were used sparingly or turned off all together during item investigations.

The respective Reson sounding profile "wedges" were 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 the ping rate.

Bathymetry, position, motion and heading data were logged in HYPACK SURVEY and HYSWEEP SURVEY. Position information from the each vessel's primary and secondary GPS receivers (POS MV and Trimble DGPS) were continuously compared in HYPACK SURVEY and status indicators were monitored in real time. By means of a utility in the HYPACK SURVEY program a position disparity between the primary and secondary positioning systems that exceeded two (2) meters would be reported by means of a visual alarm on the data acquisition screen of each vessel.

The HYSWEEP SURVEY program allows for real-time monitoring of surface sound speed as transmitted by the respective vessel's transducer-mounted sound speed device. A utility in HYSWEEP SURVEY allows for real-time comparison of the surface sound speed to the surface sound speed recorded in the most recently acquired water column sound speed profile. For this project the respective vessel systems were configured to provide a visual alarm if the difference between these surface sound speed values exceeded 2 meters per second. Hydrographers endeavored to acquire sound speed casts at an interval of ≤ 15 minutes on the *R/V Ocean Explorer* or every 1-2 hours on the *R/V O*sprey. However, when a dynamic surface sound speed was noted, sound speed profile casts were acquired more frequently.

On both vessels, in HYSWEEP, real-time MBES sounding wedge and digital terrain model (DTM) waterfall displays were monitored. The sounding wedge, DTM waterfall, and plan view coverage displays were corrected for draft, motion, predicted tides and sound speed. 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, day number, UTC time and line number, for example: 2017OE2320811_5458.HSX/RAW or 2017SB2581419_7419.HSX/RAW where "OE" stands for Ocean Explorer and "SB" stands for Small Boat (Osprey).

The POSView software was used to monitor position, heading and motion accuracy status indicators. Applanix "TrueHeave" data (included in 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. In most cases POSPac data were logged at least 5 minutes prior to and after MBES acquisition. POSPac TrueHeave file names include the project number, vessel abbreviation, year, device (POS MV), day number, and month/day (ex: 17ES024_OE_2017_POS_265_0922.000). POSPac files were 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.

Aboard each vessel the POS MV heave bandwidth filter was configured with a dampening ratio of 0.707. The cutoff period of the high-pass filter was determined by estimating the swell period encountered during the project. A heave bandwidth filter of 10 seconds was employed for Project OPR-K354-KR-17 data collection.

On the *R/V Ocean Explorer*, which operated on a 24-hour/day schedule, during the daily "UTC midnight" changeover, the vessel was stopped and a number of mandatory and/or elective QA/QC functions performed: a static draft physical measurement was obtained (conditions permitting), a transducer pole stilling well pressure series was acquired and processed into a static draft value (conditions permitting), and a new Applanix POSPac/Trueheave file was begun. Given that the *R/V Osprey* was operated on a nominal 12-hour/day schedule, a new POSPac file was started each day and a dockside static draft physical measurement was recorded before and after daily operations.

On each vessel data were copied, via network connection, onto a shipboard data backup computer which also served as the data QA/QC platform. Data were copied from this computer to removable media, 2-TB or 4-TB USB drives, frequently throughout each survey day. These data were periodically transferred to OSI's home office via courier delivery.

Each vessel completed the following checks periodically throughout the course of the survey: a bar check was performed to verify echosounder draft offsets and system sounding accuracy and a sound speed profile comparison cast was performed to ensure the primary sound speed profiler on each vessel compared favorably to an independent, recently calibrated sound speed profiler. In all cases for both vessels the results of the bar checks and sound speed comparisons indicated that the respective systems were functioning properly.

Finally, during home office processing, coincidental MBES data from both vessels were compared (treated like Junction Survey analysis). The results of this analysis are presented in Section B.3.

B.1.2 Imagery: Side Scan Sonar

As noted above "fixed mount" SSS is the only deployment method employed during this survey. On each vessel the horizontal position of the SSS was measured in relation to the vessel RP. These values were ultimately used in creating the CARIS vessel file (discussed later). However, horizontal offsets entered into the HYPACK SURVEY data acquisition program, used to calculate fixed mount fish position for real-time positioning, were referenced to the survey vessel "steering point" origin which was accurately related to the vessel RP.

As discussed previously, EdgeTech Discover side scan sonar acquisition software was used to log the SSS imagery and position information in JSF file format. On each vessel Discover received towfish position from HYPACK SURVEY and ship heading directly from the POS MV. SSS survey line names are identical to their simultaneously recorded HYPACK counterparts, the only difference being the .JSF file extension. For example: 2017OE2320811_5458.JSF or 2017SB2581419_7419.JSF where "OE" stands for Ocean Explorer and "SB" stands for Small Boat (Osprey).

Over much of the study area over one hundred percent (100%) SSS coverage was attained employing line spacing described in Section B.1. above. However, as mentioned above, one relatively deep section of the study area was surveyed with Complete Coverage multibeam.

Each vessel's speed was maintained such that any 1 m^3 objects would be ensonified more than three times per pass at the operating range scale.

For the fixed mount configuration, the 4125 SSS towfish height was not dynamically adjustable (as compared to a towed fish). As such, towfish altitude varied based on water depth. Therefore, on any given trackline, the SSS altitude may have been marginally below the 6-20 percent range scale limit, i.e. at times the altitude was less than 3-meters which is the shallow limit when using the 50-meter range scale. For any towfish height below 6 percent of the 50-meter range scale (3-meters), the effective scanning range is defined to equal 16.7 times the towfish height. As mentioned previously, 40-meter "splits" lines were run in the shallow reaches of the study area. By "splitting" lines the 100% SSS coverage requirement was far surpassed especially in light of the Towfish Operation (height) waiver mentioned in Section B.1.

Confidence checks observed across the full SSS range (e.g. scour marks and bottom type changes) were recorded frequently throughout each survey day (on each vessel) to verify system operation and object detection capabilities. Confidence checks were recorded with line names, observation times, and comments in the daily acquisition log.

Approximate vessel speed for SSS acquisition on the *R/V Ocean Explorer* was 7-9 knots while the *R/V Osprey* speed was 5-7 knots.

B.1.3 Sound Speed

B.1.3.1 Sound Speed Profiles

On the *R/V Ocean Explorer* sound speed profile data were acquired with the ODIM MVP30 approximately every 15 minutes, except when this 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, prompted when the surface sound speed alarm threshold was exceeded (> 2 meters/second change). Profiles were acquired to a depth approximately 0.8 meters off the bottom when operating in freewheel mode. All casts were acquired inside the bounds of the survey area or outside the survey area within 250 meters of the boundary. Profiles acquired outside the survey area (within 250 meters) were typically acquired on the lead-in to a given transect. 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 recorded in .CALC file format and saved to the designated MVP laptop computer. Profiles were named for day number and cast number, for example: MVP_DN260_0041.calc.

Aboard the *R/V Osprey* sound speed profile data were acquired with an AML Base-X approximately every 1-2 hours during survey operations. Profiles were acquired more frequently if high variability was noted in the surface sound speed or the survey vessel moved between survey area locations. The surface sound speed alarm in HYSWEEP SURVEY was used as an indicator that additional casts were necessary; however, there were certain periods during the survey when the surface sound speed was highly irregular. It would have been impractical during these periods to collect an additional sound speed cast each time the surface sound speed changed by 2 m/s. As a result, the hydrographers used their judgment about when and where to collect sound speed profile casts. Up to 11 sound speed profiles were collected on days such as this.

Profiles were manually acquired by lowering the instrument to the seafloor. Locations for the casts were selected to maximize depth and capture a profile representative of conditions observed within a daily operating area. At all times the instrument reached full bottom depth at the cast location. All casts were acquired in or within close proximity to the survey area.

Individual *R/V Osprey* sound speed profiles were named according to the following convention: Last digit of the instrument serial number, day number (DN), daily profile number, for example: 8_DN246_4.vel

Individual casts were saved in both HYPACK .VEL and CARIS .SVP format.

After a cast was downloaded and processed using the AML SeaCast software and a custom OSI EXCEL spreadsheet, the resulting HYPACK compatible VEL file was loaded in HYSWEEP SURVEY to sound speed correct the real-time waterfall and profile displays allowing for enhanced real-time QA/QC capability.

B.1.3.2 Surface Sound Speed

For the respective vessels the AML Micro-X or Sea-Bird SBE-37 sound speed sensor was installed on the multibeam transducer essentially at the draft of the transducer phase center. Real-time surface sound speed values were transmitted to the respective Reson 7125 or 8125 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.

Each vessel occasionally performed a “daily surface sound speed quality assurance (DQA) check” employing NOAA’s Velocwin software. Velocwin’s DQA comparison considers the surface sound speed sensor value to the draft-appropriate surface sound speed of a recently acquired sound speed profile.

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 for each vessel and USCG station in Angleton, TX served as the secondary horizontal position control. The POS MV primarily received pseudo range corrections from the English Turn station. However, on one occasion, the Angleton, TX signal was used on the *R/V Ocean Explorer* when the English Turn signal was unavailable or degraded due to thunderstorm activity (assumed) between English Turn and the survey boat.

Prior to the start of survey operations, navigation checkpoints were established at each vessel's Louisiana base of operations employing a Trimble 5700 with a Zephyr geodetic antenna. Multiple dual-frequency GPS observation sessions were recorded at these locations. The dual-frequency GPS observables were submitted to the National Geodetic Survey's (NGS) Online Positioning User Service (OPUS) and processed to determine the positions of the temporary control points. 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).

On the *R/V Ocean Explorer* positioning system confidence checks of the POS MV were accomplished at the start of survey and during provisioning stops in Intracoastal City, LA. On the *R/V Osprey* positioning system confidence checks were accomplished each morning prior to leaving the vessel's Cypremort Point, LA dock. In practice the distance between the respective vessel's reference point (RP) and the dockside horizontal control point, as computed by the navigation system, was compared to the tape-measured distance between the vessel RP and the horizontal control point. In all cases, dockside navigation system accuracy testing demonstrated that the each vessel's POS MV, employing USCG correctors (from either source mentioned above), had an accuracy of better than 1.0 meter. A tabulation of navigation system performance checks is included in DAPR Appendix III.

On each vessel a HYPACK SURVEY "position integrity alarm" was utilized throughout the term of the survey. In practice the utility continuously compared independent positioning sources, i.e. the position reported by the respective vessel's POS MV to the position reported by the Trimble DGPS. For the purposes of the comparison the physical, shipboard position of the DGPS antenna was related to the RP (POS MV IMU) via forward and starboard offsets in HYPACK SURVEY. The position solution difference, expressed in meters and viewed on a window on the HYPACK SURVEY display, was monitored by the acquisition team. An on-screen visual alarm notified the system operator if the difference in positions exceeded 2-meters.

The alarm proved valuable in quickly drawing attention to the DGPS beacon status when a station went offline or had a degraded signal.

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 876-4227, LAWMA, 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 LAWMA station were downloaded and reviewed for data gaps. Verified tides were downloaded and reviewed when available.

Final project data are delivered with verified tides applied using a slightly altered version of the preliminary zoning file provided by CO-OPS, "K354KR2017rev.zdf." Neither time nor magnitude multiplier changes were made to the preliminary zoning file provided by CO-OPS. However, the CO-OPS provided zoning file was found to have a minor flaw in the 6th vertex of Zone #82. It was discovered during data processing that this vertex did not fall exactly on a nearby vertex of the adjacent zone (the presumed intention of CO-OPS). The result was a long, narrow, triangular area with no zoning coverage. The non-coverage triangle had two legs roughly 11.6 kilometers long with the third leg being only about 4 meters long. OSI adjusted the Zone #82 vertex which resulted in elimination of the non-coverage area. The OSI-edited zoning file included with the project deliverables uses the same name as noted above, i.e. the file name, as delivered by CO-OPS, was retained.

B.1.5 Feature Verification

When necessary, development/investigation MBES only lines were run over significant contacts and other features observed in MBES and SSS records to determine a least depth in accordance with Complete Coverage specification in the HSSD (Section 5.2.2.3). During home office processing, once an item was deemed significant, nearly significant, or simply required more data to make a determination, the contact or outstanding sounding position was conveyed to the field team in various formats including:

- An EXCEL tracking table that was added to the acquisition log
- a HYPACK target file of point items
- an AutoCAD-compatible .DXF file for area features
- a HYPACK line file (.LNW) for SSS or MBES fill in areas

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.

Given that the SSS coverage requirement for this project was 100% (as opposed to the traditional 200%) there were many instances where the first pass, single SSS coverage was not sufficient for data analysts to confidently describe the nature of a particular feature. Furthermore, the shadowing effect of items such as oil platform legs, dense fish schools, etc. resulted in data gaps that might otherwise have been ensonified with the second coverage afforded by the traditional 200% coverage requirement. These data gaps were identified during home office data processing and conveyed to the field team via the various methods bulleted above. All such data gaps were eventually filled with 200% SSS coverage or Complete MBES coverage while the field team was still mobilized.

B.1.6 Bottom Sampling

Bottom samples were acquired in close proximity to the recommended positions included in the PRF provided with the OPR-K354-KR-17 Project Instructions. Both vessels shared responsibility for sediment sample acquisition. On each vessel a sediment sampler was deployed from a davit to acquire the requisite sample. 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 H, Bottom Classification, in the HSSD.

B.1.7 Other

B.1.7.1 Autopilot

Onboard the *R/V Ocean Explorer* the Simrad AP50 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

On each vessel 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/SSS survey line ID and start time
- Date and Time of MVP (or AML) and TrueHeave (POSPac) files
- Navigation System Performance Checks, Bar Check Table, Vessel Water Level Tabulation and Sound Speed Comparison Table
- Systematic changes (i.e. 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
- Item investigations

B.2 Data Processing

B.2.1 Bathymetry

I. Data Conversion and Preliminary Sounding Correction

QA/QC level processing was completed onboard the survey vessel; however, all formal data processing occurred at OSI’s home office. In practice, data disks were shipped via courier to the home office processing center during convenient in-ports. Using this approach the lag between acquisition and data check-in at the home office was about one week for *R/V Ocean Explorer* data and more frequently for *R/V Osprey* data. Offshore conditions permitting, disk transfers were made between vessels which allowed for more frequent transmittal of both vessels' datasets. Shipping frequency became more important near the end of the survey as quicker home office input was desirable. In addition to courier delivery, especially near the end of the field program, data were transmitted via FTP.

Upon receipt of a data disk (or FTP download), information contained in the daily acquisition log was compared to the data package to ensure that no files were lost or omitted. Prior to data processing the acquisition log was consulted to verify line names and file size and to remove any aborted lines from the preprocess folder prior to converting the data in CARIS HIPS. All accepted MBES & SSS line data, POS MV TrueHeave files, and sound speed profile data were entered into the survey processing log, which was subsequently used to track the processing progress of each line and to enter all notes pertinent to individual lines or days. The processing log was built from the acquisition log in that any pertinent information regarding accepted line data was propagated from the acquisition log.

Vessel-specific configuration files (.HVFs) 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 the MBES system to convert lines into HDCS folders according to classification, i.e. mainscheme lines, crosslines, investigation 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.

During the first few days of data acquisition the recorded, stand-alone Applanix POSPac files were affected by occasional brief network interruptions with durations on the order of around 5 to 22 seconds. It was initially believed that the cause of the outages was a faulty network cable which was replaced on DN 221. However, subsequent outages suggest that network collisions may have been responsible. As a result of the network interruptions the TrueHeave or delayed heave record within each file was affected as well.

CARIS HIPS does not allow for application of TrueHeave files with data gaps. Rather than forego using the discontinuous TrueHeave files, OSI developed a utility to "fill" TrueHeave gaps with the real-time heave data recorded by HYPACK. In practice the utility loops through a given POSPac file and searches for gaps in the TrueHeave record of > 0.1 second. If a gap is detected the utility then polls the appropriate HYPACK .HSX file and extracts the non-delayed, real-time heave values for the period of the data gap. Finally, a TrueHeave file (supplemented with real-time heave as appropriate) is written as a TrueHeave group 111-only file (.000 format). During data check-in each and every POSPac file was analyzed for TrueHeave gaps. For the few days affected by the network interruptions these .000 files were used in lieu of the POSPac .000 file for application of TrueHeave. The analysis and generation of "repaired" files described above was undertaken prior to the steps described below. The "repaired" files, included with the project deliverables, include the following:

- 17ES024_OE_2017_TH_218_0806.000
- 17ES024_OE_2017_TH_219_0807.000

- 17ES024_OE_2017_TH_220_0808.000
- 17ES024_OE_2017_TH_232_0820.000
- 17ES024_OE_2017_TH_263_0920.000
- 17ES024_OE_2017_TH_273_0930.000

It is important to note that at no time did the network outages described above result in an interruption to the real time network stream as recorded by HYPACK. TrueHeave gaps affected *only* files recorded by the *R/V Ocean Explorer* and *only* on the days indicated above.

Multibeam sonar data conversion and application of sounding correctors were completed using routines developed employing CARIS' Process Designer. The Process Designer (model) 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, establish UTM grid.
2. Enable all multibeam beams.
3. Load zoned, preliminary or verified tides (when available).
4. Load daily TrueHeave files (if available).
5. Load and apply concatenated sound speed profile data. Sound speed profiles were loaded with the CARIS *nearest in distance within time* correction method. A time basis of 1-hour or 2-hours was used for *R/V Ocean Explorer* or *R/V Osprey* data respectively. During CARIS SVP Correction, the following correctors were applied: sound speed, heave, pitch, roll and waterline.
6. 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.
7. Compute TPU (Figures 8 & 9). 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 HVF.

   A tide uncertainty value of 0.2 meters was provided in the OPR-K354-KR-17 Tides and Water Levels Statement of Work. Sound speed TPU values were estimated from manufacturer accuracy of the ODIM MVP30 and AML Micro-X and from guidance in the OCS Field Procedures Manual (FPM) Appendix 4 under CARIS HVF Uncertainty Values. The *R/V Ocean Explorer*'s MVP was deployed for a cast at a frequency of ≤15 minutes and the *R/V Osprey*'s AML Base-X was deployed at a frequency of ≤2 hours. As such a sound speed profile uncertainty value of 1 m/s and 4 m/s was chosen for the measured sound speed of the *R/V Ocean Explorer* and the *R/V Osprey* respectively. A conservative value of 2 m/s was chosen for the sound speed surface uncertainty despite the fact that the surface and near surface sound speed profile gradient was relatively uniform throughout the period of the survey.

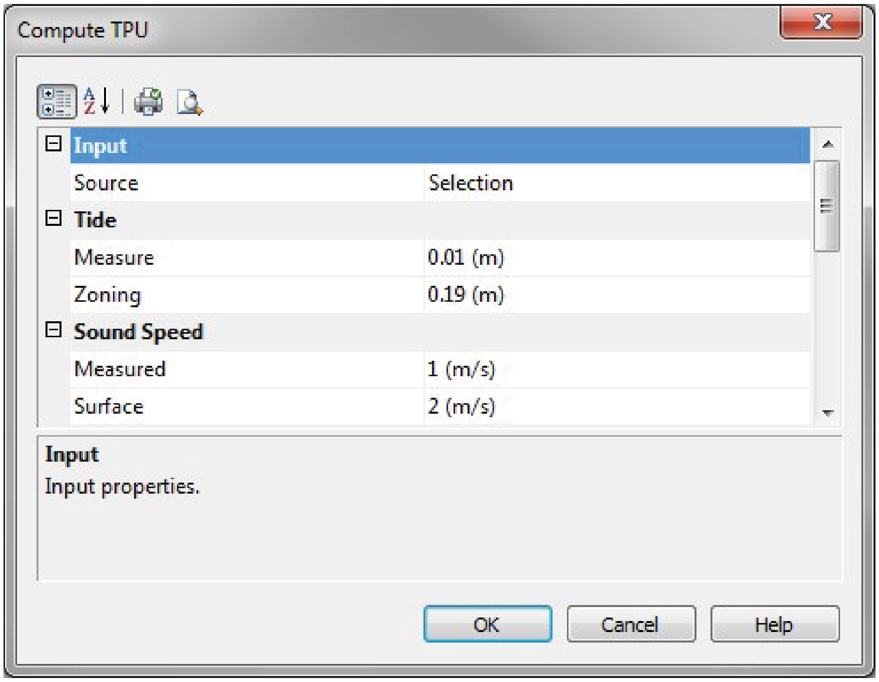


Figure 8. Uncertainty values for the *R/V Ocean Explorer* entered into the Compute TPU process in CARIS HIPS.

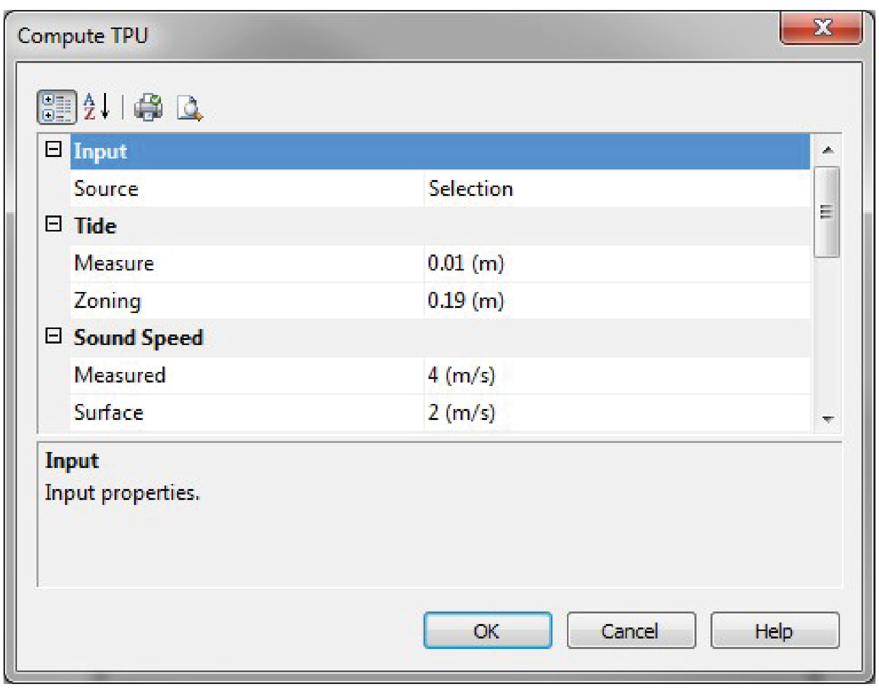


Figure 9. Uncertainty values for the *R/V Osprey* entered into the Compute TPU process in CARIS HIPS.

II. Preliminary BASE Surfaces

Preliminary field sheets and Bathymetry Associated with Statistical Error (BASE) surfaces were created for reviewing and cleaning full-density soundings using the Combined Uncertainty and Bathymetry Estimator (CUBE) process. Daily data review and cleaning were performed using 1-meter resolution CUBE surfaces as a guide for directed editing. Due to water depth and in consideration of coverage requirements defined in the Project Instructions, the survey was completed employing three types of MBES coverage, “Complete Coverage Multibeam” according to the HSSD Section 5.2.2.3 - Options A and B and “Set Line Spacing” according to the HSSD Section 5.2.2.4 – Option A. Depending on the MBES acquisition methodology employed and in consideration of water depth, various CUBE surfaces were created to evaluate coverage, e.g. 1-meter resolution CUBE for “Complete Multibeam” MBES coverage or, during early stage processing, 4-meter resolution CUBE for “Set Line Spacing.” Both in the field and during home office processing, 1-meter resolution CUBE surfaces were used to evaluate coverage for item investigations.

After the lines were run through the Process Designer, they were added to the 1-meter Cleaning surfaces and the appropriately gridded Coverage surfaces. Depth, Standard Deviation and Shoal surface models were viewed with sun illumination and/or vertical exaggeration to highlight areas that would require immediate investigation. Standard deviation surfaces were reviewed to evaluate data for consistency between overlapping coverage and crosslines, and to detect potential systematic position, motion, tide, or sound velocity errors. Highest standard deviation values were observed over obstruction features, seafloor depressions, in the vicinity of offshore platforms and, due to wind setup affecting application of zoned tides, at certain instances of overlapping/crossing data where one or more intersecting lines were acquired during periods of relatively high wind or day-to day winds with a contrary direction.

During late stage data review prior to creation of “final” surfaces it became evident that the contours in the vicinity of the 4-meter contour (the demarcation line between Complete Coverage and Set Line Spacing) were quite variable over a relatively large geographic range. This phenomenon is commonly seen in large, flat bottom areas especially when using zoned tides and DGPS positioning. Simply put, the jagged contours were visually unappealing. Given that the 4-meter contour was the intended cutoff between the Complete Coverage and Set Line Spacing surfaces (per the Project Instructions) it follows that the junction area of the submitted surfaces would have been visually unappealing as well.

The along track density of the Set Line Spacing MBES data was more than sufficient to support a 1-meter surface. As such OSI requested permission to submit Surveys H13041 and H13042 as 1-meter surfaces rather than breaking each of these surveys into 1-meter/4-meter surfaces. As seen in correspondence in DR Appendix II for the aforementioned surveys, AHB agreed to the request in an e-mail dated January 12, 2018.

Coverage surfaces were reviewed for any data gaps meeting the criteria described in HSSD Sections 5.2.2.3 and 5.2.2.4 respectively. As mentioned above, only 1-meter surfaces were delivered. All surfaces were reviewed to ensure that Complete Multibeam Coverage was obtained over significant shoals and features. Density layers were reviewed to verify that 95% of all nodes in the Complete Coverage and Set Line Spacing surfaces were populated with at least 5 soundings (using a 1-meter grid for both).

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 data or navigation jumps.

CARIS surface filters were employed to clean the majority of fish, noise, multipath returns, and gross fliers. To avoid poor surface filter performance where survey lines intersect, 2-meter surfaces were created such that no survey line overlapped another survey line. Due to the abundance of fish, shrimp, and other water column returns, surface filters were commonly run multiple times.

Swath Editor was used to review the surface filter results and further clean fliers or reaccept over-filtered soundings. Soundings were colored by depth and reviewed in multi-directional profile and plan view 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).

The CARIS Subset Editor was used to clean fully-corrected, geospatially located soundings in 2-D and 3-D displays. Soundings were primarily colored by line to verify the validity of bathy features or SSS contacts recorded by multiple MBES passes and to reject fish or water column noise recorded in one MBES pass and disproved by overlapping coverage from a different MBES line. 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 significant contacts.

“Outstanding” sounding flags were temporarily assigned to soundings on features, or possible features, which required further review. Occasionally a request would be sent to the field crew asking for additional coverage on the feature for clarification. Before finalizing the survey, all Outstanding soundings were reviewed and resolved, then either marked as “Accepted” or “Designated” as appropriate. No soundings were left with an “Outstanding” flag.

The Designated flag was used to identify the least depth of a feature and ensure that the least depth would be represented in the finalized CUBE surfaces. When a designated sounding was assigned to a feature, it indicated that no further investigation was required. OSI followed Section 5.2.1.2.3 of the HSSD guidance on the criteria for choosing designated soundings. 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 and the near nadir soundings favored over outer beam soundings.

Once the surface deliverables were finalized, chart comparisons were completed with the surveyed depths and charted depths located on all affected Electronic Nautical Charts (ENCs). The final chart comparison was completed using charts downloaded from the OCS website, nauticalcharts.noaa.gov, on November 15, 2017. CARIS HIPS & SIPS and CARIS Notebook and were utilized to complete chart comparisons with the appropriate ENCs. This was accomplished by overlaying surveyed depths in the form of finalized surface layers, sounding layers and S-57 features over the ENCs. Surveyed data were compared to all charted depths, contours and features, with agreements, discrepancies and disprovals addressed in each survey's descriptive report and final feature file.

B.2.1.1 Methods Used to Maintain Data Integrity

All project raw data files were copied onto the onboard QA/QC processing computer. The hard drives on the processing computer retained both the raw and QA/QC-processed data. Raw data on the QA/QC processing computer were backed up to a removable, 2 TB or 4 TB, USB-3 hard drive numerous times each day. During each port call the removable hard drive was shipped to OSI's home office. The removable drive was packaged for shipping only after a redundant, fully populated backup had been placed in service onboard the vessel.

B.2.1.2 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
- 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 √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 submitted surfaces.

Example for a 1-meter BASE surface in depths less than 20 meters:

CDS = 0.005
CDM = 1 / (√2) = 0.707

The CDS radius maximum value (0.005 * 20 = 0.1 meters) will not exceed the CDM value (0.707 meters) for the maximum depth, and therefore the Density Attribute Layer will represent those soundings that lie within a fixed radial distance (0.707 meters) for all nodes.

Table 5 displays the CDS and CDM values entered for the submitted grid resolution.

Table 5
CUBE Parameters Applied in Surface Generation

Grid Resolution (m)	Capture Distance Scale (%)	Capture Distance Minimum (m)
1.0	0.5	0.71

Sounding density and coverage achieved is based on requirements specified in the Project Instructions (as amended with AHB's January 12, 2018 consent to allow for submission of only 1-meter coverage surfaces). The Project Instructions' coverage requirements are shown below.

Table 6
Project Instruction Coverage Requirements

Coverage Water Depth	Coverage Required
All waters in survey area	LNM not to exceed 6300 LNM. Acquire backscatter data during all multibeam data acquisition (HSSD Section 6.2). Report significant shoaling via weekly progress report. COR may adjust survey prioritization based on observed shoaling.
Inshore limit to 4 meters water depth for H13041 - H13043	200 meter set line spacing HSSD Section 5.2.2.4 Option A.
Greater than 4 meters water depth for H13041 - H13043	Complete Coverage (refer to HSSD Section 5.2.2.3)
All waters in survey area of H13040	Complete Coverage (refer to HSSD Section 5.2.2.3)
Disproval radius of features in all waters	Complete Coverage (refer to HSSD Section 5.2.2.3)

All significant features were developed with MBES to meet Complete Multibeam Coverage standards. Feature investigations are integrated with their associated 1-meter complete coverage surfaces, i.e. there are no stand-alone investigation surfaces.

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.2.1.3 Methods Used to Derive Final Depths

The Complete Coverage and Set Line Spacing grids were "finalized" as single 1-meter surface per survey. Per the CARIS HIPS & SIPS 10 Users Guide, a finalized 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 sounding was honored in the grid. Given that the maximum project depth is < 20 meters the Complete Coverage MBES surfaces were finalized at 1-meter resolution and, as mentioned above, the Set Line Spacing data was included with the Complete Coverage surfaces at a 1-meter resolution.

B.2.2 Imagery

Preliminary QA/QC of the SSS data occurred simultaneously with data acquisition. However, all formal data processing occurred at OSI's home office. SSS data backup and shipment methodology were identical to the treatment of MBES data as described earlier. Once these data were received by the home office, the backup disk's files and acquisition log were reviewed to verify line names and file size and to remove any aborted lines from the preprocess folder prior to converting the data in CARIS HIPS. All lines 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-specific CARIS HVFs were created to convert EdgeTech JSF data files. All Preprocess EdgeTech JSF data were converted to the HDCS data format in CARIS' Conversion Wizard.

For the fixed mount SSS configuration, towfish positions were converted from the JSF sensor position field and fish heading was taken directly from the POS MV. Since the SSS towfish was mounted rigidly in relation to the vessel frame, the vessel heading derived with the POS MV was applied during SSS processing instead of using heading from the SSS compass sensor or deriving it from course over ground averaging. The real-time fixed mount SSS imagery was acquired using 1 Hz position and heading input directly from the POS MV. However, during post processing, 10 Hz position and heading data were substituted for the slower update data using the CARIS Generic Data Parser.

The EdgeTech 4125 JSF file format does not record bottom tracking, i.e. towfish altitude. The CARIS SIPS bottom tracking routine was used to 1) bottom track the imagery and 2) populate the altitude field as required in the HSSD. Although the CARIS SIPS bottom tracking routine was ultimately used to accomplish (and fine tune) the bottom tracking solution, the bulk of the bottom tracking effort was accomplished by alternate means as follows. In practice, line-by-line coincidental multibeam nadir depths were exported, corrected for the difference in draft between the MBES and the fixed mount SSS, and imported to the fixed mount SSS dataset via the CARIS Generic Data Parser. The CARIS SIPS bottom tracking routine was then employed to review the imported bottom tracking solution and make the relatively few minor corrections/edits that were needed.

The fixed mount SSS vessel file is not a "zero" configuration. During fixed mount SSS acquisition and subsequent onboard QA/QC data processing, HYPACK SURVEY-derived SSS positioning data were utilized. However, in order to improve contact selection and

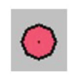
mosaic quality, the CARIS Generic Data Parser was used to overwrite positioning/heading recorded in the field with high rate position and heading information extracted from the daily Applanix POSPac files. The fixed mount SSS vessel file includes forward and starboard towpoint offsets which allowed the fish position to be recomputed using CARIS SIPS. The fixed mount configuration did not have a variable "cable out" field; therefore, this value is always shown as zero.
Navigation time stamp irregularities were edited and navigation data were reviewed in the CARIS Navigation Editor. Each side scan line was reviewed in CARIS Attitude Editor to ensure that the towfish attitude was properly represented and that there were no gaps or problems with this parameter.

The CARIS Side Scan Editor was used to bottom track, slant range correct, and apply image enhancement correction to the data. Processing was completed as follows:

1. Review the raw side scan data in Side Scan Editor. Use automated bottom detection algorithms where necessary and then correct any automated or parsed bottom tracking errors by manually re-digitizing the bottom trace.
2. Calculate and apply an average speed of sound value from sound speed casts acquired during the corresponding day of side scan acquisition. The slant range correction sound speed used for each day of side scan acquisition is noted in the processing log.
3. Lines were Beam Pattern corrected to normalize angular response across the swath.

During pre-survey planning, the CARIS HIPS/SIPS *.hips database files were 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 7 below, along with their graphical display in CARIS HIPS and a brief description of the conditions under which the contact type is selected.

Table 7
Modified OSI Contact Types Selected in Side Scan Editor

Unknown Contact **UNKCNT** Feature whose nature cannot be determined	
Obstruction - ht 0.7m+ **SIGCNT** Feature that has a SSS measured height > 0.7 meters or has significant size or features, i.e. submerged platform ruins, loose fish net, subm piling, etc.	
Feature with insig height **INSCNT** Feature that has a SSS measured height between 0.25m and 0.7m	
Fish contact **FSHCNT** Fish	
Wreck **WRECK** Boat, ship, sailboat, barge, etc. , any feature that might be a wreck.	
Platform **OFSPLF** Oil production platform. High water, not submerged.	
Navigational Aids (charted) **NAVAID** Navigation Aids that can be verified against raster chart, ENC, or CSF	
Exposed pipe and gas leak marker **QAQC** Use as a point feature marker for digitized linear pipes & cables, and possible gas seep locations	
Cable **NPCA** Linear features that are not pipelines	
Pipeline **NPPL** pipeline only	

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 dimensions were positioned and created at the top (closest to nadir) of the shadow, and attributed with the following information: feature type (obstruction, platform, unknown, wreck), 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.

SSS lines were reviewed a minimum of two times by more than one data analyst to make certain that all significant contacts were selected that may require investigation. The contacts selected in Side Scan Editor were visible in the HIPS and SIPS Display window. Contacts were reviewed in CARIS Subset Editor using full sounding density while toggling between rejected soundings being shown or hidden.

In order to ensure sufficient coverage, individual line mosaics were created with a resolution of 0.15 meter. The line mosaics were then merged and saved as 0.25-meter resolution sheet mosaics for the 100 and 200 percent side scan coverages.

During initial home office processing, the 100 and 200 percent coverage sheet mosaics were reviewed for coverage gaps and poor quality imagery that would necessitate SSS fill-in lines. Fill-in lines were assigned to the field team as necessary to supplement the existing coverage. After the completion of survey and processing operations, the final 100 and 200 percent coverage mosaics were exported from CARIS HIPS and SIPS to individual GeoTiffs.

B.2.2.1 Methods Used to Maintain Data Integrity

See Section B.2.1.1.

B.2.2.2 Methods Used to Achieve SSS Object Detection and Accuracy Requirements

As noted earlier, only one type of SSS system was employed on this project.

For fixed mount SSS operations utilizing the Edge Tech 4125, a traditional "single pulse" SSS, the system was operated only at the 50-meter range scale. At this range scale the system's pulse repetition interval was sufficiently fast for survey speeds achieved.

B.2.2.3 Methods Used to Verify Swath Coverage

During home office data review the 100 percent side scan coverage mosaic was updated frequently and reviewed for gaps or poor quality data that would require fill-in lines or re-runs of the mainscheme line. The review process occurred while the field team was still mobilized onsite.

Line spacing was planned such that there was ample overlap between adjacent lines for the single 100% coverage. All side scan lines were planned with the intention of achieving outer beam overlapping coverage of at least 20 meters. MBES near-nadir data provided secondary SSS nadir coverage which was useful in assessing near-nadir SSS contacts. Gaps in side scan coverage that occurred when the vessel steered off line to avoid oil platforms were subsequently filled with side scan development lines and/or Complete Multibeam to the extent that safety of the vessel and platforms allowed. SSS shadows created by platforms even if the vessel did not have to steer offline were also filled with either additional SSS or Complete Multibeam which were acquired from a different perspective. In many cases large fish balls caused gaps in the 100% SSS coverage mosaic. These gaps were also filled with either additional SSS or Complete Multibeam.

B.2.2.4 Criteria Used for Contact Selection

The criteria used to select contacts was based on the guidance provided in the HSSD Section 6.1.3.2 Side Scan Sonar Contacts, which defines a contact as significant based on its shadow height in different depth ranges. The HSSD significant contact specifications are summarized in Table 8.

Table 8
Significant Contact Selection Criteria

Surrounding Depth or Area	Significant Contact Height
≤ 20 meters	1 meter
> 20 meters	5% of surrounding depth

No portion of the assigned survey area was found to be over 20 meters deep. Therefore, only the ≤ 20 meter significant contact height criteria was considered. OSI used a more conservative approach than required 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 height, based on shadow length, of 0.7 meters were selected. Features smaller than 0.7 meters were sometimes chosen if they appeared navigationally "significant" in relation to the charted depth.

At times there was an abundance of fish encountered within the project area, represented in the side scan record as individual fish and as schools. Fish contacts were created when the fish schools, singular swimmers or dolphins 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 and dolphin reflections were evident in the water column, which also created shadows in the SSS record.

Individual fish contacts having a well-defined, characteristic detached shadow were not investigated further. When available, coincidental SSS and/or MBES data were consulted to bolster the decision not to investigate. Conversely, there were many cases where the character of an interpreted individual fish shadow was *not* convincing, i.e. further investigation was warranted. In these instances additional data were acquired to disprove the questionable fish feature.

The presence of fish contact symbols 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 pipeline were digitized as linear contacts. At times, contacts without a shadow were selected if there was a noteworthy shape or size to the item, despite its insubstantial relief.

B.2.3 Sound Speed

B.2.3.1 Sound Speed Profiles

As mentioned earlier an ODIM MVP was used as the primary sound speed profiling device on the *R/V Ocean Explorer* and an AML Base-X profiler was used as the primary sound speed profiling device on the *R/V Osprey*. All automated and manual comparison casts were reviewed in the field as they were acquired.

In the case of the MVP, profiles were plotted on the HYPACK SURVEY screen along with a recent history of preceding casts. In practice, as MVP casts are performed they are plotted in profile in HYPACK SURVEY displayed as a red line. As subsequent profiles are performed the previously acquired profile changes to blue and the newly acquired profile is plotted in red. This process is repeated each time an MVP cast is acquired with the older profiles turning a lighter shade of blue each time a new profile is written in red.

In the case of manual casts on the *R/V Osprey* using the AML Base-X, the profiles were downloaded with a dedicated laptop computer as they were acquired, plotted for QA/QC in comparison to prior daily casts (in EXCEL) and incorporated into HYSWEEP SURVEY for correction of the real-time sounding wedge in HYPACK. As a new AML Base-X cast is loaded into HYSWEEP SURVEY the “new” cast is shown in relation to the cast it is replacing which is another opportunity for QA/QC.

Sound speed profile data were continually assessed in the field by the following means:

- their shape in relation to previously acquired profiles
- their effect on the real time sounding wedge as displayed in HYSWEEP SURVEY
- the profile surface speed in comparison to the real time surface speed output by the MBES-mounted, vessel-specific, AML Micro-X or Sea-Bird SBE-37 sound speed sensors.

As these data were received at OSI’s home office, the delivery disk’s file listing was compared to the acquisition log to verify file names and size and to remove any aborted casts from the preprocess folder prior to converting the data to the respective vessel’s SVP file.

For the automated MVP-derived cast data, the ASCII CALC files logged with each cast were converted 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 vessel-specific survey level SVP file (ex: H13040-Master.svp) for use in sound speed correction of the *R/V Ocean Explorer* survey lines in CARIS HIPS.

For the manual AML Base-X derived cast data the .SVP files generated onboard the survey vessel were concatenated to a vessel-specific survey level SVP file (ex: H13041-Master.svp) for use in sound speed correction of the *R/V Osprey* survey lines in CARIS HIPS.

During the Load SVP step in the HIPS Batch Editor, the vessel-specific 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. Two hours was chosen as the time increment. Prior to the final application of sound speed correctors, the Master SVP file for each survey was opened as a Background File in CARIS HIPS to verify that the cast positions all fell within the area surveyed.

Occasional AML Base-X and MVP comparison casts acquired during the *R/V Ocean Explorer*'s "UTC midnight" changeover or AML Base-X to Base-X comparison casts conducted on the *R/V Osprey* were converted in Velocwin or an OSI custom EXCEL worksheet to generate ZZQ files used to compare the sound speed profiles with the "Weekly DQA" tool. The 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 respective vessel's profiler-derived surface sound speed and the surface sound speed device mounted on each vessels multibeam transducer. The comparison, observed visually by the onboard surveyor and monitored using the HYSWEEP SURVEY utility mentioned previously was occasionally documented employing Velocwin's "Daily DQA" tool. These comparison data are also included in DR Separate II.

B.2.4 Horizontal and Vertical Control

B.2.4.1 Horizontal Control

RTK GPS positioning and water level determination were employed during pre-mobilization-to-site MBES patch testing, side scan sonar positioning verification, and settlement and squat testing.

This approach was chosen in order to achieve higher accuracy positioning of the discrete objects used to determine the angular biases of the MBES transducer and to accurately account for the vessel's vertical response to changes in speed, i.e. settlement. Once the calibration values (derived using RTK GPS positioning) were known, the vessels were repositioned to the Gulf of Mexico survey area and certain processes were repeated using DGPS real-time positioning. Examples of post site arrival tests include patch and performance testing and, in the case of the *R/V Osprey*, the side scan sonar positioning verification test. For onsite testing *only*, DGPS positioning was replaced with Inertially Aided Post Processed Kinematic positioning, i.e. POSPac-derived positioning.

B.2.4.2 Vertical Control

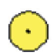
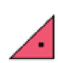
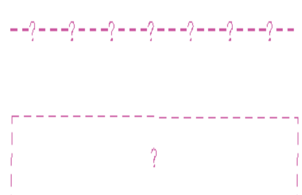
Predicted, Preliminary and Verified tides were downloaded from the CO-OPS SOAP web services website and were re-formatted as TID files to be used in CARIS HIPS tide correction.

The preliminary tidal zoning file (ZDF) that was provided by CO-OPS with the OPR-K354-KR-17 Tides Statement of Work was employed as provided by CO-OPS (with the single OSI vertex edit noted earlier). The time and height corrections in the zoning file were used to extrapolate the water level measured at the tide gauge to each modified discrete tide zone. The zoned tide correctors were then applied to the soundings.

B.2.5 Feature Verification

During home office processing contacts were exported (daily) from HIPS and SIPS to an ASCII text file, which was reformatted and imported into a CARIS Notebook edit layer (.HOB file). Senior processing personnel 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 coverage. The Investigation HOB layer was exported to an S-57 (.000) file which could be opened as a background layer in HYPACK SURVEY during acquisition of development lines. Several S-57 feature symbols were chosen and re-defined for OSI tracking purposes; the in-house descriptions of the tracking objects are included in Table 9.

Table 9
Description of Investigation Tracking HOB Layer

S-57 Symbol		Description	Parameters
	BOYISD	Indicates Survey Data Issues	SSS: Incorrect contact, Incomplete contact, Additional contact description needed MB: Fish still in data, Tide Issue, Heave Issue acqsts = Investigate
	BOYSPP	Indicates Items as Examined	Any Ftr that is not significant should be marked examined. Downgrade any investigation item that is found to be insignificant.
	BOYLAT (green)	Indicates Resolved Survey Task Items	Item Investigations Shoal Areas Photos acqsts = Resolved
	BOYLAT (red)	Indicates Unresolved Survey Investigations	Item Investigations Shoal Areas Photos acqsts = Investigate
	Cartographic Lines and Areas	Indicates Lines and Areas that require additional survey data	

Following the field team's completion of investigation and development tasks, feature verification, MBES and SSS coverage confirmation were accomplished through intensive review employing various data sources and software. Prior to the conclusion of survey operations, the home office project manager reviewed the data to ensure the following:

- Complete Coverage MBES was obtained over significant SSS contacts.
- Charted soundings were verified or disproved with MBES coverage per guidance included in HSSD Section 5.2.2.1. Bathymetric Splits.
- Complete MBES coverage was obtained over significant shoals.
- CSF "assigned" items were adequately addressed.
- Photos were obtained of high-water features, e.g. platforms.

The item investigation and development lines were converted and processed in CARIS HIPS following the bathymetry processing procedures outlined above. CUBE surfaces with a grid resolution of 1-meter were created over the investigated significant features. The density layers were reviewed to verify that the Complete Multibeam Coverage requirement of 5 soundings per node was met. Least depths were designated on all verified features and significant contacts.

Contacts were evaluated with respect to available correlating SSS as well as BASE surfaces, charted information, and designated soundings. Significant contacts were evaluated in full density sounding subsets to ensure that there was adequate MBES coverage.

Contacts, contact images, and designated soundings were exported from CARIS HIPS and SIPS. All contacts were imported into a HOB file which was the foundation of the S-57 SSS Contact File included with the project deliverables. The designated soundings were imported into a HOB file, as well, and were utilized in the production of the S-57 Final Feature File (FFF), wherein the positions and designated least depths were used to update existing chart features or create new features in the FFF.

Shoal soundings, designated soundings and contacts were compared to the largest scale charts in the survey area to identify Dangers to Navigation (DtoNs). All DtoNs were submitted to AHB as attributed S-57 .000 files per the specifications laid out for Contractors in the HSSD. All features submitted as DtoNs are included in the FFF.

I. SSS Contact File

It was discovered during data processing that, even despite the use of high-performance computers, the CARIS 10.2.3. Contacts Database file became unstable/unusable when the number of contacts approached 3,000. The project-wide SSS imagery contains many thousands of fish contacts. For example, Survey H13040 contains over 14,000 fish contacts. Given that fish contacts had to be considered during contact feature analysis and correlation, an alternate method was devised to manage fish and fish-like contacts.

Initially, all SSS imagery was reviewed in the CARIS SSS View window. Due to the limitations of the CARIS Contact Database the *only* contacts chosen in the traditional manner, i.e. within the SSS View waterfall, were those contacts presenting themselves as "obvious" seafloor-prone features and features with a questionable character. Those items interpreted to clearly be fish or other nondescript water column targets (due to their character, e.g. detached shadow) were intentionally *not* chosen as a traditional contact in the SSS View waterfall.

Upon choosing all traditional contacts a new feature layer, i.e. a .HOB layer, was created for each coverage percentage per vessel, e.g. a 100% mainscheme coverage layer from the OE, a 200% investigation coverage layer for the SB. The number of feature layer .HOB files varied by Survey based on the number of SSS coverage surfaces created and the number of vessels that actually contributed to a survey (only the *R/V Ocean Explorer* worked in Survey H13043). The .HOB layer names included the sheet name and a color designation. The color designation was used in a later step during feature correlation.

In practice each 15 cm line mosaic was loaded into CARIS HIPS/SIPS and reviewed as a stand-alone layer in concert with the SIPS traditional contacts layer, the appropriate ENC chart background, and a CSF-assigned features layer. All layers were toggled on and off throughout the process to ensure each mosaic was viewed in the context of all available supporting information. As a given mosaic was reviewed (at a scale appropriate for target identification on a 49-inch 4k monitor) individual fish targets were chosen with the mouse cursor (on the plan view mosaic) and appended the appropriate coverage percentage/vessel .HOB file. The operator used the SIPS contact layer overlay to help make informed fish target picking decisions and to help avoid placing fish targets on top of previously chosen SIPS traditional targets. A column entitled "fish positioned" was added to the data processing log to ensure each SSS line file was reviewed in the manner described above.

Once all fish targets were chosen the .HOB files were loaded into the CARIS HIPS/SIPS main operator window and the display properties of each fish feature layer adjusted such that the displayed fish symbols were colored according to their associated file name color designation. The end result was a CARIS operator window displaying thousands of fish targets colored according to their source file, e.g. red, green, blue, cyan. The intent of this approach was to allow for the opportunity to discern any actual features from the visual background noise created by thousands of fish contacts.

It follows thus that during contact review and correlation the four-color fish symbols were viewed in relation to one another *and* the SIPS contact layer. Fish contacts, regardless of color, were dismissed if there was not a correlating fish contact (of a different color) in close proximity. In instances when two or more fish contact symbols (of different colors) were found in close proximity to one another then further investigation was undertaken. Individual fish contact .HOB layers were concatenated (per Survey) and are included with the project deliverables in the Ancillary Data directory.

All SIPS traditional SSS contacts, point and linear features, were exported from HIPS and SIPS to an ASCII file and imported into a .HOB File. Individual contacts were correlated manually with respect to available overlapping SSS coverage, fish contact .HOBs, BASE surfaces, charted information, field photos and observations, and designated soundings. Correlation was accomplished by selecting all contacts found to represent the same independent feature in the Display Window and assigning each group a unique correlation number in the Primary Key ID (prkyid) attribute field. All contacts with the same prkyid are a correlating contact group. Singular contacts were not assigned a correlation number.

Each feature in the S-57 SSS Contact File includes the required NOAA Extended Attributes as specified in the table from Section 6.1.3.3 of the HSSD. The contact number is composed of the SSS line number and the number assigned in the HDCS line Contact file, for example: 2017OE2331204_60840191.

The contact image from SIPS Side Scan Editor is embedded in the S-57 contact file in the Image (images) attribute field.

II. Final Feature File

A Final Feature File (FFF) in S-57 .000 format was created in CARIS HIPS/SIPS per the guidance in HSSD 2017 Section 7.3. The feature file included all source features assigned for investigation in the OCS-provided Composite Source File (CSF) and new navigationally significant objects discovered during the survey that required additional description beyond inclusion in the submitted bathymetric surfaces. The FFF includes new survey features, and updated and disproved charted features. Per Section 2.2. of the HSSD the FFF is submitted in the WGS84 datum, unlike all other project deliverables which are submitted in the NAD83 datum.

Regarding the OCS-provided CSF, it should be noted that not all “assigned” features included in the CSF were addressed during the survey. This note is made in light of the Project Instructions’ directive that, “all features with attribute ‘asgnmnt’ populated with ‘Assigned’ shall be addressed in accordance with Chapter 7 of the HSSD.” The following timeline and narrative are offered as an explanation thereof. The Draft Project Instructions are dated May 2, 2017 and the Draft Composite Source File (CSF) and Project Reference File (PRF) were issued on May 19, 2017. The Final Project Instructions are dated June 21, 2017, and the Final Data Package (including "final" CSF and PRF) was issued to OSI on July 5, 2017.

The draft directives included seven (7) potential sheets, i.e. HXXXXX Registry Numbers. The negotiated survey effort, reflected in the Final Project Instructions and PRF include four (4) of the seven (7) original sheets. The remaining three (3) sheets are depicted as “unassigned” in the figure included with the Final Project Instructions. However, the Final CSF (file date 5-19-2017) does not reflect the reduction in sheets mentioned above. As such, there are a number of Final CSF “assigned” features that fall well outside of the four surveyed sheets. OSI’s assumption that the CSF “assigned” features falling within the three “unassigned” sheets was confirmed in correspondence with the COR concluding on November 17, 2017 (see Descriptive Reports Appendix II, Correspondence).

For clarity the CSF “assigned” features that fall within the three “unassigned” sheets mentioned above are not included in the FFFs.

OSI followed the feature attribution guidance in Section 7.5, S-57 Feature Attribution, of the 2017 HSSD, while building the FFF. In particular, the determination of a charted feature as an "Update" or a "New/Delete" item was based on the guidance that an Update is a modification to "attribution, geometry, and/or feature object class" and that a charted feature should be given the New/Delete treatment when the distance between the charted position and new position is "greater than 2mm at the scale of the survey (20m for 1:10,000)." Further guidance on this subject was offered by the COR in an e-mail dated November 17, 2017 (see DR Appendix II). The guidance on positioning wellheads and platforms follows, “Include both the significant wellheads and platform features in the FFF, and reposition any platform that deviates greater than 10 meter from the center point of the corresponding charted feature, based on the page 97 of the HSSD. These are all delete/add for the charted platforms.”

New or Updated point features’ depths (VALSOU – value of sounding) and positions were imported from Designated soundings selected in CARIS HIPS and SIPS.

High-water features such as platforms were digitized into the FFF with the position determined from the MBES data or from the 25-centimeter SSS mosaic.

Descriptive information pertinent to each feature was entered in the IHO S-57 attribute fields and the NOAA extended attribute fields as specified in Section 7.5 and Appendix F: Feature of the HSSD.

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,H12905. New, updated or verified features only.
- descrp (Description) – New, Update, Delete, Retain
- remrks (Remarks) – Processing remarks including survey techniques, feature classification (i.e. obstruction, rock, platform).
- recomd (Recommendations) – Hydrographer’s charting recommendations.
- sftype (Special Feature Type) – Only updated for ATON and/or DTON items.
- images (Images) – Contact images, CARIS screen grabs or shoreline photographs included in the multimedia folder. Not Applicable for “Delete” features.

The mandatory S-57 attribution for each S-57 object class was updated as specified in Section 7.5 of the HSSD. The required attributes vary with S-57 object class (i.e. OBSTRN, OFSPLF, SBDARE).

B.2.6 Bottom Samples

Bottom sample positions were imported into CARIS from the HYPACK target file then included in the FFF. The bottom samples were classified as SBDARE (Seabed area) objects and attributed as instructed in Section 7.5 of the HSSD. 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

A full crossline sounding data set was acquired at the start of acquisition, prior to collection of mainscheme coverage. Crosslines were run nominally perpendicular to mainscheme lines. Soundings from mainscheme lines and crosslines were compared periodically throughout survey operations using preliminary CUBE surfaces and using CARIS HIPS Subset Editor. Crossline comparisons provided confirmation that the system offsets and biases were entered correctly and verified the accuracy of sounding correctors (i.e. tide, sound speed, TrueHeave).

As required in the HSSD, the planned crossline mileage was > 4% of mainscheme mileage for Complete Multibeam Coverage areas and > 8% of mainscheme mileage for Set Line Spacing areas.

Statistical quality control information was generated periodically during data acquisition by comparing the beams of each crossline to CUBE Surfaces generated from mainscheme data using the CARIS QC Report Utility. At the completion of MBES data processing, for each survey, difference surfaces were generated between a surface compiled from mainscheme/investigation MBES data and a surface compiled only from crossline MBES data. The results from the difference surface creation and the statistical analyses are discussed in the descriptive reports for each survey.

As a project wide, data quality assurance measure a surface-to-surface comparison was performed using coincidental MBES data acquired independently by both vessels while on the same trackline and as close in time as practical given the differing vessel schedules. The intention of the comparison was to evaluate vessel-to-vessel depth sounding agreement independent, to the extent practical, of the influences of using zoned tides. In order to mitigate the potential for tide related influences, MBES data from one vessel were acquired within an hour of the other vessel.

In performing the evaluation, mainscheme project data from the *R/V Ocean Explorer* were compared to coincidental line data acquired by the *R/V Osprey* (whose data were used only for the purposes of the comparison presented herein). The MBES data acquired by the *R/V Osprey* for this test are not included with the mainscheme project data. Rather, the *R/V Osprey*'s data are included in the MBES Calibration folder along with the Survey H13042 HDCS data. Survey H13042 is the survey area in which the comparison was undertaken. The *R/V Ocean Explorer* line used in the comparison is 2017OE2581453_7260 and the *R/V Osprey* line used in the comparison is 2017SB2581447_7260.

Depths from 1-meter BASE surfaces compiled from the MBES data from each vessel were compared using the CARIS HIPS Difference Surface function. A histogram of the differences is shown in Figure 10. Depths from the *R/V Ocean Explorer* show excellent agreement with the depths from the *R/V Osprey*. Depth discrepancies generally equaled 5 centimeters or less with a mean difference of 2 centimeters.

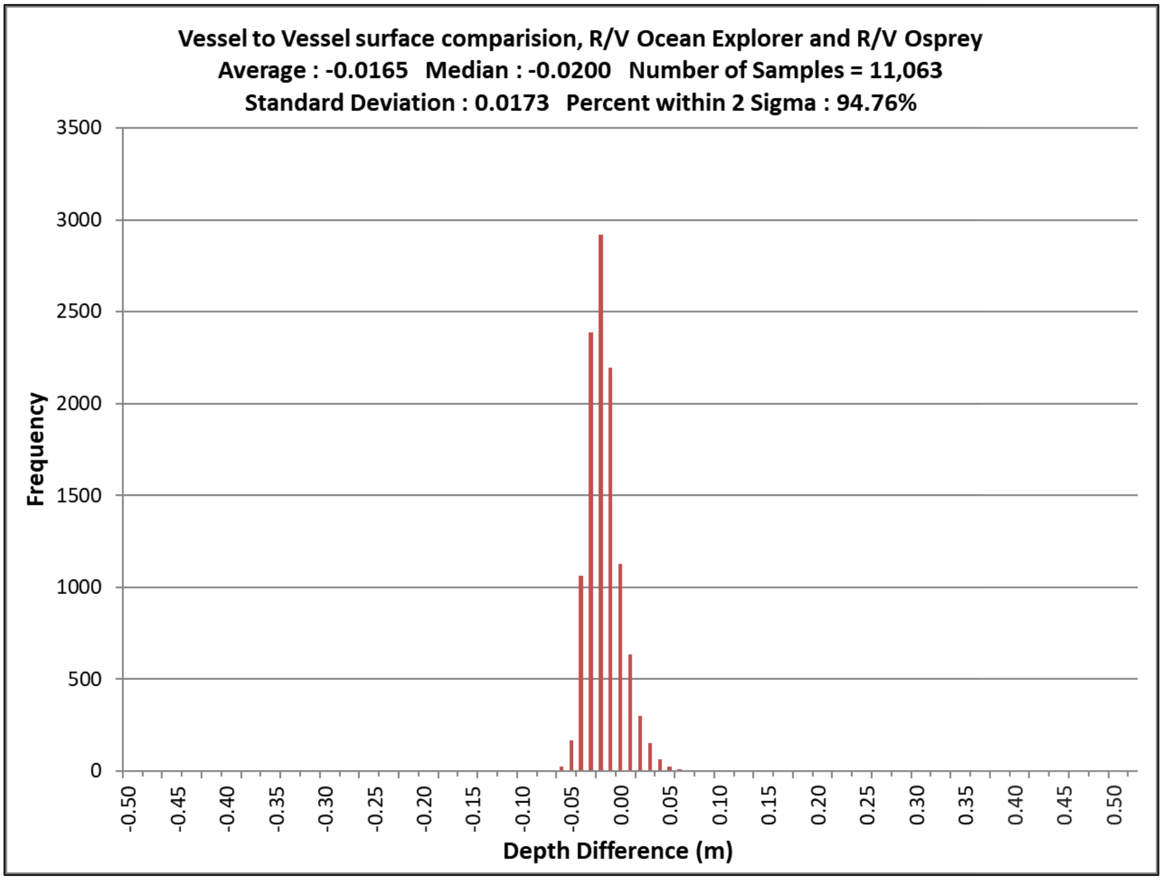


Figure 10. Surface-to-surface difference histogram comparing coincident trackline depths from the *R/V Ocean Explorer* with depths from the *R/V Osprey*.

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, and TrueHeave correction or to errors in system alignment.

Sound speed profiles were plotted by day to visualize the variation over time and space (Figure 11). Relatively rapid increases or decreases in sound speed in the top few meters of the water column generally correlated with higher error in the sounding position, as evidenced by a “smile” or “frown” effect across the MBES swath. Surface sound speed logged in the raw HYPACK files was extracted and plotted for every line. Relative higher deviation and more rapid changes in the surface sound speed over a line were also an indicator of increased sound speed error in sounding correction which was most severe in the outer beams (Figure 12). Given the relatively shallow water depths in this project area, overall, the effect of the sound speed profile shape/severity was less pronounced than it may have been for a deep water survey. On this project, sound speed was simply not a substantial negative factor for overall data quality. Even so, 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.

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

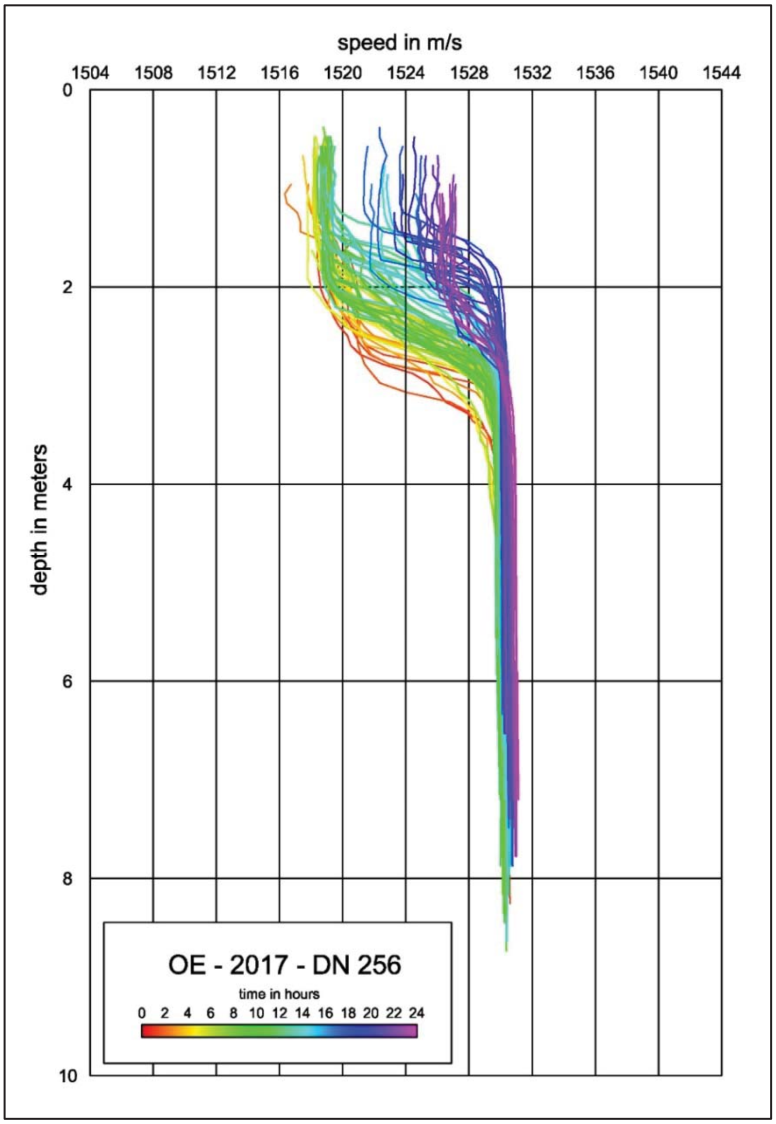


Figure 11. Plot of sound speed casts from the *R/V Ocean Explorer*, September 13, 2017 (DN 256).

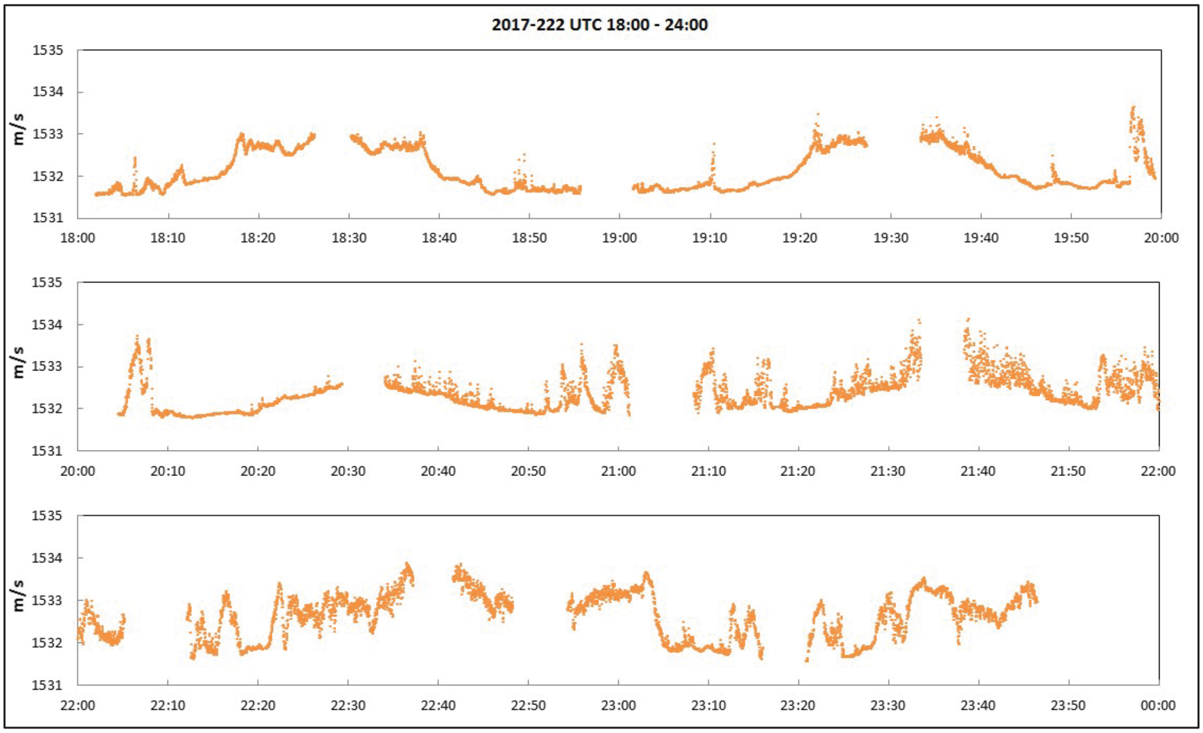


Figure 12. *R/V Ocean Explore*r surface sound speed plot by survey line for August 10, 2017 (DN 222) spanning 18:00 to 24:00 UTC.

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 “TPU 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 10 and 11 list the standard deviation and uncertainty estimates used for all measurements incorporated into the TPU estimates for the Reson 7125 and Reson 8125 echo soundings.

Table 10
***R/V Ocean Explorer* Reson 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)	0.530
Heave Measurement σ (m)	0.05	Loading Measurement σ (m)	0.030
Roll Measurement σ (deg)	0.02	Draft Measurement σ (m)	0.030
Pitch Measurement σ (deg)	0.02	Delta Draft Measurement σ (m)	0.030
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)	0.19
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)	2.00

Table 11
***R/V Osprey* Reson 8125 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)	0.530
Heave Measurement σ (m)	0.05	Loading Measurement σ (m)	0.030
Roll Measurement σ (deg)	0.02	Draft Measurement σ (m)	0.030
Pitch Measurement σ (deg)	0.02	Delta Draft Measurement σ (m)	0.010
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)	0.19
Pitch Timing σ (sec)	0.01	Sound Speed Error Measured (m/s)	4.00
Roll Timing σ (sec)	0.01	Sound Speed Error Surface (m/s)	2.00

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 values for the XYZ Offset and static draft measurements were calculated from distances acquired with the coarsest tool used to verify vessel offsets, the steel tape.

For the *R/V Ocean Explorer*, standard deviation for the loading measurement was calculated from the measure down values acquired on the port and starboard sides as well as pressure gauge-derived static draft values measured during the daily changeover. For the *R/V Osprey* the standard deviation for the loading measurement was calculated from the measure down values acquired on the starboard side.

The uncertainty for the delta draft was established by calculating the standard deviation of the differences between settlement values of reciprocal runs per each vessel speed tested. 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.

Sound speed TPU values were estimated from manufacturer accuracy of the ODIM MVP30 and AML Micro-X and from guidance in the OCS Field Procedures Manual (FPM) Appendix 4 under CARIS HVF Uncertainty Values. The *R/V Ocean Explorer*'s MVP was deployed for a cast at a frequency of ≤15 minutes and the *R/V Osprey*'s AML Base-X was deployed at a frequency of ≤ 2 hours. As such a sound speed profile uncertainty value of 1 m/s and 4 m/s was chosen for the measured sound speed of the *R/V Ocean Explorer* and the *R/V Osprey* respectively. A conservative value of 2 m/s was chosen for the sound speed surface uncertainty despite the fact that the surface and near surface sound speed profile gradient was relatively uniform throughout the period of the survey.

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 each vessel's reference frame. The RP on the *R/V Ocean Explorer* was the phase center or "bullseye" of the POS MV IMU. The RP on the *R/V Osprey* was located at the X, Y position of the POS MV bullseye, but, at the base of the POS MV IMU rather than the top of the IMU where the bullseye is located. The measured offsets included the distance between the MBES transducer phase center to the RP, the distances between the GPS antenna phase centers and the RP, and the distance from the fixed mount SSS to the RP.

C.1.2 Methods and Procedures

As mentioned earlier an optical total station was used to complete a full survey of the *R/V Ocean Explorer* on May 6, 2015 prior to mobilizing Project OPR-J377-KR-15. Since the 2015 total station survey only one change was made to the physical configuration of the vessel. Near the location of the POS MV antennas the boat was fitted with new spot lights. As a result the POS MV antennas were raised 2.0 feet (0.610 meters) in order to escape the GPS signal shadowing effects of the new hardware. This year-to-year change is reflected in the table below. However, since the antenna offsets are entered directly into the POS MV controller software the change is not reflected in any HVF. The offsets on the *R/V Osprey* were also established with an optical total station survey. The *R/V Osprey*'s total station survey was completed on July 27, 2017.

Onboard the *R/V Ocean Explorer* and the *R/V Osprey* the respective POS MV IMU was mounted on a permanent plate close to the vessel's center of rotation (Figure 13 and Figure 14). The total station was used to measure the offsets from the IMU bullseye or RP to the POS MV GPS port and starboard antenna mounts, the Trimble DGPS antenna mount, and multiple port/starboard reference points including the draft measurement point(s). When the multibeam/fixed mount SSS pole(s) mount were fully deployed, the offsets between the MBES and fixed mount SSS transducers were related to the respective vessel's RPs via repeated measurement between the transducers and the starboard side reference points mentioned above. These measurements were made using a steel tape measure. The MBES and fixed mount SSS transducers are located directly below conveniently situated starboard side reference points allowing for an unobstructed measurement paths.

On both vessels the IMU and transducer mounting hardware were co-aligned employing a gyrocompass.

C.1.3 Vessel Offset Correctors

Instrument offsets input to the respective CARIS vessel configuration files are included in Table 12 and Table 13 below. Systems layout schematics for both vessels are presented in Figure 13 and Figure 14 respectively.

Table 12
***R/V Ocean Explorer* Sensor Offsets**

***R/V Ocean Explorer* 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 Bullseye 0,0,0	0.000	0.000	0.000	-0.480
POS MV GPS Antenna Phase Center Port	4.900	-1.200	6.339	5.859
POS MV GPS Antenna Phase Center Starboard	4.883	1.239	6.333	5.853
Positioning Integrity Comparison GPS Antenna Phase Center	2.713	0.948	7.972	7.492
7125 Transducer Phase Center	0.629	2.870	-1.423	-1.903
Fixed Mount SSS (EdgeTech 4125)	1.139	2.870	-1.016	-1.496
Starboard Side Draft Measurement Point	-0.325	2.542	1.975	1.495
Port Side Draft Measurement Point	-0.329	-2.494	1.979	1.499

Table 13
***R/V Osprey* Sensor Offsets**

***R/V Osprey* 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 = Base of IMU at bullseye X,Y 0,0,0	0.000	0.000	0.000	0.034
POS MV GPS Antenna Phase Center Port	0.991	-0.748	2.150	2.184
POS MV GPS Antenna Phase Center Starboard	1.015	0.750	2.160	2.194
Positioning Integrity Comparison GPS Antenna Phase Center	-0.311	0.170	3.459	3.493
8125 Transducer Phase Center	-0.830	1.516	-0.884	-0.850
Fixed Mount SSS (EdgeTech 4125)	-2.979	1.516	-0.948	-0.914
Starboard Side Draft Measurement Point	-0.782	1.324	0.927	0.961

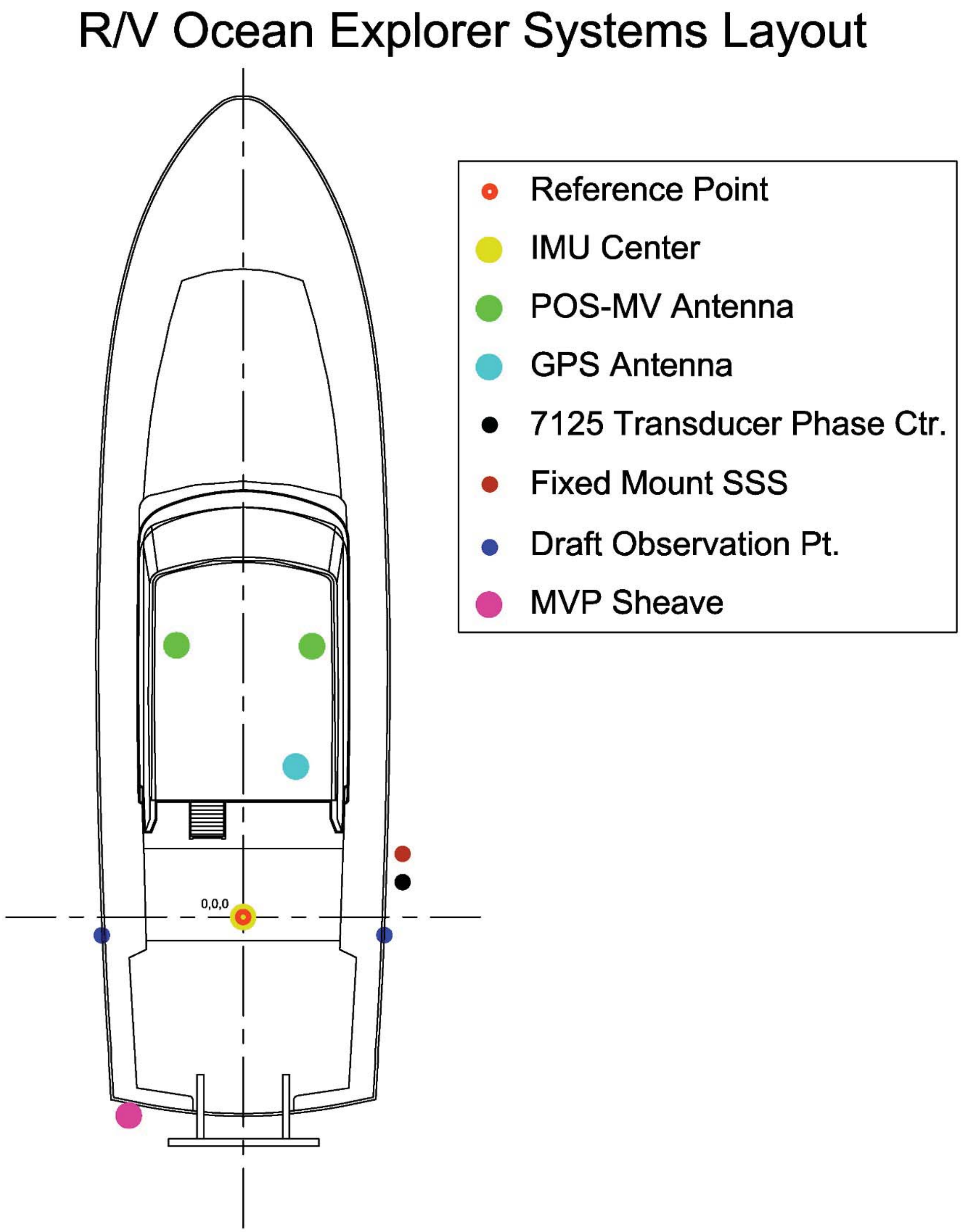


Figure 13. *R/V Ocean Explorer* systems layout.

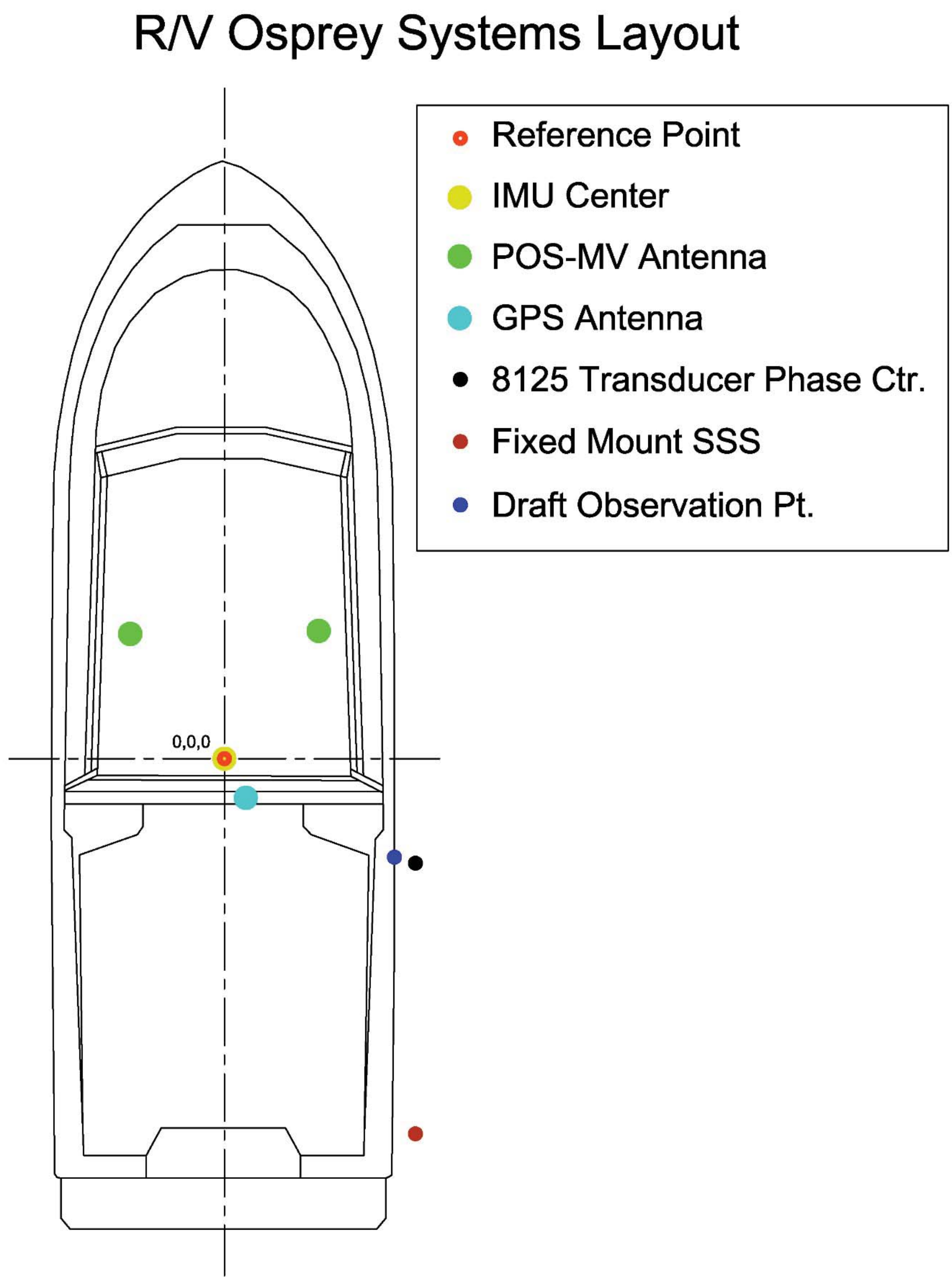


Figure 14. *R/V Osprey* systems layout.

C.1.4 SSS Positioning

C.1.4.1 Fixed Mount Configuration

The respective vessel's SSS were operated exclusively in a rigid, fixed-mount configuration, i.e. no towed SSS imagery was collected on this project. Positioning was accomplished in real-time using HYPACK SURVEY configured using the generic offset device (genoffset.dll). HYPACK SURVEY transmitted fish position to the SSS acquisition software package, Discover, based upon the fixed physical offsets of the EdgeTech 4125 SSS relative to each vessel's steering point which is turn was related to each vessel's RP. The Discover software also recorded vessel heading (analogous with fish heading) which was supplied to the software via a direct serial connection to the POS MV.

As mentioned earlier, a utility developed by OSI was used to extract high rate position and heading data from the raw POSPac files. This information was used in recalculating fixed-mount side scan sonar fish position. The practice of recalculating fish position using high rate position data via the CARIS Generic Data Parser utility results in image mosaics that have far less pixel stretching artifacts than realized using the relatively slow update rate positioning/heading recorded with the Discover software in real time. Recalculating fish position in CARIS SIPS required that a non-zero vessel file was used, i.e. a vessel file containing the starboard and forward offsets of the fixed mount towfish relative to the vessel RP.

Positioning accuracy of the fixed mount system was verified prior to commencing survey operations by comparing the position of a known feature (position determined using MBES data) to the same feature positions as recorded in multiple SSS passes. The multiple SSS passes were collected at varying distances from the feature to confirm overall system accuracy. As mentioned previously, each vessel's SSS was operated only at the 50 meter range scale. Test results are presented in 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. For the *R/V Ocean Explorer* the vertical offset to account for the distance from the RP to the water surface was updated once a day into the Waterline Height field in the HVF. On the *R/V Osprey* this value was often updated twice per day, dockside before and after daily operations. 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

Onboard the *R/V Ocean Explorer* static draft measurements were taken during mobilization, prior to the start of the survey (July 14, 2017, DN 195), and periodically throughout the term of the survey. Direct measurements or “measure downs” from the water surface to both the starboard and port draft observation point “benchmarks” were made employing a steel tape measure. 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. Minor variations in vessel attitude were negated as the final measured waterline height value is an average of the port and starboard measured values.

For the *R/V Ocean Explorer* a GE/Druck pressure sensor (water level gauge) was installed within the transducer pole providing an alternate method to monitor the change in static draft due to changes in vessel loading. The 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 pressure sensor depth below the water surface was calibrated prior to the start of survey to determine its vertical offset constant in reference to the RP. When the vessel was at a full stop for the daily “UTC midnight” changeover, the pressure sensor water level data were logged for 5-10 minutes using HYPACK SURVEY. The water level values were extracted from the raw HYPACK file and averaged to obtain the depth of the pressure sensor below the water line. The waterline height was calculated by subtracting the vertical offset between the pressure sensor and the RP from the pressure sensor average depth. Once the measure down-to-pressure sensor corrector constant was established (and subsequently confirmed with later measurements) the pressure sensor gauge water level determination method was used almost exclusively for static draft measurements offshore as the sea state made measure downs impractical when the vessel was offshore.

When offshore on the *R/V Ocean Explorer* the waterline height measurement was calculated daily using the pressure sensor water level gauge method and measure down values were acquired only when the vessel was offshore during calm conditions. Given that the vessel’s operations dock was located well into the Intracoastal Waterway (in fresh water) the dockside measure down values were not included in the HVF for fear that these values would be biased due to the difference in water density between the fresh water dockside location and the salt water environment of both the survey area and the pressure sensor constant determination location. The min/max range of waterline height measurements for the *R/V Ocean Explorer* was less than 7 cm for the period of the survey.

Onboard the *R/V Osprey* waterline height measurements were completed each day before and after operations and/or before and after daily fueling. In practice the vessel trim was adjusted before each measurement such that the roll value, as displayed on the MV POS View software, read nominally zero. At this point, using a steel tape measure, the physical measurement from the starboard side reference point to the water surface was recorded. The min/max range of waterline height measurements for the *R/V Osprey* was less than 3 cm for the period of the survey.

The waterline height measurement was corrected to the vessel reference point and recorded in the respective acquisition logs. Waterline height values calculated from physical measurement, “measure downs,” or the pressure sensor 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 each vessel’s 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 on the *R/V Ocean Explorer* was measured on July 19, 2017 (DN 200) with the vessel configured for data acquisition with an average loading weight and vessel trim. Calibration test lines were acquired in water with a nominal depth of 6-20 meters; the sea-state was calm during collection. Data were acquired along tracklines nominally 1,000 to 4,000 meters long at regular intervals of speed, beginning with the engines at various “troll” settings and increasing by 100 RPMs until the maximum practical survey speed was surpassed. During testing reciprocal line pairs were acquired at each RPM setting to average out the effect of any current present. Tidal variations were accounted for by recording a “drift line” with the vessel at rest at the beginning and end of each test line run at speed. Lines, at speed or at rest, were only logged after the vessel speed leveled out or stabilized to a steady state. The data were collected with the POS MV in RTK mode using a base station approximately three miles away. However, the real time RTK solution was abandoned in favor of a seemingly more stable single base IAPPK solution. The test was conducted in the vicinity of the vessel’s home port in Noank, CT which is the location the vessel was mobilized and from where initial calibrations were staged.

Dynamic draft on the *R/V Osprey* was measured on August 18, 2017 (DN 230) with the vessel configured for data acquisition with an average loading weight and vessel trim. Calibration test lines were acquired in water with a nominal depth of 3-9 meters; the sea-state was calm during collection. Data were acquired along tracklines nominally 200 to 1,200 meters long at regular intervals of speed, beginning with the engines at various “clutch ahead” and increasing RPMs to various thresholds until the maximum practical survey speed was surpassed. During testing reciprocal line pairs were acquired at each RPM setting to average out the effect of current. Tidal variations were accounted for by recording a “drift line” with the vessel at rest at the beginning and end of each test line run at speed. Lines, at speed or at rest, were only logged after the vessel speed leveled out or stabilized to a steady state. The data were collected with the POS MV in DGPS mode. Vertical values were derived employing a single base IAPPK solution. The test was conducted in the vicinity of the vessel's home port in Old Saybrook, CT which is the location the vessel was mobilized and from where initial calibrations were staged.

Table 14 and Table 16 summarize the as-measured settlement test results for the *R/V Ocean Explorer* and *R/V Osprey* respectively. In populating the CARIS HVF draft table, the settlement curves generated using the values shown in Tables 14&16 were smoothed and densified using a 4th Order polynomial curve fit in EXCEL. Settlement values entered into the CARIS HVFs were taken from the smooth curve at regular speed intervals. These values are shown in Table 15 and Table 17.

Between Survey OPR-J377-KR-15 and Survey OPR-K354-KR-16 the propellers were changed on the *R/V Ocean Explorer*. The "new" propellers had a different diameter and pitch. There was a minor but noticeable difference in the settlement curve at higher speeds between the 2015 and 2016 field seasons. Prior to mobilizing the vessel for the 2017 field season the "original" propellers were reinstalled on the *R/V Ocean Explorer*. It follows then that the contemporary settlement test results differ slightly from the 2016 test results and are more in keeping with the 2015 results.

C.2.2.3 Dynamic Draft Correctors *R/V Ocean Explorer*

Table 14
***R/V Ocean Explorer* As-Measured Dynamic Draft Correctors**

RPM Both Engines	Speed		Dynamic Draft Meters
	M/S	Knots	
Static	0	0	0
Troll Setting 1	1.47	2.86	-0.003*
Troll Setting 2	1.60	3.10	-0.007
Troll Setting 3	1.91	3.72	-0.009
Troll Setting 4	2.38	4.63	-0.011
600	3.61	7.02	-0.045
700	4.12	8.01	-0.062
800	4.54	8.84	-0.091
900	5.18	10.07	-0.149

*Negative value indicates the boat is settling. CARIS correctors are the opposite sign.

Table 15
***R/V Ocean Explorer* - Polynomial Curve Fit Dynamic Draft Correctors**
As entered into CARIS HVFs

Speed		Dynamic Draft Meters
M/S	Knots	
1.03	2.00	0.001
1.29	2.50	0.003
1.54	3.00	0.006
1.80	3.50	0.009
2.06	4.00	0.013
2.31	4.50	0.016
2.57	5.00	0.020
2.83	5.50	0.025
3.08	6.00	0.030
3.34	6.50	0.036
3.60	7.00	0.044
3.86	7.50	0.053
4.11	8.00	0.065
4.37	8.50	0.079
4.63	9.00	0.097
4.88	9.50	0.119
5.14	10.00	0.146

C.2.2.4 Dynamic Draft Correctors *R/V Osprey*

Table 16
***R/V Osprey* As-Measured Dynamic Draft Correctors**

RPM Both Engines	Speed		Dynamic Draft Meters
	M/S	Knots	
600	0.93	1.82	-0.001*
1,000	1.64	3.19	-0.010
1,500	2.67	5.19	-0.035
2,000	3.41	6.64	-0.050
2,500	3.99	7.76	-0.040
3,000	4.30	8.37	-0.030
3,400	4.69	9.12	-0.010

*Negative value indicates the boat is settling. CARIS correctors are the opposite sign.

Table 17
***R/V Osprey* - Polynomial Curve Fit Dynamic Draft Correctors**
As entered into CARIS HVFs

Speed		Dynamic Draft Meters
M/S	Knots	
1.03	2.00	0.000
1.29	2.50	0.004
1.54	3.00	0.009
1.80	3.50	0.015
2.06	4.00	0.021
2.31	4.50	0.027
2.57	5.00	0.033
2.83	5.50	0.039
3.08	6.00	0.043
3.34	6.50	0.046
3.60	7.00	0.046
3.86	7.50	0.044
3.98	7.75	0.042
4.11	8.00	0.038
4.24	8.25	0.034
4.37	8.50	0.028
4.50	8.75	0.021
4.63	9.00	0.013
4.75	9.25	0.004

C.3 System Alignment

C.3.1 Description of Correctors

A multibeam sonar calibration was completed to determine residual navigation timing error and angular 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 vessel. The initial patch test of record for the *R/V Ocean Explorer* was performed in Fishers Island Sound off Noank, CT on July 17, 2017 (DN 198). The Noank, CT area patch test area was chosen given the anticipated paucity of suitable patch test areas within the project area. As mentioned earlier, none of the survey systems were removed from the *R/V Ocean Explorer* between mobilization in Connecticut and the end of data acquisition. The initial patch test of record for the *R/V Osprey* was performed in southern Vermillion Bay, LA (Southwest Pass) on August 24, 2017 (DN 236). Data were acquired in accordance with HSSD April 2017 Section 5.2.4.1.

On the *R/V Ocean Explorer*, throughout the course of the survey the multibeam pole was occasionally recovered (pivoted out of the water for transit and docking). On the *R/V Osprey* the multibeam pole was deployed and recovered each day for transit. For both vessels, if the pole was moved, an abbreviated patch test was performed. On the *R/V Ocean Explorer*, despite the unlikely possibility that the multibeam pole would move during 24-hour operations, as a conservative measure, an abbreviated patch test was performed daily whether or not the pole was recovered and redeployed.

For the “interim” or abbreviated daily patch tests reciprocal multibeam data were collected on a short set of lines at a convenient time each day and processed onboard to confirm system stability. In all cases results of interim roll testing indicated that the respective multibeam poles were stable.

For both vessels the full suite of patch testing, i.e. verification patch testing, was performed at the completion of the project on October 12, 2017 (DN 285). As mentioned above, close out test results were in keeping with the pre-survey results. Patch test results of record are presented in DAPR Appendix II.

For the *R/V Ocean Explorer* pre-survey patch test calibrations were accomplished employing RTK GPS positioning. For the *R/V Osprey* pre-survey patch test calibrations were accomplished employing real-time DGPS positioning but processing of this vessel’s patch test was accomplished employing IAPPK SBET positions. All interim roll check lines were acquired with the POS MV in DGPS mode.

For each full suite patch test, test lines were 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 15) was primarily used to determine offset values. All patch test values were verified with the HYPACK HYSWEEP patch test routine (Figure 16).

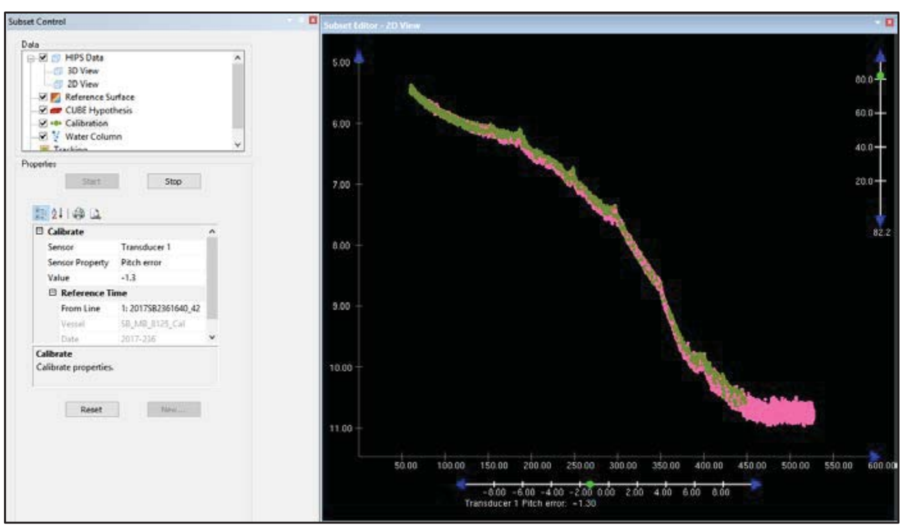


Figure 15. CARIS HIPS Calibration Tool.

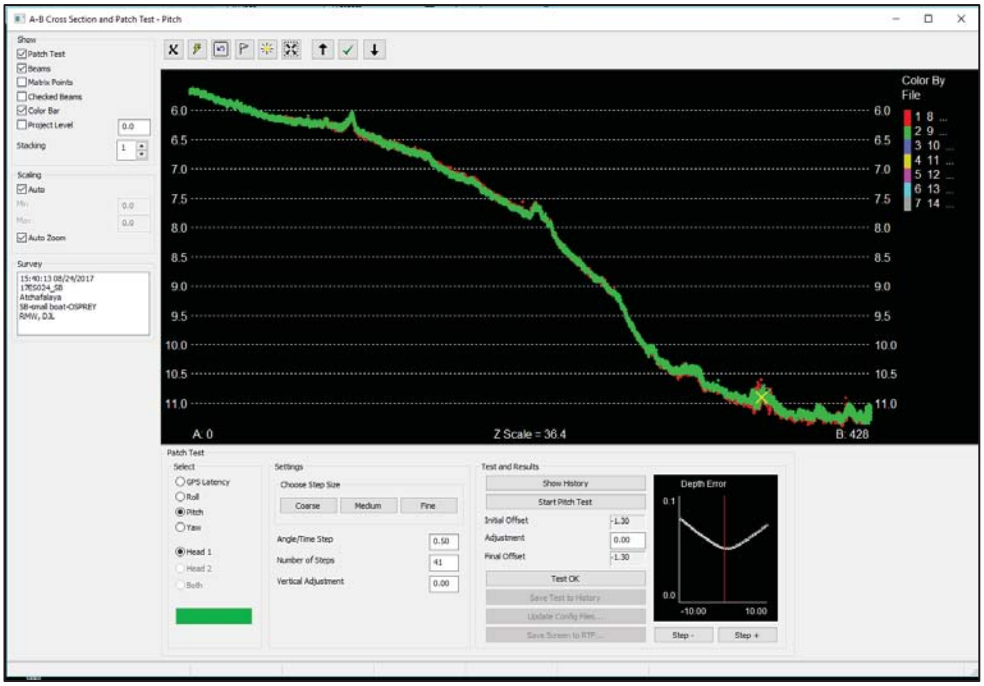


Figure 16. HYPACK HYSWEEP Patch Test Utility.

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 Table 18 and Table 19 respectively. The patch test results were of high quality and repeatability.

The initial performance test of record on the *R/V Ocean Explorer* was performed south of the Freshwater Bayou Canal Lock on August 3, 2017 (DN 215). The initial performance test of record for the *R/V Osprey* was performed in southern Vermillion Bay, LA (Southwest Pass) on August 24, 2017 (DN 236).

Verification performance testing was performed by both vessels at the completion of the project on October 12, 2017 (DN 285). As mentioned above, close out test results were in keeping with the pre-survey results.

In practice a performance surface was created from a high density, near nadir sounding set collected with the Reson 7125 or Reson 8125. For each vessel's surface ten MBES lines were acquired over a relatively 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. Performance test results of record are presented in DAPR Appendix II.

C.3.3 System Alignment Correctors

Table 18
***R/V Ocean Explorer* MBES Patch Test Alignment Correctors**

CARIS Patch Test Results	
Latency	0.00 sec
Pitch	0.00°
Roll	-0.29°
Yaw (heading)	0.32°

Table 19
***R/V Osprey* MBES Patch Test Alignment Correctors**

CARIS Patch Test Results	
Latency	0.00 sec
Pitch	-1.30°
Roll	0.91°
Yaw (heading)	-0.38°

C.4 Positioning and Attitude

C.4.1 Description of Correctors

DGPS correctors received from the USCG are used to improve positioning accuracy as compared to 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 or V.5 was employed for motion, heading, and position determination on the *R/V Ocean Explorer* and *R/V Osprey* respectively. Manufacturer's stated accuracy values, for DGPS mode operation, are tabulated below.

Table 20
POS MV Specifications

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

For each vessel 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 LAWMA, LA (876-4227), 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 NOAA CO-OPS and applied with final zoning for all final soundings and BASE surfaces.

As mentioned previously, preliminary zoning provided by CO-OPS (with the OSI vertex edit) was retained and used as final zoning.

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

Aboard the *R/V Ocean Explorer* the sound speed profiles used to correct the echo soundings were exclusively acquired with an ODIM MVP30 equipped with two sensors: a sensor that measured sound speed directly at a frequency of 10Hz during its descent through the water column and a pressure sensor for profile depth measurement. Due to a mid-project depth sensor failure in the primary MVP sensor package, two sensor packages were employed during the course of the project. The MVP sensors (sound speed and depth) used during mobilization testing, during the initial alignment and settlement testing of record, and during the beginning of the project were manufacturer calibrated July 13, 2017 (DN 194) and July 17, 2017 (DN 198). The MVP sensors that were used toward the end of the project were calibrated on July 26, 2017 (DN 207), July 31, 2017 (DN 212), and August 2, 2017 (DN 214).

On the *R/V Osprey* the sound speed profiles used to correct the echo soundings were exclusively acquired with an AML Oceanographic Base-X profiler. The sound speed and pressure sensors on the Base-X profiler were manufacturer calibrated on July 13, 2017 (DN 194) and July 17, 2017 (DN 198).

Calibration reports are included in DAPR Appendix IV.

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 (2-hour) 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

On the *R/V Ocean Explorer,* surface sound speed correctors were sent directly from the AML Micro-X sensor to the Reson 7125 TPU. On the *R/V Osprey*, a Sea-Bird Electronics SBE-37 supplied the Reson 8125 with surface sound speed correctors. The *R/V Ocean Explorer's* AML Micro-X sound speed sensor was calibrated by the manufacturer on July 13, 2017 (DN 194). The R/V Osprey's SBE-37 sensor was manufacturer calibrated on May 31, 2017 (DN 151).

D. APPROVAL SHEET

LETTER OF APPROVAL

REGISTRY NOS.
H13040, H13041, H13042, AND H13043

This report and the accompanying data are respectfully submitted.

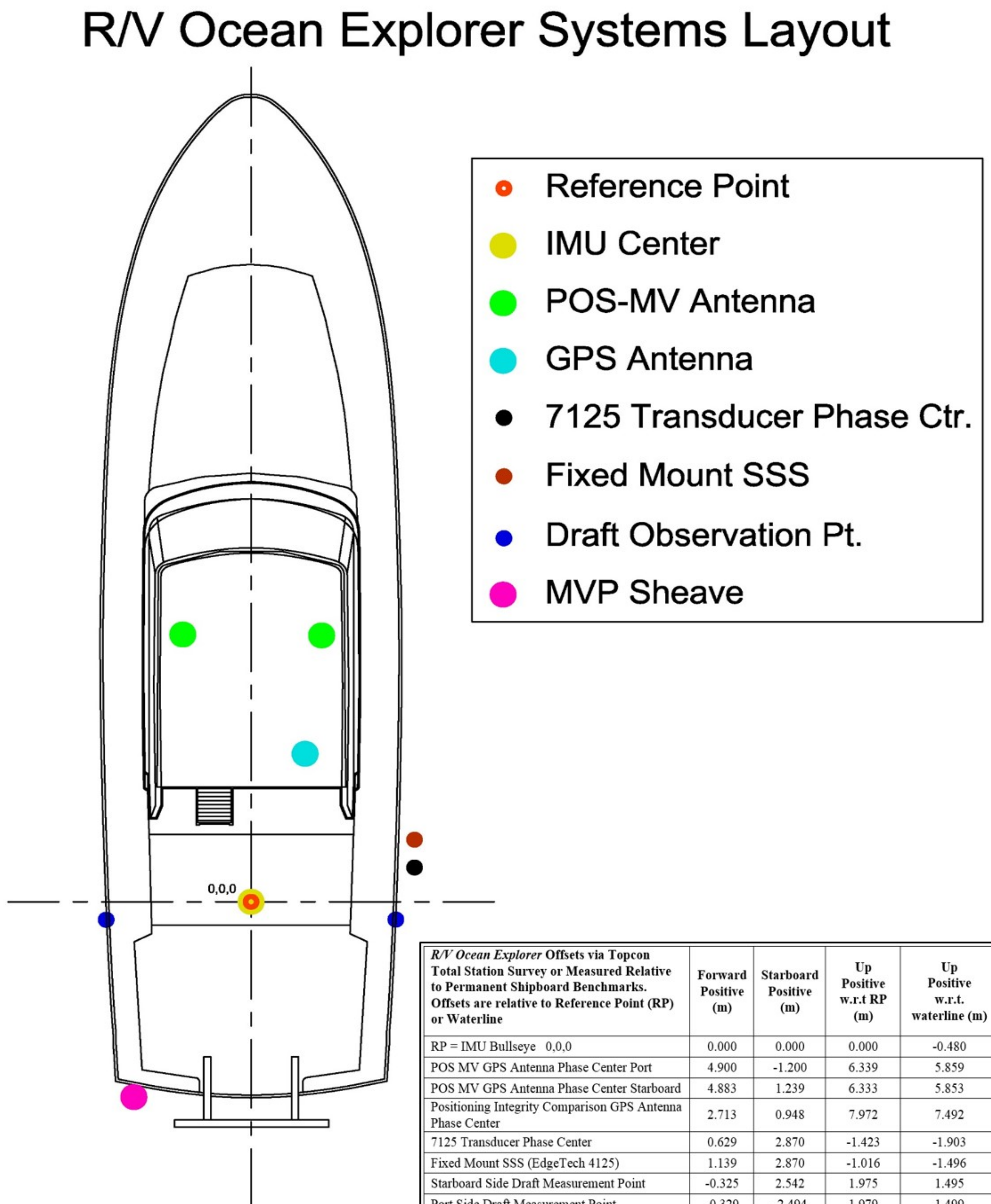
Field operations contributing to the accomplishment of Surveys H13040, H13041, H13042, and H13043 were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and associated data have been closely reviewed and are considered complete and adequate as per the Statement of Work.

Digitally signed by George G. Reynolds
Date: 2018.01.19 10:49:35 -05'00'

George G. Reynolds
Ocean Surveys, Inc.
Chief of Party
January 19, 2018

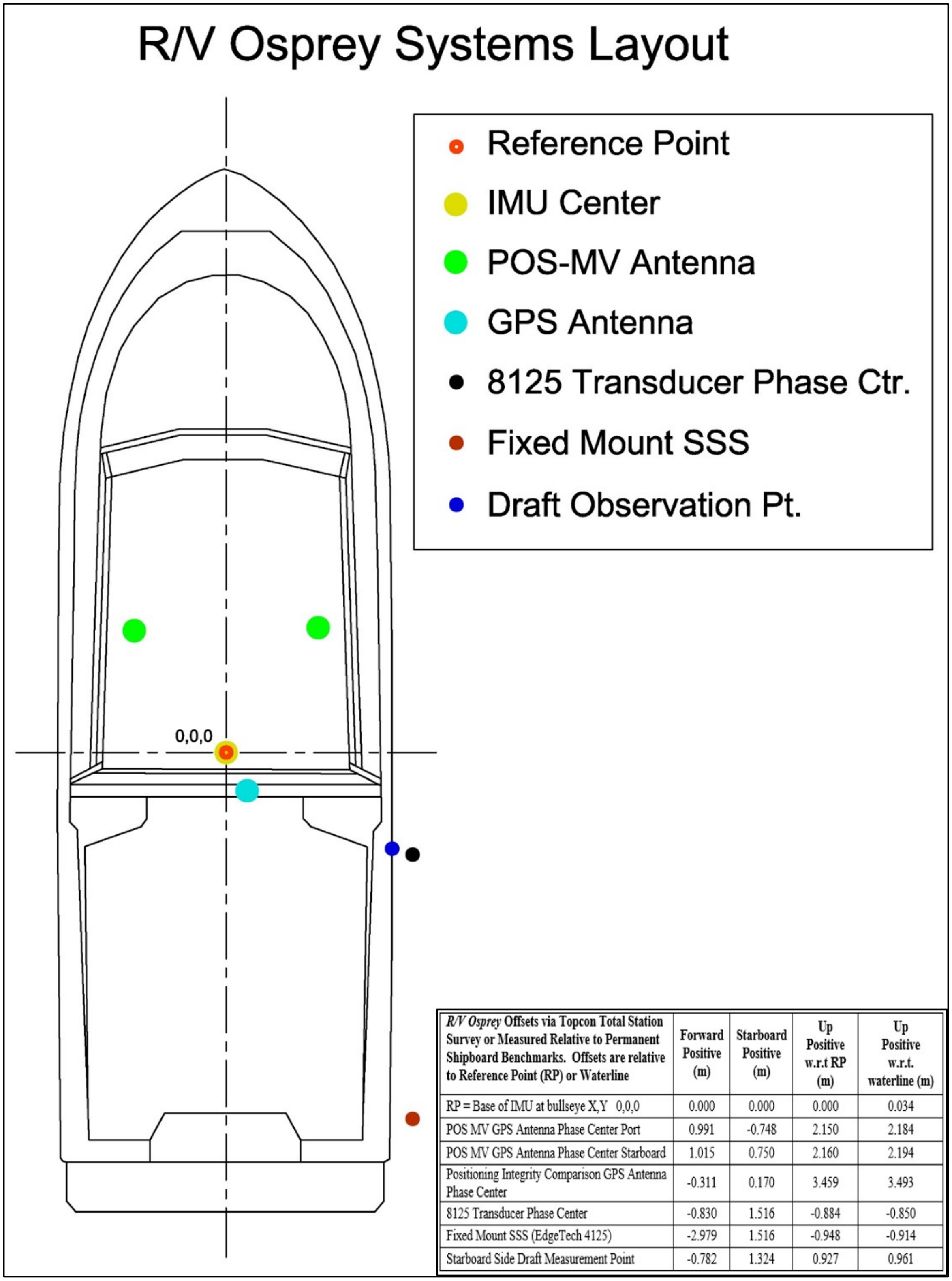
DAPR Appendix I

Vessel Reports



R/V Ocean Explorer 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 Bullseye 0,0,0	0.000	0.000	0.000	-0.480
POS MV GPS Antenna Phase Center Port	4.900	-1.200	6.339	5.859
POS MV GPS Antenna Phase Center Starboard	4.883	1.239	6.333	5.853
Positioning Integrity Comparison GPS Antenna Phase Center	2.713	0.948	7.972	7.492
7125 Transducer Phase Center	0.629	2.870	-1.423	-1.903
Fixed Mount SSS (EdgeTech 4125)	1.139	2.870	-1.016	-1.496
Starboard Side Draft Measurement Point	-0.325	2.542	1.975	1.495
Port Side Draft Measurement Point	-0.329	-2.494	1.979	1.499

Figure 1: *R/V Ocean Explorer* vessel offsets.



R/V Osprey 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 = Base of IMU at bullseye X,Y 0,0,0	0.000	0.000	0.000	0.034
POS MV GPS Antenna Phase Center Port	0.991	-0.748	2.150	2.184
POS MV GPS Antenna Phase Center Starboard	1.015	0.750	2.160	2.194
Positioning Integrity Comparison GPS Antenna Phase Center	-0.311	0.170	3.459	3.493
8125 Transducer Phase Center	-0.830	1.516	-0.884	-0.850
Fixed Mount SSS (EdgeTech 4125)	-2.979	1.516	-0.948	-0.914
Starboard Side Draft Measurement Point	-0.782	1.324	0.927	0.961

Figure 2: *R/V Osprey* vessel offsets.

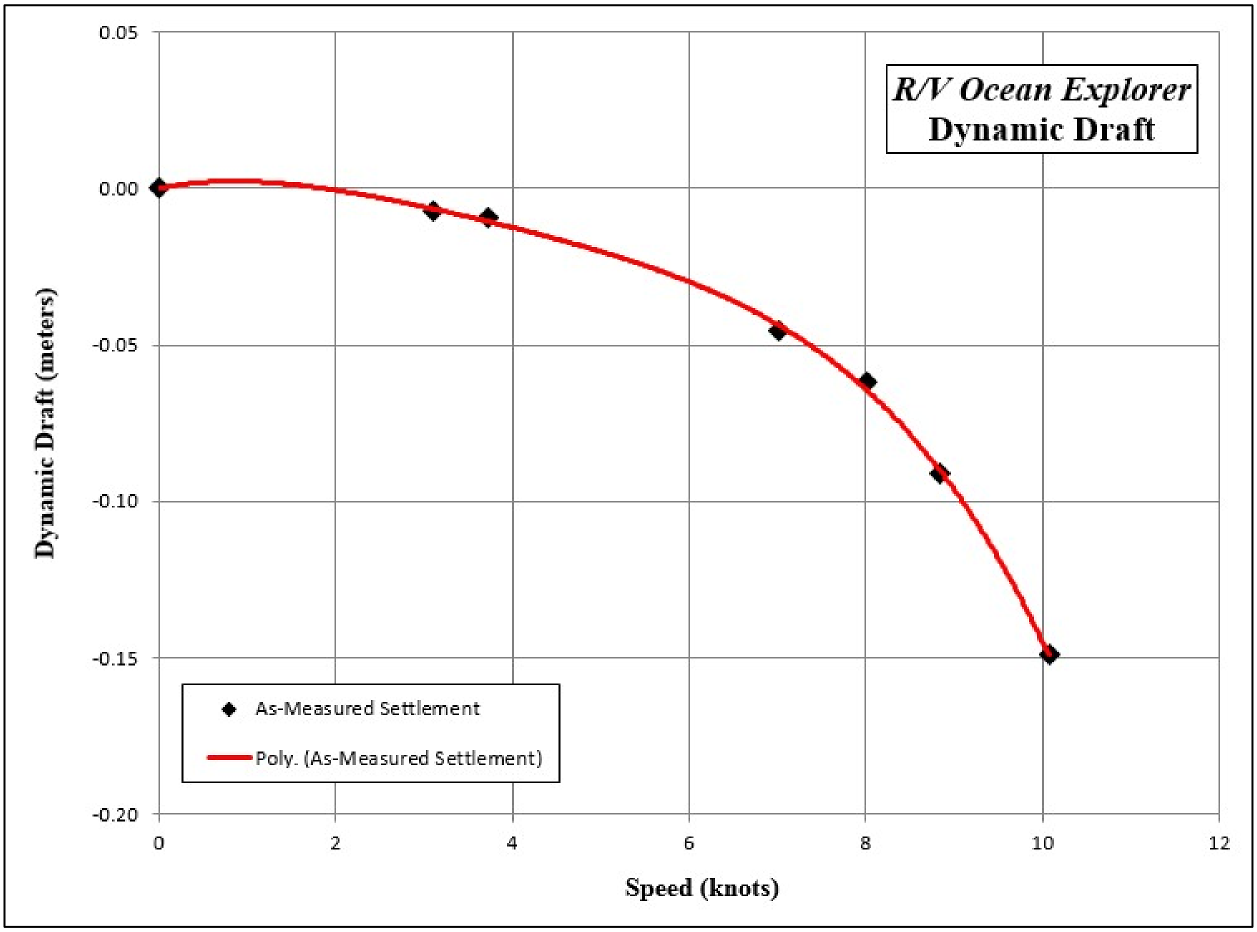


Figure 3. Plot of as-measured dynamic draft values and polynomial curve fit derived from July 19, 2017 (DN 200) Settlement Test.

Table 1
***R/V Ocean Explorer* As-Measured Dynamic Draft Correctors**
Negative value indicates the boat is settling.
CARIS correctors are opposite sign.

RPM Both Engines	Speed		Dynamic Draft Meters
	M/S	Knots	
Static	0	0	0
Troll Setting 1	1.47	2.86	-0.003*
Troll Setting 2	1.60	3.10	-0.007
Troll Setting 3	1.91	3.72	-0.009
Troll Setting 4	2.38	4.63	-0.011
600	3.61	7.02	-0.045
700	4.12	8.01	-0.062
800	4.54	8.84	-0.091
900	5.18	10.07	-0.149

Table 2
***R/V Ocean Explorer* - Polynomial Curve Fit Dynamic Draft Correctors**
As entered into CARIS HVFs

Speed		Dynamic Draft Meters
M/S	Knots	
1.03	2.00	0.001
1.29	2.50	0.003
1.54	3.00	0.006
1.80	3.50	0.009
2.06	4.00	0.013
2.31	4.50	0.016
2.57	5.00	0.020
2.83	5.50	0.025
3.08	6.00	0.030
3.34	6.50	0.036
3.60	7.00	0.044
3.86	7.50	0.053
4.11	8.00	0.065
4.37	8.50	0.079
4.63	9.00	0.097
4.88	9.50	0.119
5.14	10.00	0.146

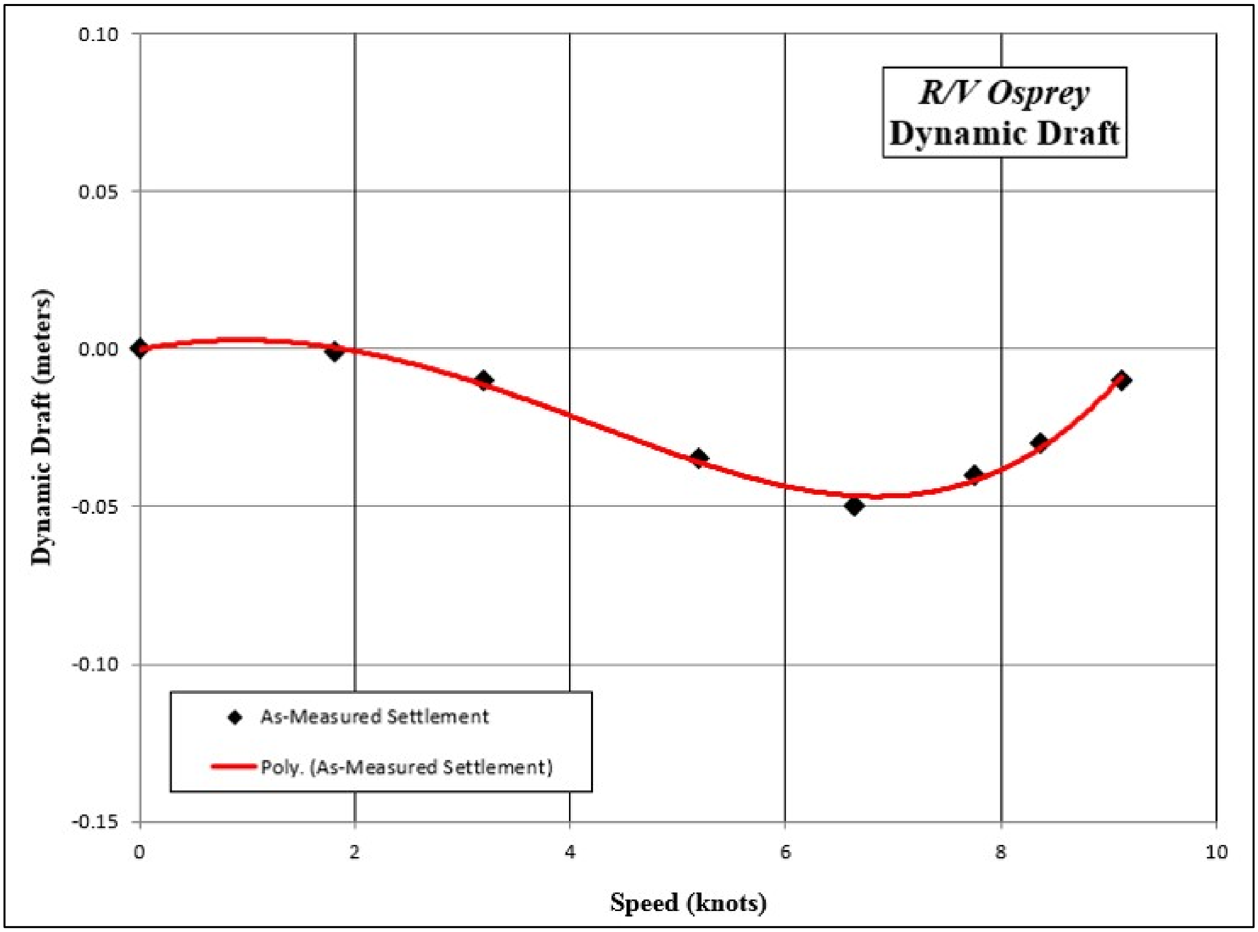


Figure 4. Plot of as-measured dynamic draft values and polynomial curve fit derived from August 18, 2017 (DN 230) Settlement Test.

Table 3
***R/V Osprey* As-Measured Dynamic Draft Correctors**
Negative value indicates the boat is settling.
CARIS correctors are opposite sign.

RPM Both Engines	Speed		Dynamic Draft Meters
	M/S	Knots	
600	0.93	1.82	-0.001
1,000	1.64	3.19	-0.010
1,500	2.67	5.19	-0.035
2,000	3.41	6.64	-0.050
2,500	3.99	7.76	-0.040
3,000	4.30	8.37	-0.030
3,400	4.69	9.12	-0.010

Table 4
***R/V Osprey* - Polynomial Curve Fit Dynamic Draft Correctors**
As entered into CARIS HVFs

Speed		Dynamic Draft Meters
M/S	Knots	
1.03	2.00	0.000
1.29	2.50	0.004
1.54	3.00	0.009
1.80	3.50	0.015
2.06	4.00	0.021
2.31	4.50	0.027
2.57	5.00	0.033
2.83	5.50	0.039
3.08	6.00	0.043
3.34	6.50	0.046
3.60	7.00	0.046
3.86	7.50	0.044
3.98	7.75	0.042
4.11	8.00	0.038
4.24	8.25	0.034
4.37	8.50	0.028
4.50	8.75	0.021
4.63	9.00	0.013
4.75	9.25	0.004

DAPR Appendix II

Echosounder Reports

Table 1

R/V Ocean Explorer
Reson SeaBat 7125 System Accuracy Tests
(Bar Checks - Spot Sounding Checks)
Conducted using Lead Line/Bar Check SN 2010B

Date	Lat, Long	Sounding Systems	Bar Depth (m)	MBES Depth (m)	Spot Depth (m)	MBES Depth (m)	Comments
July 17, 2017 (DN 198)	41 18 02.89 N, 071 59 51.39 W	Lead Line, Reson 7125	3.00 4.00 5.00 6.00 7.00 8.00 9.00	3.00 4.00 5.00 6.00 7.01 8.00 9.00	9.69 8.25	9.74 8.20	Vessel Acceptance Bar Check. Fishers Island Sound, Noank, CT, Calm
Aug 3, 2017 (DN 215)	29 33 46.49 N, 091 13 52.91 W	Lead Line, Reson 7125	3.00 4.00 5.00	3.00 4.00 5.00	6.00	6.05	Freshwater Bayou Channel Safety Fairway, LA, 3 foot swell
Aug 21, 2017 (DN 233)	29 20 01.87 N, 092 02 01.31 W	Lead Line, Reson 7125	3.00 4.00 5.00 6.00	3.00 4.00 5.00 5.99	N/A	N/A	Eastern side of H13040, too choppy for reliable spot check.
Sept 21, 2017 (DN 264)	29 09 06.67 N 091 50 34.90 W	Lead Line, Reson 7125	3.00 4.00 5.00 6.00	3.00 4.00 5.00 6.00	N/A	N/A	Eastern side of H13043, too choppy for reliable spot check.
Oct 12, 2017 (DN 285)	29 23 40.26 N 092 19 19.95 W	Lead Line, Reson 7125	3.00 4.00 5.00 6.00 7.00 8.00	3.00 4.00 5.00 6.00 7.00 8.00	8.47	8.50	West of H13040. Calm.

Table 2

R/V Ocean Explorer
Lead Line Accuracy Confirmation

Lead Line Bar Check Calibration Report - SN 2010B

Field unit: ***R/V Ocean Explorer***

Date of Calibration: July 15, 2017

Method of Calibration: Plastic Beads were adjusted to account for any discrepancies between the graduated marking and the steel tape measurement such that the final lead line graduated marks matched the steel tape.

Location: OSI

Lead Hydrographer: RMW

Lead Line Bar Check Unit of Measure: Meters

Measured by: RMW | **Recorded by: GLS** | **Checked by: JRB**

Graduated Marking (a)	Calibration Measurement (b)	Lead Line Corrector (c = b - a)
1	1.00	0.00
2	2.00	0.00
3	3.00	0.00
4	4.00	0.00
5	5.00	0.00
6	6.00	0.00
7	7.00	0.00
8	8.00	0.00
9	9.00	0.00
10	10.00	0.00
12	12.00	0.00
14	14.00	0.00
16	16.00	0.00
18	17.99	-0.01
20	20.00	0.00
22	22.00	0.00

Table 3

R/V Osprey
Reson SeaBat 8125 System Accuracy Tests
(Bar Checks - Spot Sounding Checks)
Conducted using Lead Line/Bar Check SN OSI 50-2

Date	Lat, Long	Sounding Systems	Bar Depth (m)	MBES Depth (m)	Spot Depth (m)	MBES Depth (m)	Comments
Aug 23, 2017 (DN 235)	29 43 38.64 N, 091 50 44.02 W	Lead Line, Reson 8125	1.50 2.00	1.50 2.00	2.49	2.49	Quintana Canal, Cypremort Point, LA Calm
Sept 6, 2017 (DN 249)	29 42 44.64 N, 091 52 47.72 W	Lead Line, Reson 8125	1.50 2.00 3.00	1.50 2.00 3.00	2.07	2.07	Vermillion Bay, Cypremort Point, LA, Calm at check location
Sept 29, 2017 (DN 272)	29 42 43.36 N, 091 52 57.44 W	Lead Line, Reson 8125	1.50 2.00 3.00	1.50 2.00 3.00	3.33	3.32	Vermillion Bay, Cypremort Point, LA, Calm at check location
Oct 12, 2017 (DN 285)	29 37 06.96 N 091 59 46.23 W	Lead Line, Reson 8125	1.50 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00	1.50 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00	11.60	11.59	Vermillion Bay, Southwest Pass, LA, Calm

Table 4

R/V Osprey
Lead Line Accuracy Confirmation

Lead Line Bar Check Calibration Report - SN OSI 50-2

Field unit: ***R/V Osprey***

Date of Calibration: July 20, 2017

Method of Calibration: This bar check was built and calibrated immediately prior to mobilization of the survey. Depth bead placement was accomplished using a steel tape measure.

Location: OSI

Lead Hydrographer: RMW

Lead Line Bar Check Unit of Measure: Meters

Measured by: RMW	Recorded by: GLS	Checked by: JRB
Graduated Marking (a)	**Calibration Measurement (b)**	**Lead Line Corrector (c = b - a)**
1	1.00	0.00
1.5	1.50	0.00
2	2.00	0.00
3	3.00	0.00
4	4.00	0.00
5	5.00	0.00
6	6.00	0.00
7	7.00	0.00
8	8.00	0.00
9	9.00	0.00
10	10.00	0.00
11	11.00	0.00
12	12.00	0.00
13	13.00	0.00
14	14.99	0.00
15	15.00	0.00

Table 5

R/V Ocean Explorer
Reson Seabat 7125 Pre-Survey Patch Test Results

TEST INFORMATION
Test Date(s) / DN(s): July 17, 20176 (DN 198)
Wind / Seas: S ~10 knots; seas calm
Locality: Noank, CT **Sub-Locality:** Fishers Island Sound **Bottom Type:** mud (assumed based on chart notation) **Approximate Water Depth:** ~21 meters average
TEST RESULTS
Navigation Timing Error: 0.0 seconds **Pitch Timing Error:** 0.0 seconds **Roll Timing Error:** 0.0 seconds **Pitch Bias:** 0.00 degrees **Roll Bias:** -0.29 degrees **Heading Bias:** 0.32 degrees **Resulting CARIS HIPS HVF File Names:** OE_MB_7125_Main.hvf, OE_MB_7125_Inv.hvf, OE_MB_7125_XL.hvf, OE_MB_7125_Cal.hvf

Table 6
R/V Ocean Explorer
EdgeTech 4125 Target Positioning Accuracy Confirmation (Fixed Mount Configuration)

TEST INFORMATION
Test Date(s) / DN(s): July 17, 2017 (DN 198)
Wind / Seas: S ~10 knots; seas calm
Locality: Noank, CT
Sub-Locality: Fishers Island Sound
Description of Bathymetry: generally flat, clean bottom with discrete boulders
Bottom Type: soft with boulders
Approximate Water Depth: 11 meters
Description of Target: discrete feature (boulder)
Target Position: 4,576,786.8 N, 750,662.0 E (UTM 18N, NAD83, Meters)
Description of Positioning Method: RTK-GPS and HYPACK Genoffset.DLL
Approximate Survey Speed: 7 knots
Approximate Towfish Altitude: 10 meters
TEST RESULTS
Number of Passes on Target: six (6) **Successful Target Detections:** six (6) **Mean Detected Position:** 4,576,787.2 N, 750,661.4 E **Distance from Mean Position to True Position:** 0.7 meters **Estimated Target Position Error:** 0.48 meter* **Approximate 95% Confidence Radius:** 1.9 meters**

*Calculated from the standard deviation of differences between individual SSS detected positions (using the 50-meter range scale) and the MBES defined position of the discrete feature.

**Per guidance in the FPM, results were obtained by measuring the error for each detection (the distance from the absolute target position to the detected position) and computing the sample mean and standard deviation of the errors. The approximate 95% Confidence Radius is then the sample mean plus 1.96 times the standard deviation.

Table 7

R/V Osprey
Reson Seabat 8125 Pre-Survey Patch Test Results

TEST INFORMATION
Test Date(s) / DN(s): August 24, 2017 (DN 236)
Wind / Seas: ENE ~20 knots; seas relatively calm in lee of Marsh Island
Locality: Vermillion Bay, LA **Sub-Locality:** Southwest Pass **Bottom Type:** sandy mud (assumed) **Approximate Water Depth:** ~8 meters average
TEST RESULTS
Navigation Timing Error: 0.0 seconds **Pitch Timing Error:** 0.0 seconds **Roll Timing Error:** 0.0 seconds **Pitch Bias:** -1.30 degrees **Roll Bias:** 0.91 degrees **Heading Bias:** -0.38 degrees **Resulting CARIS HIPS HVF File Names:** SB_MB_8125_Main.hvf, SB_MB_8125_Inv.hvf, SB_MB_8125_XL.hvf, SB_MB_8125_Cal.hvf

Table 8
R/V Osprey
EdgeTech 4125 Target Positioning Accuracy Confirmation (Fixed Mount Configuration)

TEST INFORMATION
Test Date(s) / DN(s): August 24, 2017 (DN 236)
Wind / Seas: ENE ~20 knots; seas calm in lee of Marsh Island
Locality: Vermillion Bay, LA
Sub-Locality: Southwest Pass
Description of Bathymetry: shallow side of steep channel edge
Bottom Type: sandy mud (assumed)
Approximate Water Depth: 5 meters
Description of Target: discrete feature (navigation day shape piling)
Target Position: 3,275,631.1 N, 595,966.7 E (UTM 15N, NAD83, Meters)
Description of Positioning Method: DGPS and HYPACK Genoffset.DLL
Approximate Survey Speed: 5 knots
Approximate Towfish Altitude: 8-10 meters (boat is in deeper water than target
TEST RESULTS
Number of Passes on Target: six (6) **Successful Target Detections:** six (6) **Mean Detected Position:** 3,275,630.6 N, 595,966.9 E **Distance from Mean Position to True Position:** 0.5 meters **Estimated Target Position Error:** 0.31 meter* **Approximate 95% Confidence Radius:** 1.4 meters**

*Calculated from the standard deviation of differences between individual SSS detected positions (using the 50-meter range scale) and the MBES defined position of the discrete feature.

**Per guidance in the FPM, results were obtained by measuring the error for each detection (the distance from the absolute target position to the detected position) and computing the sample mean and standard deviation of the errors. The approximate 95% Confidence Radius is then the sample mean plus 1.96 times the standard deviation.

Table 9

R/V Ocean Explorer

Performance Surface Test Results

Performance Test	Reson 7125 August 4, 2017 DN 216
*	-0.008 to 0.048 meters
**	0.008 to 0.025 meters
IHO Special Order	100 %
IHO Order 1a	100 %

Table 10

R/V Osprey

Performance Surface Test Results

Performance Test	Reson 8125 August 24, 2016 DN 236
*	-0.056 to -0.003 meters
**	0.022 to 0.047 meters
IHO Special Order	100 %
IHO Order 1a	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
***R/V Ocean Explorer* Tabulation of Navigation System Performance Checks**

Coordinates are referenced to UTM 15N - NAD 83, meters. Navigation checks are made relative to a temporary control point established at the vessel's base of operation in Intracoastal City, LA. The coordinates of the temporary points were established via NGS-OPUS processing. The precise OPUS solution follows.

- SMIC-01 Dock Piling Nail – E 581,615.52, N 3,295,068.34

Date	Time UTC	Nav. Check-point	DGPS Beacon	Observed Easting UTM 15N, NAD83 (meters)	Observed Northing UTM 15N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
08/03/17 (DN 215)	13:54	SMIC Nail	English Turn, LA	581,622.2	3,295,069.0	6.7	7.2	0.5
08/03/17 (DN 215)	14:00	SMIC Nail	Angleton TX	581,623.3	3,295,070.1	7.9	7.2	0.7
08/04/17 (DN 216)	5:45	SMIC Nail	English Turn, LA	581,624.9	3,295,069.9	9.5	8.9	0.6
08/10/17 (DN 222)	5:22	SMIC Nail	English Turn, LA	581,623.1	3,295,068.1	7.6	8.5	0.9
08/16/17 (DN 228)	8:12	SMIC Nail	English Turn, LA	581,625.0	3,295,067.1	9.5	9.1	0.5
08/22/17 (DN 234)	10:22	SMIC Nail	English Turn, LA	581,624.1	3,295,066.6	8.7	8.8	0.1
09/01/17 (DN 244)	0:44	SMIC Nail	English Turn, LA	581,622.4	3,295,068.2	6.9	7.8	0.9
09/11/17 (DN 254)	21:11	SMIC Nail	English Turn, LA	581,623.9	3,295,066.9	8.4	8.9	0.5
09/25/17 (DN 268)	2:56	SMIC Nail	English Turn, LA	581,624.3	3,295,065.5	9.3	9.7	0.4
10/10/17 (DN 283)	9:46	SMIC Nail	English Turn, LA	581,624.0	3,295,066.5	8.7	9.3	0.7

Table 2
***R/V Osprey* Tabulation of Navigation System Performance Checks**

Coordinates are referenced to UTM 15N - NAD 83, meters. Navigation checks are made relative to a temporary control point established at the vessel's base of operation in Cypremort Point, LA. The coordinates of the temporary points were established via NGS-OPUS processing. The precise OPUS solution follows.

- CP-01 Dock Piling Nail – E 611,648.92, N 3,289,143.20

Date	Time UTC	Nav. Check-point	DGPS Beacon	Observed Easting UTM 15N, NAD83 (meters)	Observed Northing UTM 15N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
08/24/17 (DN 226)	7:42	CP Nail	English Turn, LA	611647.3	3289135.4	8.0	6.8	1.2
08/24/17 (DN 236)	23:16	CP Nail	English Turn, LA	611651.0	3289135.9	7.6	6.8	0.8
09/01/17 (DN 244)	12:16	CP Nail	English Turn, LA	611647.6	3289135.8	7.5	6.8	0.7
09/02/17 (DN 245)	11:57	CP Nail	English Turn, LA	611649.9	3289137.0	6.3	6.8	0.5
09/03/17 (DN 246)	11:58	CP Nail	English Turn, LA	611649.4	3289136.3	6.9	6.8	0.1
09/04/17 (DN 247)	12:03	CP Nail	English Turn, LA	611648.3	3289136.6	6.6	6.8	0.2
09/05/17 (DN 248)	12:03	CP Nail	English Turn, LA	611648.5	3289135.9	7.3	6.8	0.5
09/06/17 (DN 249)	12:08	CP Nail	English Turn, LA	611647.6	3289135.8	7.5	6.8	0.7
09/08/17 (DN 251)	12:03	CP Nail	English Turn, LA	611646.3	3289137.4	6.4	6.8	0.4
09/09/17 (DN 252)	12:05	CP Nail	English Turn, LA	611649.1	3289135.7	7.5	6.8	0.7
09/11/17 (DN 254)	16:56	CP Nail	English Turn, LA	611650.5	3289136.0	7.4	6.8	0.6
09/12/17 (DN 255)	12:03	CP Nail	English Turn, LA	611647.8	3289135.8	7.5	6.8	0.7

Date	Time UTC	Nav. Check-point	DGPS Beacon	Observed Easting UTM 15N, NAD83 (meters)	Observed Northing UTM 15N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
09/13/17 (DN 256)	10:14	CP Nail	English Turn, LA	611648.2	3289136.6	6.6	6.8	0.2
09/14/17 (DN 257)	12:08	CP Nail	English Turn, LA	611646.4	3289137.2	6.6	6.8	0.2
09/15/17 (DN 258)	12:07	CP Nail	English Turn, LA	611647.7	3289136.1	7.3	6.8	0.5
09/16/17 (DN 259)	12:12	CP Nail	English Turn, LA	611648.4	3289136.9	6.3	6.8	0.5
09/17/17 (DN 260)	12:08	CP Nail	English Turn, LA	611648.9	3289137.0	6.2	6.8	0.6
09/18/17 (DN 261)	12:09	CP Nail	English Turn, LA	611650.2	3289136.6	6.7	6.8	0.1
09/19/17 (DN 262)	12:12	CP Nail	English Turn, LA	611648.2	3289136.4	6.9	6.8	0.1
09/20/17 (DN 263)	12:06	CP Nail	English Turn, LA	611648.3	3289136.9	6.4	6.8	0.4
09/21/17 (DN 264)	12:03	CP Nail	English Turn, LA	611648.9	3289136.9	6.3	6.8	0.5
09/22/17 (DN 265)	12:32	CP Nail	English Turn, LA	611647.3	3289136.9	6.6	6.8	0.2
09/23/17 (DN 266)	12:22	CP Nail	English Turn, LA	611648.5	3289136.3	6.9	6.8	0.1
09/26/17 (DN 269)	12:00	CP Nail	English Turn, LA	611649.0	3289136.3	6.9	6.8	0.1
09/27/17 (DN 270)	12:05	CP Nail	English Turn, LA	611649.6	3289136.6	6.6	6.8	0.2
09/28/17 (DN 271)	12:17	CP Nail	English Turn, LA	611648.8	3289136.8	6.4	6.8	0.4
09/29/17 (DN 272)	12:12	CP Nail	English Turn, LA	611647.4	3289136.7	6.7	6.8	0.1
10/10/17 (DN 283)	12:00	CP Nail	English Turn, LA	611649.0	3289136.3	6.9	6.8	0.1
10/11/17 (DN 284)	12:05	CP Nail	English Turn, LA	611649.6	3289136.6	6.6	6.8	0.2

Date	Time UTC	Nav. Check-point	DGPS Beacon	Observed Easting UTM 15N, NAD83 (meters)	Observed Northing UTM 15N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
10/12/17 (DN 285)	12:17	CP Nail	English Turn, LA	611648.8	3289136.8	6.4	6.8	0.4
10/12/17 (DN 285)	12:12	CP Nail	English Turn, LA	611647.4	3289136.7	6.7	6.8	0.1

R/V Ocean Explorer
POS/MV GAMS Calibration Report
7-17-2017 (DN 198)

POS/MV Calibration Report

Field Unit: Ocean Explorer

SYSTEM INFORMATION

Vessel: Ocean Explorer

Date: 7/17/2017 **Dn:** 198

Personnel: RMW, JRB

PCS Serial # 3352

IP Address: 11.69.10.5

POS controller Version (Use Menu Help > About) 7.92

POS Version (Use Menu View > Statistics) MV 320 ver 4

GPS Receivers

Primary Receiver SN: 4834K32758

Secondary Receiver SN: 4384K32790

CALIBRATION AREA

Location: Noank, CT

Approximate Position:

	D	M	S
Lat	41	19	17
Lon	71	59	31

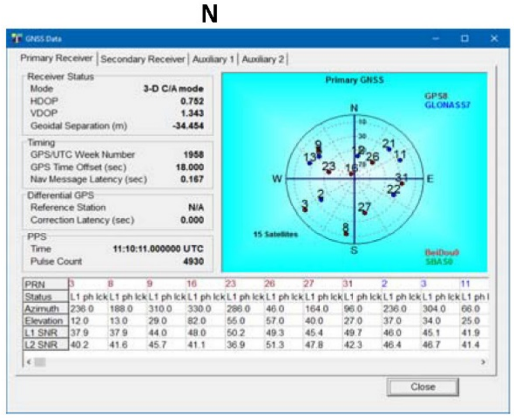
DGPS Beacon Station: (Used RTK)

Frequency: 293

Satellite Constellation (Use View> GPS Data)

Primary GPS (Port Antenna)

N



HDOP: 0.752

VDOP: 1.343

Sattelites in Use: 15

2,5,6,9,12,19,25,29,4,5,6,19,20,21

PDOP 2.120 (Use View> GAMS Solution)

Note: Secondary GPS satellite constellation and number of satellites were exactly the same as the Primary GPS

POS/MV CONFIGURATION

Settings

Gams Parameter Setup (Use Settings > Installation > GAMS Intallation)

User Entries, Pre-Calibration		Baseline Vector	
2.421	Two Antenna Separation (m)	**0.014**	X Component (m)
0.50	Heading Calibration Threshold	**-2.421**	YComponent (m)
0	Heading Correction	**-0.019**	Z Component (m)

Configuration Notes:

POS/MV CALIBRATION

Calibration Procedure:

(Refer to POS MV V3 Installation and Operation Guide, 4-25)

Start time: 11:08

End time: 11:28

Heading accuracy achieved for calibration: 0.017

Calibration Results:

Gams Parameter Setup (Use Settings > Installation > GAMS Intallation)

POS/MV Post-Calibration Values		Baseline Vector	
2.421	Two Antenna Separation (m)	**0.009**	X Component (m)
0.500	Heading Calibration Threshold	**-2.421**	YComponent (m)
0.000	Heading Correction	**-0.027**	Z Component (m)

GAMS Status Online? X

Save Settings? X

Calibration Notes:

Save POS Settings on PC (Use File > Store POS Settings on PC)

File Name: OE_07172017_postcal.nvm

R/V Osprey
POS/MV GAMS Calibration Report
8-23-2017 (DN 235)

POS/MV Calibration Report

Field Unit: Ocean Surveys

SYSTEM INFORMATION

Vessel: Osprey

Date: 8/23/2017 **Dn:** 235

Personnel: RMW, DJL

PCS Serial # 6415

IP Address: 11.69.10.6

POS controller Version (Use Menu Help > About) 7.92

POS Version (Use Menu View > Statistics) MV 320 ver 5

GPS Receivers

Primary Receiver BD982, SN: 5403C86282

Secondary Receiver BD 982, SN unknown

CALIBRATION AREA

Location: Cypremort Point, LA

Approximate Position:

	D	M	S
Lat	29	43	38
Lon	91	50	44

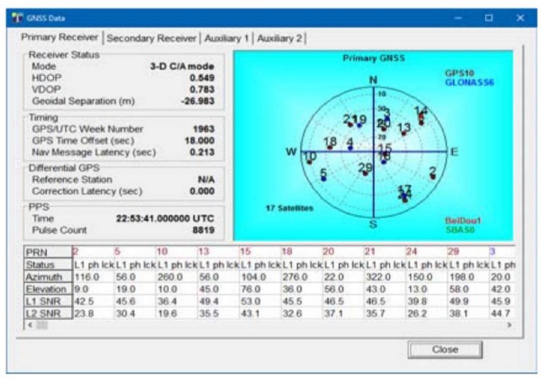
DGPS Beacon Station: English Turn, LA

Frequency: 293

Satellite Constellation

Primary GPS (Port Antenna) (Use View> GPS Data)

N



HDOP: 0.549

VDOP: 0.785

Sattelites in Use: 17

2,5,10,13,15,18,20,21,24,29,3,4,5,17,18,19,14

PDOP 1.479 (Use View> GAMS Solution)

Note: Secondary GPS satellite constellation and number of satellites were exactly the same as the Primary GPS

POS/MV CONFIGURATION

Settings

Gams Parameter Setup (Use Settings > Installation > GAMS Intallation)

User Entries, Pre-Calibration		Baseline Vector	
1.499	Two Antenna Separation (m)	**0.01**	X Component (m)
0.50	Heading Calibration Threshold	**-1.499**	YComponent (m)
0	Heading Correction	**-0.028**	Z Component (m)

Configuration Notes:

POS/MV CALIBRATION

Calibration Procedure:

(Refer to POS MV V3 Installation and Operation Guide, 4-25)

Start time: 22:55

End time: 22:58

Heading accuracy achieved for calibration: 0.023

Calibration Results:

Gams Parameter Setup (Use Settings > Installation > GAMS Intallation)

POS/MV Post-Calibration Values		Baseline Vector	
1.504	Two Antenna Separation (m)	**0.006**	X Component (m)
0.50	Heading Calibration Threshold	**-1.504**	YComponent (m)
0	Heading Correction	**-0.021**	Z Component (m)

GAMS Status Online? X

Save Settings? X

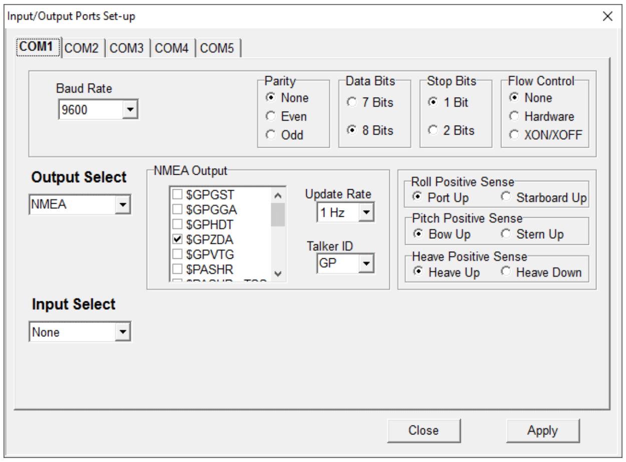
Calibration Notes:

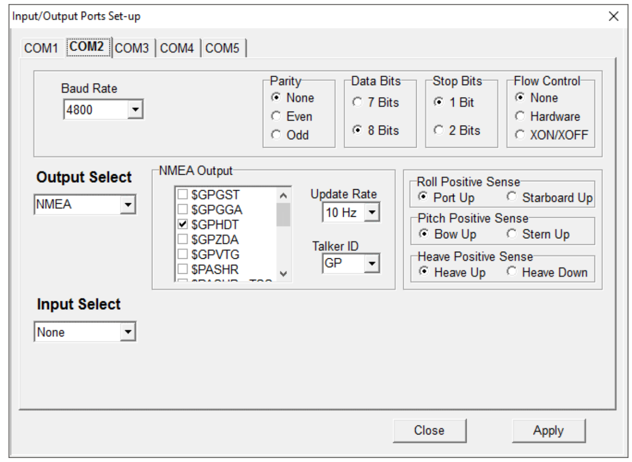
Save POS Settings on PC (Use File > Store POS Settings on PC)

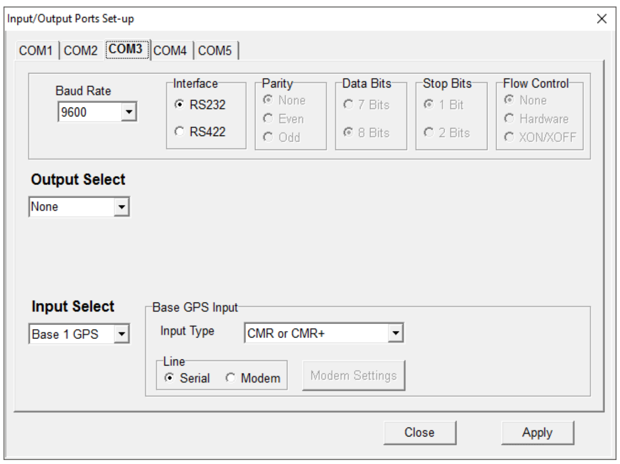
File Name: Osprey_Post-GAMS-cal_08232017.nvm

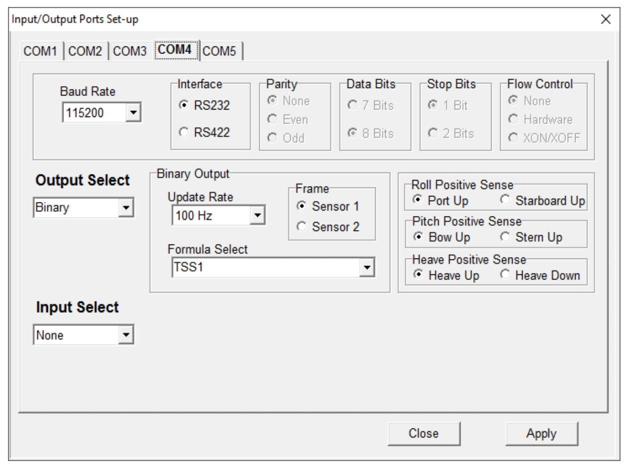
R/V Ocean Explorer

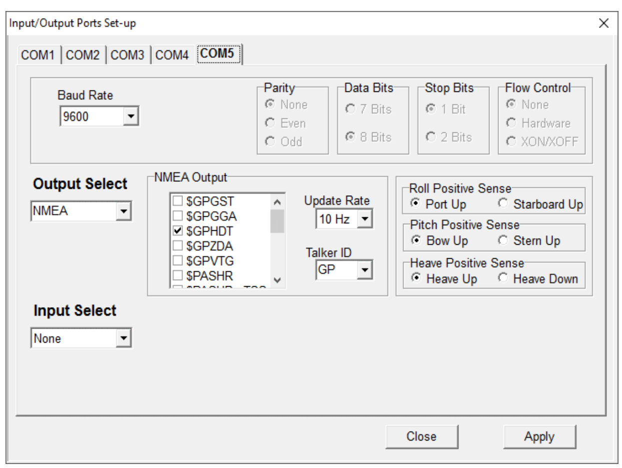
POS/MV Settings and Configuration

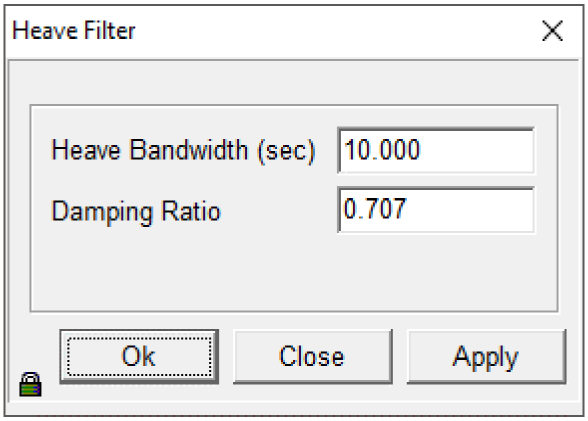


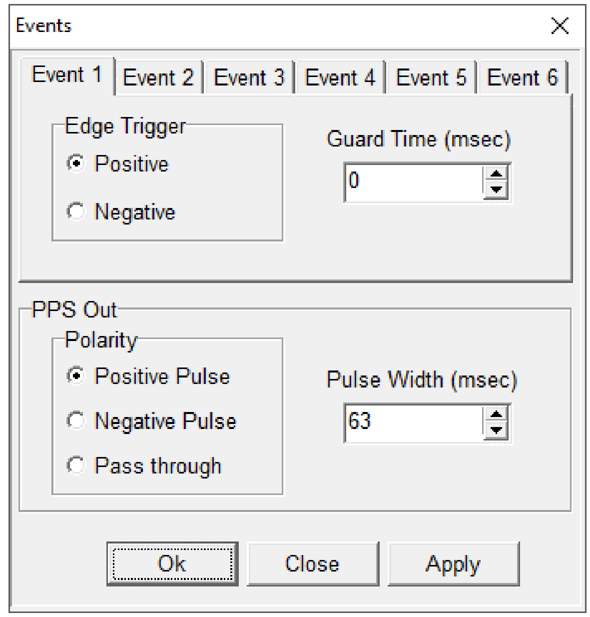


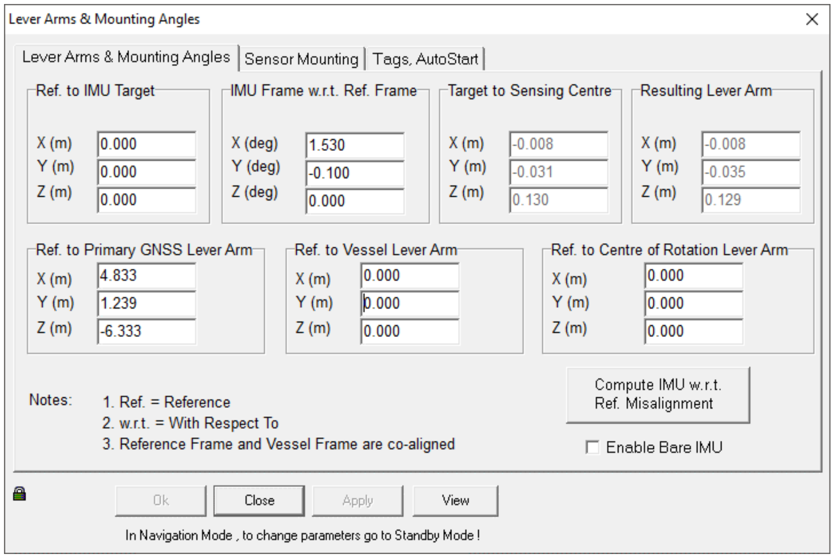




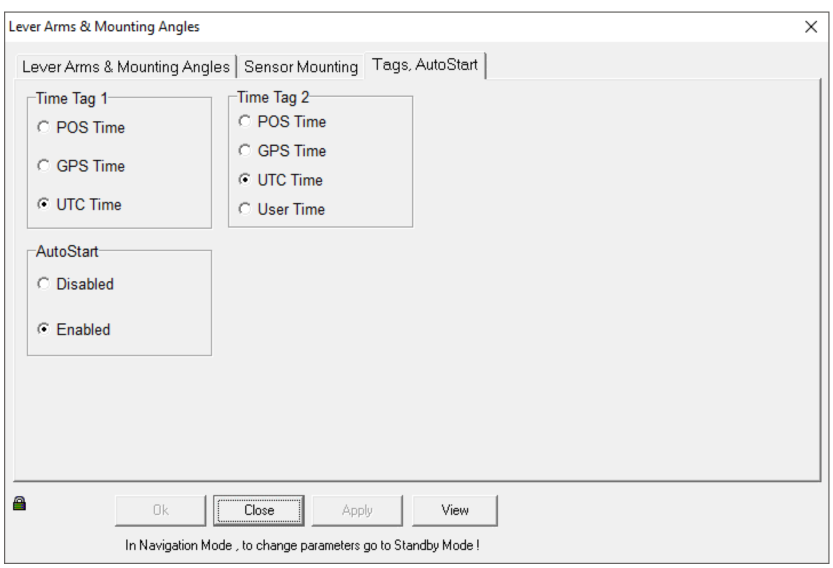


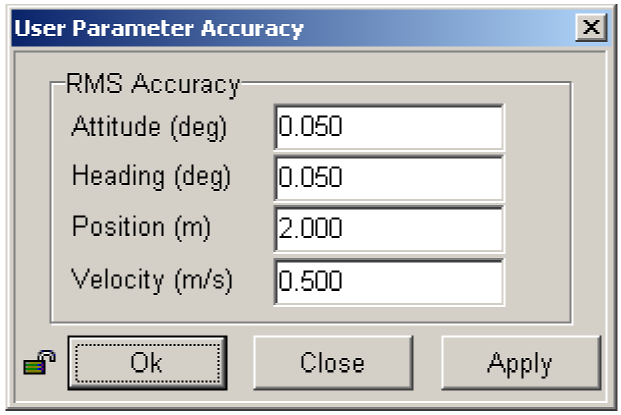

Heave Filter
Heave Bandwidth (sec)
10.000
Damping Ratio
0.707
Ok
Close
Apply

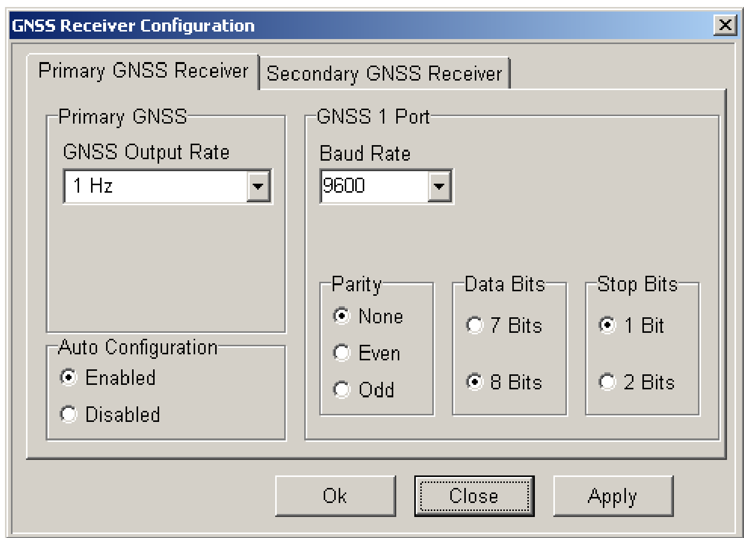

Events
Event 1
Event 2
Event 3
Event 4
Event 5
Event 6
Edge Trigger
Positive
Negative
Guard Time (msec)
0
PPS Out
Polarity
Positive Pulse
Negative Pulse
Pass through
Pulse Width (msec)
63
Ok
Close
Apply

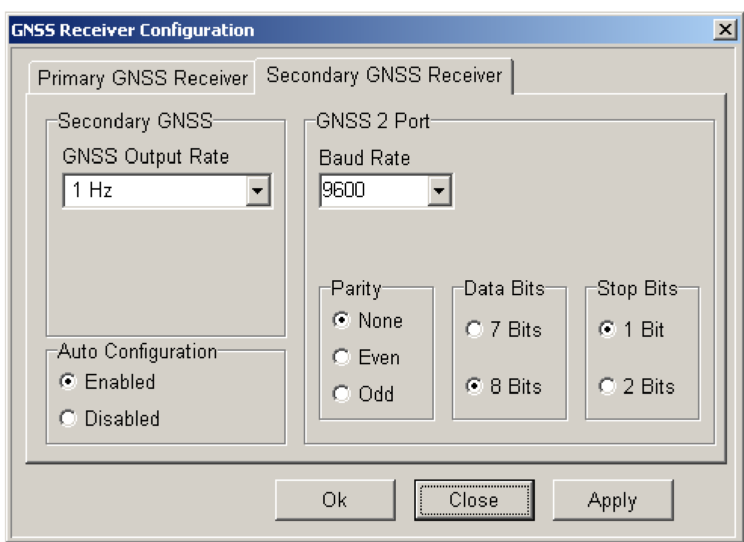

Lever Arms & Mounting Angles
Lever Arms & Mounting Angles
Sensor Mounting
Tags, AutoStart
Ref. to IMU Target
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
IMU Frame w.r.t. Ref. Frame
X (deg) 1.530
Y (deg) -0.100
Z (deg) 0.000
Target to Sensing Centre
X (m) -0.008
Y (m) -0.031
Z (m) 0.130
Resulting Lever Arm
X (m) -0.008
Y (m) -0.035
Z (m) 0.129
Ref. to Primary GNSS Lever Arm
X (m) 4.833
Y (m) 1.239
Z (m) -6.333
Ref. to Vessel Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Ref. to Centre of Rotation Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Compute IMU w.r.t. Ref. Misalignment
Notes:
1. Ref. = Reference
2. w.r.t. = With Respect To
3. Reference Frame and Vessel Frame are co-aligned
Enable Bare IMU
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, AutoStart
Ref. to Aux. 1 GNSS Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Ref. to Aux. 2 GNSS 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, AutoStart
Time Tag 1
POS Time
GPS Time
UTC Time
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 !

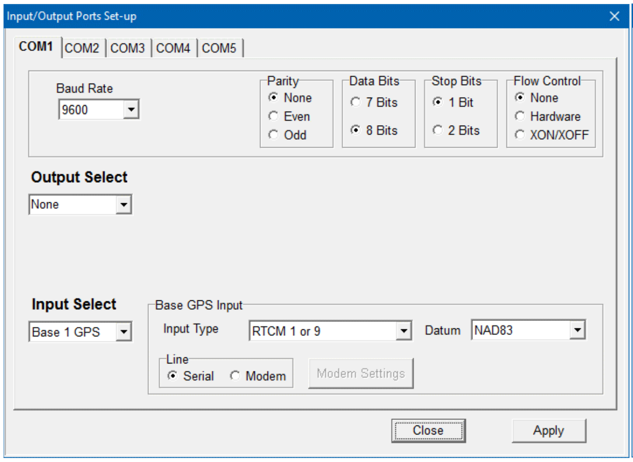

User Parameter Accuracy
RMS Accuracy
Attitude (deg)
0.050
Heading (deg)
0.050
Position (m)
2.000
Velocity (m/s)
0.500
Ok
Close
Apply

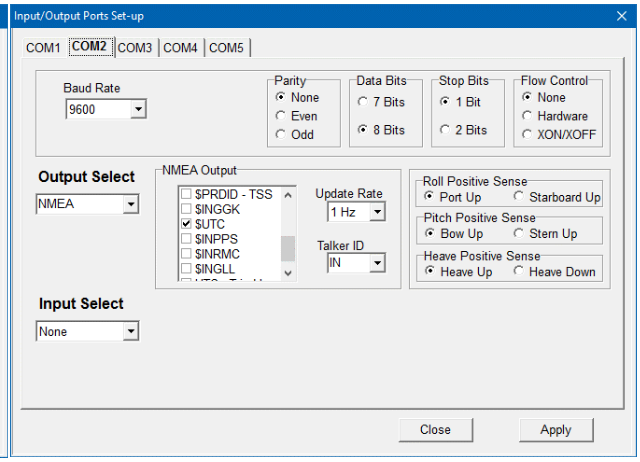

GNSS Receiver Configuration
Primary GNSS Receiver
Secondary GNSS Receiver
Primary GNSS
GNSS Output Rate
1 Hz
GNSS 1 Port
Baud Rate
9600
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Auto Configuration
Enabled
Disabled
Ok
Close
Apply

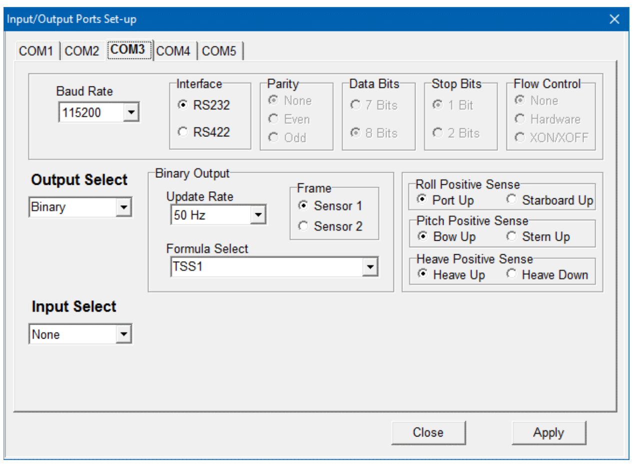

GNSS Receiver Configuration
Primary GNSS Receiver
Secondary GNSS Receiver
Secondary GNSS
GNSS Output Rate
1 Hz
GNSS 2 Port
Baud Rate
9600
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Auto Configuration
Enabled
Disabled
Ok
Close
Apply

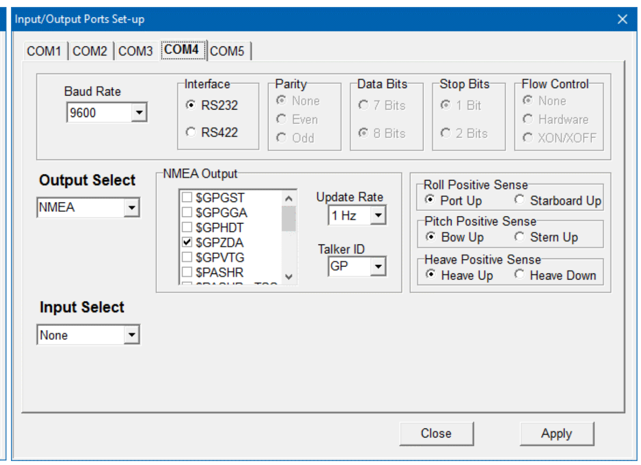
R/V Osprey

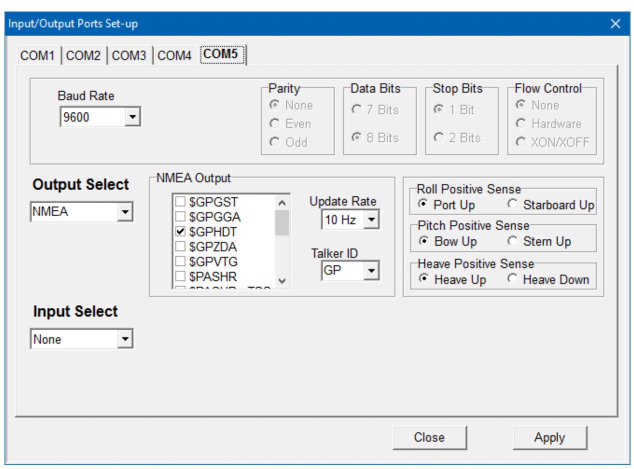
POS/MV Settings and Configuration

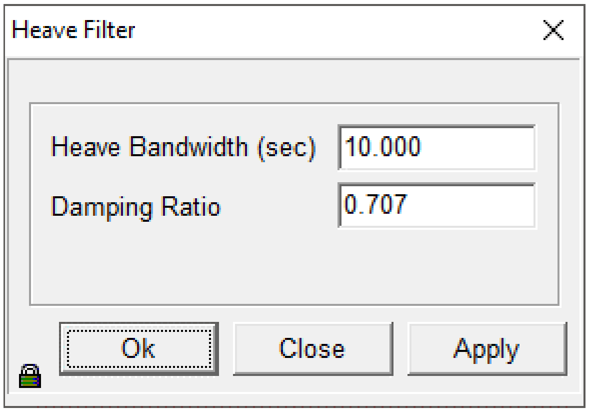


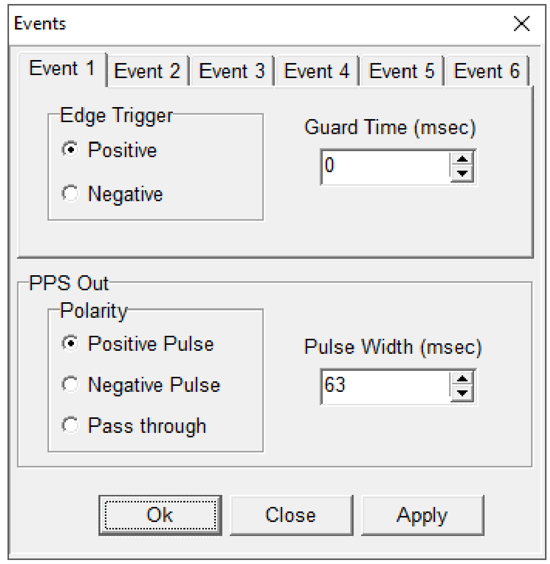


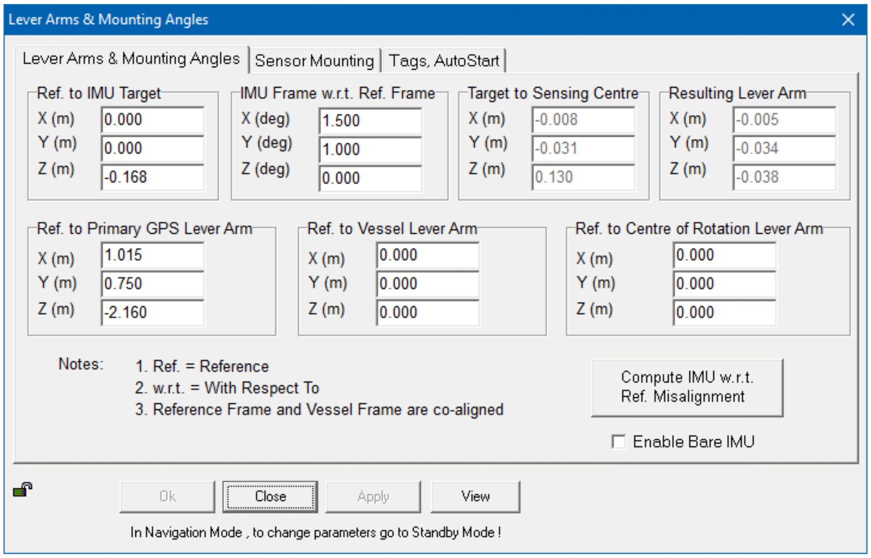




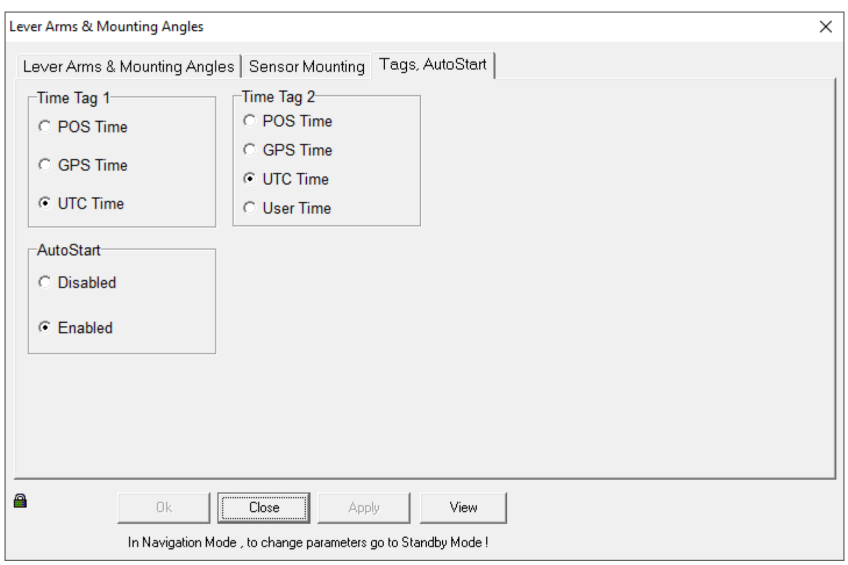


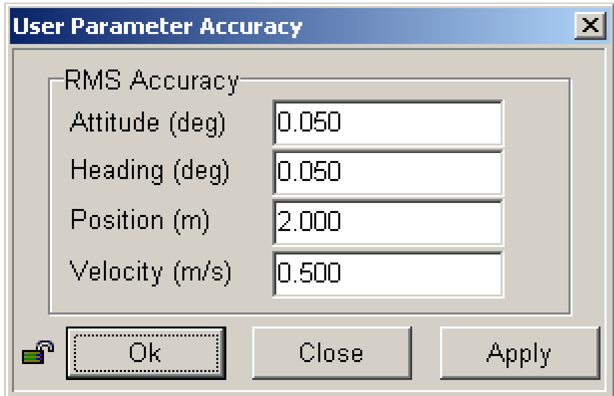

Heave Filter
Heave Bandwidth (sec)
10.000
Damping Ratio
0.707
Ok
Close
Apply

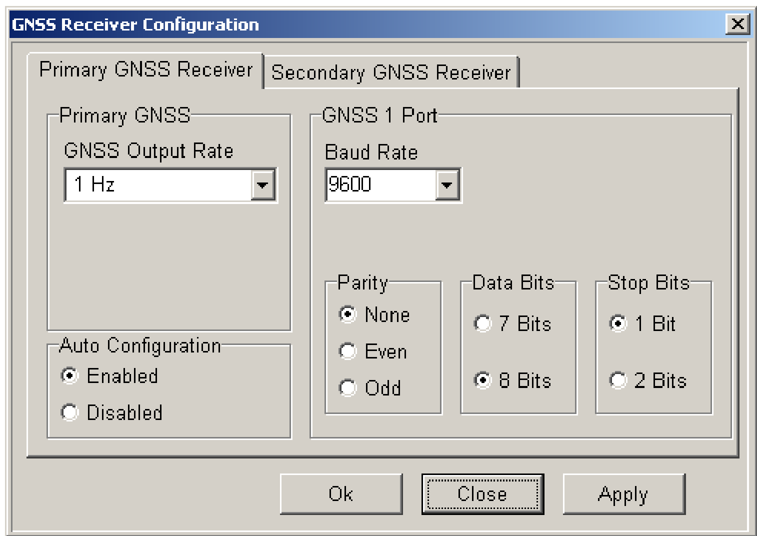

Events
Event 1
Event 2
Event 3
Event 4
Event 5
Event 6
Edge Trigger
Positive
Negative
Guard Time (msec)
0
PPS Out
Polarity
Positive Pulse
Negative Pulse
Pass through
Pulse Width (msec)
63
Ok
Close
Apply

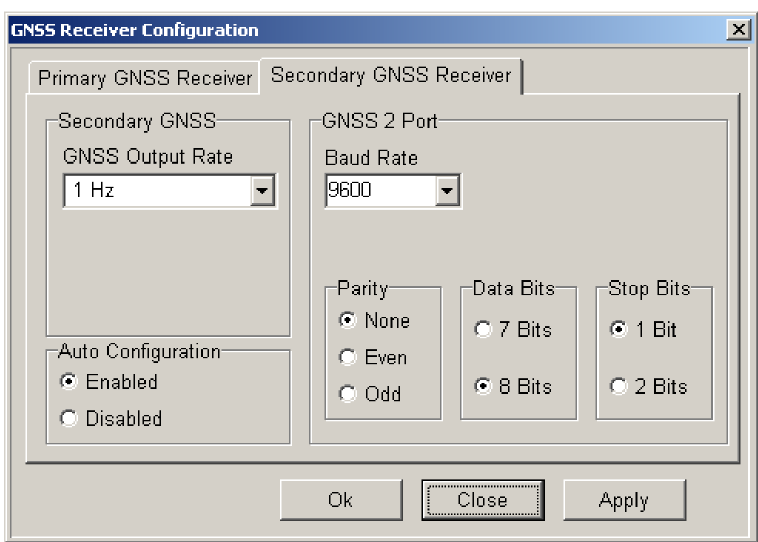

Lever Arms & Mounting Angles
Lever Arms & Mounting Angles | Sensor Mounting | Tags, AutoStart
Ref. to IMU Target
X (m) 0.000
Y (m) 0.000
Z (m) -0.168
IMU Frame w.r.t. Ref. Frame
X (deg) 1.500
Y (deg) 1.000
Z (deg) 0.000
Target to Sensing Centre
X (m) -0.008
Y (m) -0.031
Z (m) 0.130
Resulting Lever Arm
X (m) -0.005
Y (m) -0.034
Z (m) -0.038
Ref. to Primary GPS Lever Arm
X (m) 1.015
Y (m) 0.750
Z (m) -2.160
Ref. to Vessel Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Ref. to Centre of Rotation 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
Compute IMU w.r.t. Ref. Misalignment
Enable Bare IMU
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, AutoStart
Ref. to Aux. 1 GNSS Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Ref. to Aux. 2 GNSS 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, AutoStart
Time Tag 1
POS Time
GPS Time
UTC Time
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)
0.050
Position (m)
2.000
Velocity (m/s)
0.500
Ok
Close
Apply


GNSS Receiver Configuration
Primary GNSS Receiver
Secondary GNSS Receiver
Primary GNSS
GNSS Output Rate
1 Hz
GNSS 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


GNSS Receiver Configuration
Primary GNSS Receiver
Secondary GNSS Receiver
Secondary GNSS
GNSS Output Rate
1 Hz
GNSS 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:	Electronic Sales of New England
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:	.008
Calibration ID:	201525 999999 201525 130717 105604
Installed On:	

Coefficient A:	0.000000E+0	Coefficient H:	1.946885E-7
Coefficient B:	0.000000E+0	Coefficient I:	0.000000E+0
Coefficient C:	6.928073E-7	Coefficient J:	0.000000E+0
Coefficient D:	1.947096E-7	Coefficient K:	0.000000E+0
Coefficient E:	-1.721717E-5	Coefficient L:	0.000000E+0
Coefficient F:	1.951610E-7	Coefficient M:	0.000000E+0
Coefficient G:	8.250593E-7	Coefficient N:	0.000000E+0

Calibration Date (dd/mm/yyyy): 13/7/2017

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 1. Sensor Calibration Certificate – *R/V Ocean Explorer* - AML SV.Xchange Sensor SN 201525 installed on the AML Micro-X SN 10315 mounted on the Reson 7125.

AML OCEANOGRAPHIC
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Certificate of Calibration

Customer:	Electronic Sales of New England
Asset Serial Number:	203108
Asset Product Type:	SV•Xchange™ Calibrated Sensor
Calibration Type:	Sound Velocity
Calibration Range:	1375 to 1625 m/s
Calibration RMS Error:	.005
Calibration ID:	203108 999999 203108 130717 105502
Installed On:	

Coefficient A:	0.000000E+0	Coefficient H:	1.944896E-7
Coefficient B:	0.000000E+0	Coefficient I:	0.000000E+0
Coefficient C:	1.090799E-6	Coefficient J:	0.000000E+0
Coefficient D:	1.945449E-7	Coefficient K:	0.000000E+0
Coefficient E:	-1.704328E-5	Coefficient L:	0.000000E+0
Coefficient F:	1.950628E-7	Coefficient M:	0.000000E+0
Coefficient G:	1.332700E-6	Coefficient N:	0.000000E+0

Calibration Date (dd/mm/yyyy): 13/7/2017

Certified By:

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Robert Haydock
President, AML Oceanographic

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Figure 2. Sensor Calibration Certificate – *R/V Ocean Explorer* - AML SV.Xchange Sensor SN 203108 installed on the AML Micro SVPT 7786 used on the ODIM MVP.

AML OCEANOGRAPHIC
Xchange your old ideas

Certificate of Calibration

Customer: Electronic Sales of New England
Asset Serial Number: 007786
Asset Product Type: ZZZMicro SVTP, Fixed Sensors, for Brooke MVP -
Calibration Type: Pressure
Calibration Range: 200 dBar
Calibration RMS Error: .0109
Calibration ID: 007786 001051 D00026 170717 092201
Installed On:

Coefficient A:	-2.543544E+1	Coefficient H:	0.000000E+0
Coefficient B:	0.000000E+0	Coefficient I:	-3.183394E-10
Coefficient C:	0.000000E+0	Coefficient J:	0.000000E+0
Coefficient D:	0.000000E+0	Coefficient K:	0.000000E+0
Coefficient E:	3.816281E-3	Coefficient L:	0.000000E+0
Coefficient F:	0.000000E+0	Coefficient M:	7.231540E-16
Coefficient G:	0.000000E+0	Coefficient N:	0.000000E+0

Calibration Date (dd/mm/yyyy): 17/7/2017
Certified By:

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President, AML Oceanographic

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Figure 3. Sensor Calibration Certificate – *R/V Ocean Explorer* - MVP Micro SVTP Pressure Sensor on SN 7786 used on the ODIM MVP.

AML OCEANOGRAPHIC
Xchange your old ideas

Certificate of Calibration

Customer: Electronic Sales of New England
Asset Serial Number: 007786
Asset Product Type: ZZZMicro SVTP, Fixed Sensors, for Brooke MVP -
Calibration Type: Temperature
Calibration Range: -2 to +32 Dec C
Calibration RMS Error: .0016
Calibration ID: 007786 001051 125479 130717 222411
Installed On:

Coefficient A:	-9.718361E+0	Coefficient H:	0.000000E+0
Coefficient B:	8.885547E-4	Coefficient I:	0.000000E+0
Coefficient C:	-1.024250E-8	Coefficient J:	0.000000E+0
Coefficient D:	2.359527E-13	Coefficient K:	0.000000E+0
Coefficient E:	-3.487201E-18	Coefficient L:	0.000000E+0
Coefficient F:	3.288514E-23	Coefficient M:	0.000000E+0
Coefficient G:	-1.172707E-28	Coefficient N:	0.000000E+0

Calibration Date (dd/mm/yyyy): 13/7/2017
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Figure 4. Sensor Calibration Certificate – *R/V Ocean Explorer* - MVP Micro SVTP Temperature Sensor on SN 7786 used on the ODIM MVP.

AML OCEANOGRAPHIC
Xchange your old ideas

Certificate of Calibration

Customer:	Electronic Sales of New England
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:	.004
Calibration ID:	201527 999999 201527 310717 104737
Installed On:	

Coefficient A:	0.000000E+0	Coefficient H:	1.946520E-7
Coefficient B:	0.000000E+0	Coefficient I:	0.000000E+0
Coefficient C:	1.006635E-6	Coefficient J:	0.000000E+0
Coefficient D:	1.945742E-7	Coefficient K:	0.000000E+0
Coefficient E:	-1.733442E-5	Coefficient L:	0.000000E+0
Coefficient F:	1.951095E-7	Coefficient M:	0.000000E+0
Coefficient G:	7.847014E-7	Coefficient N:	0.000000E+0

Calibration Date (dd/mm/yyyy): 31/7/2017

Certified By:

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Robert Haydock
President, AML Oceanographic

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Figure 5. Sensor Calibration Certificate – *R/V Ocean Explorer* - AML SV.Xchange Sensor SN 201527 installed on the AML Micro SVPT 7777 used on the ODIM MVP.

AML OCEANOGRAPHIC
Xchange your old ideas

Certificate of Calibration

Customer:	Electronic Sales of New England
Asset Serial Number:	007777
Asset Product Type:	ZZZMicro SVTP, Fixed Sensors, for Brooke MVP -
Calibration Type:	Pressure
Calibration Range:	200 dBar
Calibration RMS Error:	.0155
Calibration ID:	007777 142686 0AX984 020817 105940
Installed On:	

Coefficient A:	7.330288E+3	Coefficient H:	4.160638E-16
Coefficient B:	-4.822219E-1	Coefficient I:	-1.901934E-6
Coefficient C:	1.058694E-5	Coefficient J:	1.260468E-10
Coefficient D:	-7.818996E-11	Coefficient K:	-2.784536E-15
Coefficient E:	-4.808766E-2	Coefficient L:	2.050525E-20
Coefficient F:	3.180522E-6	Coefficient M:	0.000000E+0
Coefficient G:	-6.331035E-11	Coefficient N:	0.000000E+0

Calibration Date (dd/mm/yyyy): 2/8/2017

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President, AML Oceanographic

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Figure 6. Sensor Calibration Certificate – *R/V Ocean Explorer* - MVP Micro SVTP Pressure Sensor on SN 7777 used on the ODIM MVP.

AML OCEANOGRAPHIC
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Certificate of Calibration

Customer:	Electronic Sales of New England
Asset Serial Number:	007777
Asset Product Type:	ZZZMicro SVTP, Fixed Sensors, for Brooke MVP -
Calibration Type:	Temperature
Calibration Range:	-2 to +32 Dec C
Calibration RMS Error:	.0015
Calibration ID:	007777 999999 007777 260717 221851
Installed On:	

Coefficient A:	-8.921527E+0	Coefficient H:	0.000000E+0
Coefficient B:	8.820256E-4	Coefficient I:	0.000000E+0
Coefficient C:	-9.322953E-9	Coefficient J:	0.000000E+0
Coefficient D:	1.868434E-13	Coefficient K:	0.000000E+0
Coefficient E:	-2.216849E-18	Coefficient L:	0.000000E+0
Coefficient F:	1.697135E-23	Coefficient M:	0.000000E+0
Coefficient G:	-4.024335E-29	Coefficient N:	0.000000E+0

Calibration Date (dd/mm/yyyy): 26/7/2017

Certified By:

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President, AML Oceanographic

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Figure 7. Sensor Calibration Certificate – *R/V Ocean Explorer* - MVP Micro SVTP Temperature Sensor on SN 7777 used on the ODIM MVP.

AML OCEANOGRAPHIC
Xchange your old ideas

Certificate of Calibration

Customer:	Electronic Sales of New England
Asset Serial Number:	201521
Asset Product Type:	SV•Xchange™ Calibrated Sensor
Calibration Type:	Sound Velocity
Calibration Range:	1375 to 1625 m/s
Calibration RMS Error:	.025
Calibration ID:	201521 999999 201521 130717 105546
Installed On:	007786

Coefficient A:	0.000000E+0	Coefficient H:	1.944808E-7
Coefficient B:	0.000000E+0	Coefficient I:	0.000000E+0
Coefficient C:	1.862403E-6	Coefficient J:	0.000000E+0
Coefficient D:	1.944561E-7	Coefficient K:	0.000000E+0
Coefficient E:	-1.661926E-5	Coefficient L:	0.000000E+0
Coefficient F:	1.950674E-7	Coefficient M:	0.000000E+0
Coefficient G:	1.821086E-6	Coefficient N:	0.000000E+0

Calibration Date (dd/mm/yyyy): 13/7/2017

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President, AML Oceanographic

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Figure 8. Sensor Calibration Certificate – *R/V Ocean Explorer* and *R/V Osprey* - AML SV.Xchange Sensor SN 201521 installed on the AMLBase-X profiler SN 25016 (shared between both vessels for comparison casting).

AML OCEANOGRAPHIC
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Certificate of Calibration

Customer:	Electronic Sales of New England
Asset Serial Number:	303077
Asset Product Type:	P•Xchange™ Calibrated Sensor, 100 dBar
Calibration Type:	Pressure
Calibration Range:	100 dBar
Calibration RMS Error:	.0125
Calibration ID:	303077 999999 303077 170717 132416
Installed On:	025016

Coefficient A:	-1.241000E+1	Coefficient H:	0.000000E+0
Coefficient B:	0.000000E+0	Coefficient I:	-4.128781E-10
Coefficient C:	0.000000E+0	Coefficient J:	0.000000E+0
Coefficient D:	0.000000E+0	Coefficient K:	0.000000E+0
Coefficient E:	1.920703E-3	Coefficient L:	0.000000E+0
Coefficient F:	0.000000E+0	Coefficient M:	3.511229E-15
Coefficient G:	0.000000E+0	Coefficient N:	0.000000E+0

Calibration Date (dd/mm/yyyy): 17/7/2017

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President, AML Oceanographic

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Figure 9. Sensor Calibration Certificate - *R/V Ocean Explorer* and *R/V Osprey* - AML P.Xchange Sensor SN 303077 installed on the AMLBase-X profiler SN 25016 (shared between both vessels for comparison casting).

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 6372
CALIBRATION DATE: 31-May-17

SBE 37 V2 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -9.518198e-001
h =  1.341216e-001
i = -4.784230e-004
j =  5.297682e-005

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

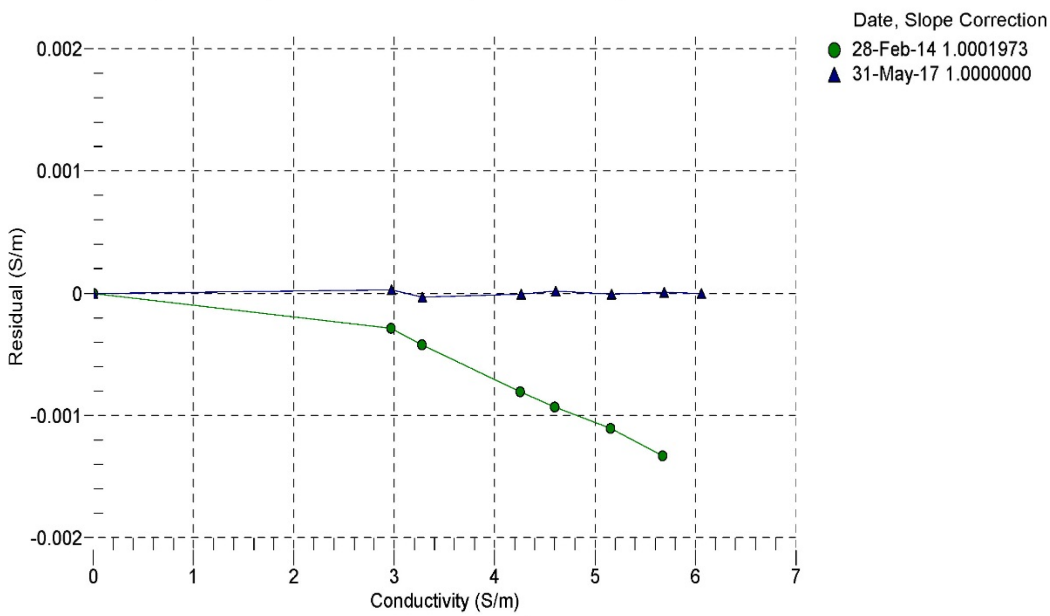
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
22.0000	0.0000	0.00000	2672.95	0.00000	0.00000
1.0000	34.7952	2.97433	5431.50	2.97436	0.00003
4.5000	34.7757	3.28127	5639.32	3.28124	-0.00003
15.0000	34.7340	4.26258	6256.84	4.26258	-0.00001
18.5000	34.7252	4.60759	6459.60	4.60760	0.00002
24.0000	34.7157	5.16531	6774.14	5.16531	-0.00001
29.0000	34.7109	5.68700	7055.25	5.68700	0.00001
32.5000	34.7084	6.05930	7248.94	6.05929	-0.00000

f = Instrument Output(Hz) * sqrt(1.0 + WBOTC * t) / 1000.0

t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



1

Figure 10. Sensor Calibration Certificate – *R/V Osprey* – Conductivity Calibration for SBE-37 Sound Speed Sensor mounted on the Reson 8125.

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 6372
CALIBRATION DATE: 31-May-17

SBE 37 V2 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:
a0 = 6.092434e-005
a1 = 2.686011e-004
a2 = -2.020565e-006
a3 = 1.396355e-007

BATH TEMP (° C)	INSTRUMENT OUTPUT (counts)	INST TEMP (° C)	RESIDUAL (° C)
1.0000	693367.9	1.0000	0.0000
4.5000	591528.8	4.4999	-0.0001
15.0000	374610.5	15.0000	0.0000
18.5000	323720.6	18.5001	0.0001
24.0000	258901.5	24.0000	-0.0000
29.0000	212607.6	28.9999	-0.0001
32.5000	185839.8	32.5001	0.0001

n = Instrument Output (counts)

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

Residual (°C) = instrument temperature - bath temperature

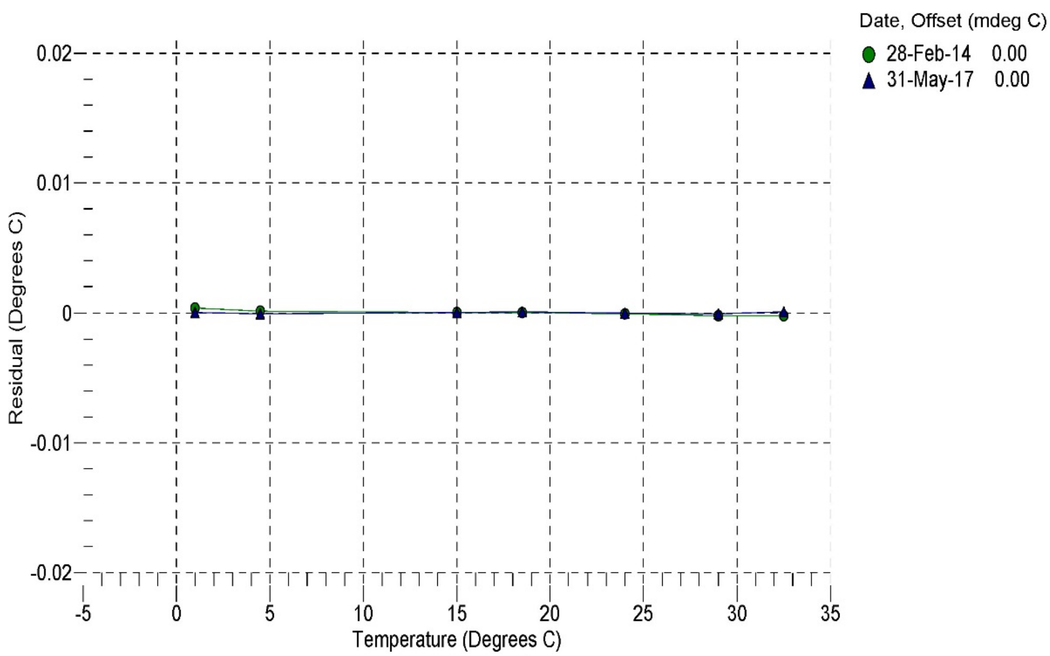


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Figure 11. Sensor Calibration Certificate – *R/V Osprey* – Temperature Calibration for SBE-37 Sound Speed Sensor mounted on the Reson 8125.

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Certificate of Calibration

Customer:	Electronic Sales of New England
Asset Serial Number:	203524
Asset Product Type:	SV•Xchange™ Calibrated Sensor
Calibration Type:	Sound Velocity
Calibration Range:	1375 to 1625 m/s
Calibration RMS Error:	.014
Calibration ID:	203524 999999 203524 130717 105522
Installed On:	010315

Coefficient A:	0.000000E+0	Coefficient H:	1.947737E-7
Coefficient B:	0.000000E+0	Coefficient I:	0.000000E+0
Coefficient C:	4.023842E-7	Coefficient J:	0.000000E+0
Coefficient D:	1.948279E-7	Coefficient K:	0.000000E+0
Coefficient E:	-1.821299E-5	Coefficient L:	0.000000E+0
Coefficient F:	1.954723E-7	Coefficient M:	0.000000E+0
Coefficient G:	6.351400E-7	Coefficient N:	0.000000E+0

Calibration Date (dd/mm/yyyy): 13/7/2017

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 12. Sensor Calibration Certificate – *R/V Osprey* - AML SV.Xchange Sensor SN 203524 installed on the AMLBase-X profiler SN 25028.

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Certificate of Calibration

Customer: Electronic Sales of New England
Asset Serial Number: 304351
Asset Product Type: P•Xchange™ Calibrated Sensor, 100 dBar
Calibration Type: Pressure
Calibration Range: 100 dBar
Calibration RMS Error: .0159
Calibration ID: 304351 999999 304351 170717 132402
Installed On:

Coefficient A:	-1.250735E+1	Coefficient H:	0.000000E+0
Coefficient B:	0.000000E+0	Coefficient I:	-9.318120E-11
Coefficient C:	0.000000E+0	Coefficient J:	0.000000E+0
Coefficient D:	0.000000E+0	Coefficient K:	0.000000E+0
Coefficient E:	1.911900E-3	Coefficient L:	0.000000E+0
Coefficient F:	0.000000E+0	Coefficient M:	1.331198E-15
Coefficient G:	0.000000E+0	Coefficient N:	0.000000E+0

Calibration Date (dd/mm/yyyy): 17/7/2017
Certified By:

AML Oceanographic

Robert Haydock
President, AML Oceanographic

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Figure 13. Sensor Calibration Certificate – *R/V Osprey* - AML P.Xchange Sensor SN 304351 installed on the AMLBase-X profiler SN 25028.