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-J377-KR-15

Time Frame: June – July 2015

LOCALITY

State: Louisiana

General Locality: Gulf of Mexico

Sub-locality: Approaches to Breton Sound, LA

2015

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	H12733, H12734 H12735, H12736

State:	**Louisiana**
General Locality:	**Gulf of Mexico**
Sub-Locality:	**Approaches to Breton Sound, LA**
Scale:	**1:20,000 and 1:40,000**
Date of Survey:	**June 18 to July 28, 2015**
Instructions Dated:	**April 23, 2015**
Project No.:	**OPR-J377-KR-15**
Vessel:	**R/V Ocean Explorer- Official Number 905425**
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 survey is to update existing NOS nautical charts within a high commercial traffic area. All times are recorded in UTC. Data recorded and presented relative to UTM Zone 16 North.

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APPENDICES

A. EQUIPMENT

A.1 Survey Vessel: *R/V Ocean Explorer*

All survey operations were conducted from the *R/V Ocean Explorer* (Figure 1). *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.
5. To support towed SSS operations a hydraulically actuated A-frame was installed on the stern of the vessel. The SSS towfish was flown from the starboard side of the A-frame as close as practical to the athwart ship position of the multibeam transducer pole. An electric, multi-purpose, slip ring winch was installed on the main deck and was used to control the towed SSS.
6. 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 May 6, 2015 (DN 126) by OSI during which reference points (permanent shipboard benchmarks) were established on the *R/V Ocean Explorer* 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.

The multibeam transducer pole is capable of variable draft settings. During the 2015 vessel mobilization the initial transducer phase center-to-RP value was established relative to shipboard benchmarks employing a steel tape measure. During the course of the survey one draft change was effected. The magnitude of this change was also recorded using a steel tape measure. Survey offsets and estimated measurement accuracies were incorporated into the CARIS vessel configuration file.

Major data acquisition system components that were employed during the project are summarized in Table 1 below. A brief description of the equipment follows.

Table 1
Acquisition Equipment

System	Data	Manufacturer	Model/ Version No.	Firmware/Software Ver.	Serial Number (s)
Side Scan Sonar Towfish	Imagery/Contacts	EdgeTech	4125	N/A	46118
Side Scan Sonar Processor	Imagery/Contacts	EdgeTech	4125P	4125D V. 35.0.1.104	46921
Side Scan Sonar Towfish	Imagery/Contacts	EdgeTech	4200-MP	N/A	48869
Side Scan Sonar Processor	Imagery/Contacts	EdgeTech	701-DL	Discover 4200-MP V. 35.0.1.104	48629
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 203108
Moving Vessel Profiler (MVP)	Sound Speed	ODIM	MVP30	MVP Controller 2.43	10646
MVP Sound Speed Profile Sensors (Two Systems Employed)	Sound Speed	AML Oceanographic	Micro SVPT SV-Xchange & Pressure/Temp Sensor	N/A	SV-X-201527 PT-7786 SV-X-201525 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 304351
Navigation, Vessel Attitude & Heading (Two Systems Employed)	Position, Attitude, Heading	Applanix/ Trimble	POS MV 320 V.4	HW 1.1-7 SW 05.03	TPU 2483 IMU 497 TPU 3352 IMU 861
Navigation	Position	Trimble	MS750	1.58	220332327
U.S.C.G. Differential Beacon Receivers (2)	DGPS correctors	Trimble	ProBeacon	3	0220033958 0220181939
SSS Cable Payout Indicator	SSS Fish Layback	Hydrographic Consultants	SCC16”	2	1603

System	Data	Manufacturer	Model/ Version No.	Firmware/Software Ver.	Serial Number (s)
Land Survey GPS	RTK GPS Base Station	Trimble	5700	V3.01	220247153
Water Level Gauge	Static Draft	GE/Druck	PDCR-830	N/A	363764
Lead Line	Bar Check	OSI	Lead Disk	N/A	2010A
Stadia Rod	Static Draft	Crain	CR-4.0M	N/A	OSI SR-02
Autopilot	Vessel Steering	Simrad	AP50	V1R4	20212221 DA1711

A.2 Echo Sounding Equipment

A.2.1 Side Scan Sonar Systems

A.2.1.1 EdgeTech 4125

The fixed-mount or "pole mount" SSS system 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. The 600 kHz frequency 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 system was affixed to the multibeam pole, none of these sensor data were used during data processing. The TPU connected to the SSS acquisition computer through a dedicated Ethernet cable. A 4125 positioning verification test was performed on June 18-19, 2015 (DN 169-170) and is documented in the DAPR Appendix II: Echosounder Reports. Positioning accuracy was verified during the course of the survey by observation of coincidental data. Another positioning verification test was performed on the last day of the survey, July 28, 2015 (DN 209).

Figure 2. Pole-mounted EdgeTech 4125 SSS transducer. 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 sun protection cover is on the Reson 7125 transducer in this photo.

A.2.1.2 EdgeTech 4200-MP

An EdgeTech 4200-MP (multi-pulse) side scan sonar system was used to acquire imagery in the deeper reaches of the survey area as well as in the relatively shallow reaches when sea conditions did not favor use of the pole mounted SSS. The 4200-MP employed on this project is a dual-frequency sonar capable of operating at 300 kHz and/or 600 kHz. For this survey the system was operated in dual-frequency mode employing the “high speed” mode exclusively. Of the available range scales, only the 50 and 75 meter settings were used. The system consists of a Topside Processor Unit (TPU), coaxial double armored steel tow cable, electric powered slip ring winch, digital cable payout meter, and sonar towfish. System components were interfaced to the acquisition system and other ancillary devices, via a local network hub or serial cable connections. The towfish was equipped with a pressure sensor which was used to measure towfish depth. The towfish was deployed either with or without a depressor fin depending on sea conditions and water depth in the operating area. Positioning verification testing was completed during mobilization in Connecticut on May 30, 2015 (DN 150). The SSS calibration test results are documented in the DAPR Appendix II: Echosounder Reports.

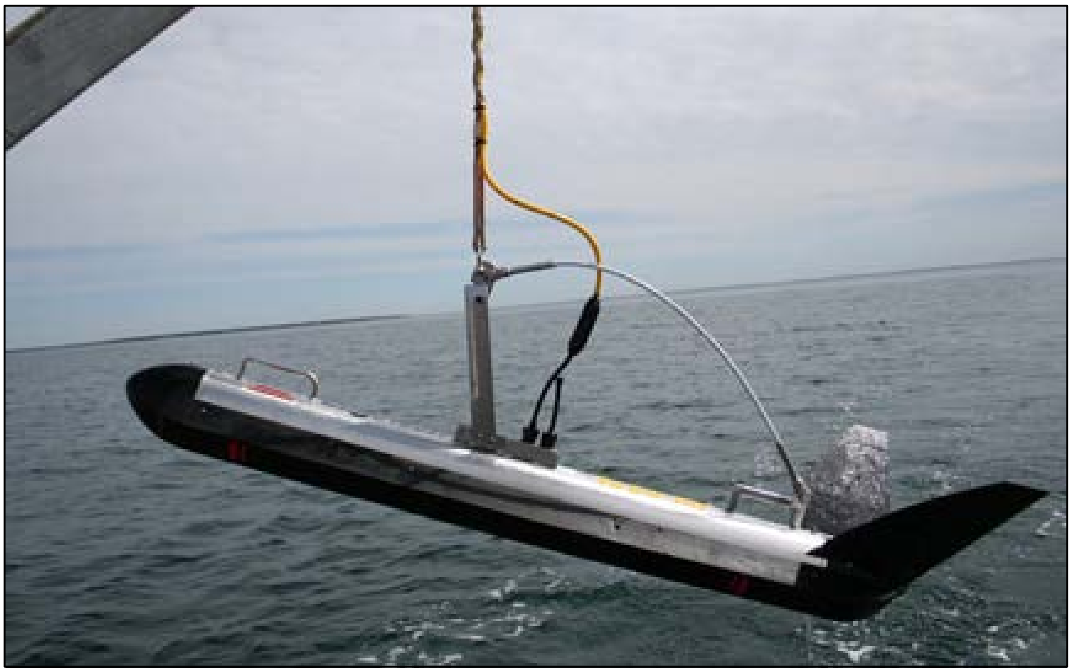


Figure 3. EdgeTech 4200-MP towfish as shown on the EdgeTech website.

A.2.2 Multibeam Echosounder

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-J377-KR-15, the echosounder's 400 kHz capability was employed. At this frequency the 7125 system illuminates a swath of the seafloor that is 140º across track by 1.1º 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-J377-KR-15. 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 4. Pole-mounted Reson 7125 transducer on the *R/V Ocean Explorer*.

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 full static survey on May 6, 2015 (DN 126). A patch test and performance test were completed during mobilization in Connecticut. However, the initial patch test of record was performed in Venice, LA on June 18, 2015 (DN 169). The initial performance test of record was performed within the survey area on June 21, 2015 (DN 172). On July 5, 2015 (DN 186) the draft of the multibeam transducer was changed (made deeper). Prior to the draft change a verification patch test was performed to confirm the values derived during the DN 169 test. Upon changing the transducer draft another patch test was completed to establish new angular offset values. These pre- and post-draft change patch tests were both performed on

July 4-5, 2015 (DN 185-186) respectively. A performance test of the deeper draft configuration was completed on July 8, 2015 (DN 189). Finally, verification patch and performance testing was performed at the completion of the project on July 28, 2015 (DN 209). Patch test and performance tests results of record are presented in DAPR Appendix II.

A.3 Manual Sounding Equipment

A.3.1 Lead Line

The lead line was constructed by OSI utilizing a 9 kilogram, 0.3-meter round lead disk attached to a stainless steel cable with permanent index markers established at measured 1-meter intervals (from 1-10 meters) and then 2-meter intervals thereafter.

Prior to survey operations the lead line was calibrated on May 15, 2015 (DN 135) with a steel survey tape to verify index mark accuracy.

A.4 Positioning and Attitude Equipment

A.4.1 Applanix POS MV

An Applanix POS MV 320 V.4 system was installed on the survey vessel 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 ≥ 2meters) 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.

During the course of the survey the POS MV positioning solution was occasionally corrupted due to what was ultimately determined to be a rogue serial signal voltage due to a failing serial cable that was connected to the PCS. While troubleshooting the source of the occasional positioning errors, the system's PCS and accompanying GPS antennas were temporarily replaced. All project data acquired during the infrequent periods of corrupted positioning were discarded.

IMU and antenna offsets and mounting angles, relative to the vessel frame and a vessel RP, were measured during the full static survey on May 6, 2015 (DN 126). An Applanix-specified GAMS calibration procedure was conducted during mobilization on May 29, 2015 (DN 149). Due to the temporary replacement of the system's PCS and GPS antennas, additional GAMS calibrations were performed immediately following the system hardware changes. Specifically, a GAMS calibration was performed on July 12, 2015 (DN 193) when the replacement PCS was installed and again on July 19, 2015 (DN 200) when the original PCS was reinstalled. At no time was the original IMU moved from its initial mounting location.

A.4.2 DGPS

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

A.4.3 Other Positioning and Attitude Equipment

A.4.3.1 Secondary Positioning: Trimble MS750

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

A.4.3.2 SSS Cable Out Indicator

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

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

The accuracy of the system was checked repeatedly during towed SSS operations by comparing sensor display values to calibration marks on the tow cable. These checks were performed frequently during each survey day. The counter system was recalibrated as-needed to account for minor cable slippage; these occasional recalibrations were noted in the data acquisition log.

A.5 Sound Speed Equipment

The surface sound speed sensor, the sound speed comparison profiler, and the undulating velocimeter (ODIM MVP) sensors were all fitted with AML Oceanographic instruments which were manufacturer calibrated prior to survey data acquisition. Copies of the calibration sheets are included in DAPR Appendix IV.

A.5.1 Sound Speed Profiles

A.5.1.1 Sound Speed Profiler: ODIM MVP30

The ODIM MVP30 Moving Vessel Profiler allows sound speed profiles to be collected while the vessel is underway. The ODIM MVP consists of towfish-mounted sensors (AML sound speed, temperature, and depth “micro SVPT”), 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. The MVP30 was the primary sound speed profiler employed during this survey. Sound speed data from the AML Base-X used for comparison casts and the AML Micro-X surface sound speed sensor at the MBES transducer head were frequently referenced to confirm proper operation of the MVP30 AML sensors.

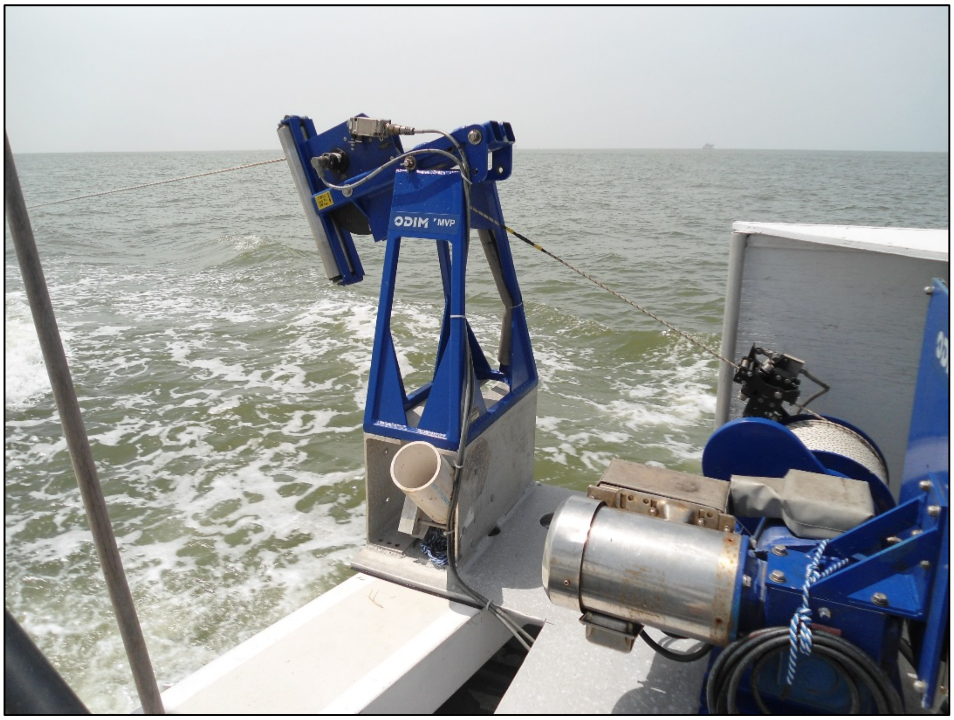


Figure 5. ODIM MVP30 as mounted on the vessel stern.

A.5.1.2 Sound Speed Profiler: AML Oceanographic Base-X

An AML Oceanographic Base-X logging profiler was employed to acquire comparison cast data for "monthly" sound speed confidence checks. In fact, sound speed confidence checks were performed almost daily during the course of the survey. This instrument collects high-precision direct sound speed and pressure measurements. The instrument 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.

There were two instances when the primary sound speed profiling device, the ODIM MVP, was rendered inoperable for mechanical reasons. For one of these periods, occurring on July 17, 2015 (DN198), the AML Base-X was used to acquire sound speed profile data in lieu of the MVP while repairs were made on the MVP. For the second short period of mechanical maintenance on July 27, 2015 (DN 208), the MVP sensor package (freefall fish) was deployed manually to acquire the sound speed profile.

A.5.2 Surface Sound Speed: 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.6 Horizontal and Vertical Control Equipment

A.6.1 Precise Positioning: Trimble 5700 GPS

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

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

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 string via radio modem. The pressure transducer was installed well below the waterline at a fixed elevation within the multibeam transducer pole. As mentioned earlier, the sealed base of the multibeam pole was configured with a small copper orifice, in effect making the transducer pole a stilling well. The physical offset between the sensor and vessel draft was established dockside during a series of physical draft measurements versus sensor value observations (static dockside calibration).

During offshore operations, sensor data were logged once a day (when practical) when the vessel was at full stop. The sensor was configured to record a water level at a rate of 2 Hz. The radio modem receiver was interfaced with the acquisition computer through a serial port and the water level reading was logged to a HYPACK .RAW file for approximately 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.

A.6.3 Stadia Rod

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

A.7 Additional Acquisition Equipment

A.7.1 Bottom Sampler

A sediment sampler was employed to obtain seafloor sediment samples within the survey area. A hydraulic pot hauler aboard the *R/V Ocean Explorer* was employed to recover the unit.

A.7.2 Auto Pilot

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

A.8 Computer Hardware and Software

A.8.1 Computer Hardware

Table 2
Computer Hardware

Use	Manufacturer	Model	Operating System
MBES Acquisition	Shuttle	XPC SH67H3	Windows 7 64-bit
SSS Acquisition	Shuttle	XPC SH67H3	Windows 7 64-bit
MVP Acquisition	Hewlett Packard	HP 530	Windows XP
Onboard Data QA/QC	Shuttle	XPC SH67H3	Windows 7 64-bit

MBES acquisition was accomplished using HYPACK software installed on 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, two gigabit network adapters, 8.0 GB of RAM, dedicated graphics, and multiple display monitors. This computer was also used to control and monitor the POS MV using the MV POSView controller and to record POSPac data.

Side scan sonar data were logged with EdgeTech Discover software using 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 multiple display monitors.

Data processing was completed at the home office using multiple Windows 7 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 3 below.

Table 3
Computer Software

Manufacturer	Application	Version	Version Date
HYPACK	HYPACK SURVEY	13.0.9.28	Sept. 26, 2013
HYPACK	HYSWEEP SURVEY	13.0.20.0	Oct. 15, 2013
EdgeTech	Discover 4125D 5.00	35.0.1.104	May 19, 2015
EdgeTech	Discover 4200-MP 4.00	35.0.1.104	May 19, 2015
Universal Systems, Ltd.	CARIS HIPS/SIPS	7.1.2	SP2 2012
Universal Systems, Ltd.	CARIS Notebook	3.1.1	SP1 2011
HYPACK	MBMax	13.0.1.0	Jan.28, 2013
Chesapeake Technology	Sonar Wiz 5	5.1.0.40	Sept 4, 2013
NOAA	NOAA Velocwin	8.92	May 8, 2008
AML Oceanographic	SeaCast	3.2.9 4.0.6	Apr. 15, 2010 June 26, 2015
Microsoft	Office (Word, Excel, PowerPoint)	2010	Apr. 15, 2010
ODIM Brooke Ocean	MVP Controller	2.430	Jan. 20, 2010
Applanix	MV POS View	5.1.0.2	Dec. 2, 2009
Applanix	POSPac MMS	6.2	July 30, 2013
Global Mapper Software LLC	Global Mapper	13.2	June 20, 2012
AutoDesk Inc.	AutoCAD	2004	Feb. 14, 2003
Hydrographic Consultants	CALLOAD	2.0	Dec. 18, 2005
Trimble	MS Controller	1.0.1.0	May 21, 2002
Trimble	Pro Beacon (DOS)	N/A	Sept 12, 1994
Trimble	GPS Configurator	4.10	March 20, 2013
National Geodetic Survey	OPUS-RS	2.3	May 14, 2015

A.8.2.1 HYPACK SURVEY

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 50 Hz frequency and transmitted to the navigation computer system, which processed these data in real-time into the desired mapping coordinate system (UTM Zone 16 North, NAD 83). Raw and processed position data were continuously logged onto the computer hard drive, sent to the autopilot, and displayed on a video monitor, enabling the vessel's helmsman (and autopilot) to guide the survey vessel accurately along pre-selected tracklines. Tracklines and survey features were displayed on the helm monitor with geographic reference data that included current NOS raster nautical charts (RNCs) and 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).

HYPACK SURVEY was used to generate real-time SSS positioning which was transmitted to and recorded by the individual instances of Discover SSS software. In the case of pole-mounted 4125 SSS, HYPACK's "Genoffset.dll" was used to calculate SSS fish position. In the case of the towed 4200 SSS, HYPACK's "Towfish.dll" was used to calculate SSS fish position. These processes are described in more detail in Section C.1.4. Towfish position parameters applicable for each system, e.g. depth, cable out, layback, and position, were 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 SSS system.

A separate instance of HYPACK SURVEY was run on the side scan sonar acquisition computer, which was also used to control the autopilot. Each acquisition computer's HYPACK SURVEY program was configured to use GPS UTC time to continuously sync the computer time. Both the MBES and SSS acquisition PCs were synced using the Group 7 message from the POS MV.

A.8.2.2 HYSWEEP SURVEY

Multibeam data were logged with HYPACK HYSWEEP software which was run simultaneously with HYPACK SURVEY. Multibeam raw beam ranges, intensities, and quality flags were time tagged with UTC time by the Reson 71P processor and recorded by 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 format.

A.8.2.3 EdgeTech Discover 4125D and 4200-MP

Discover is a side scan sonar control and acquisition software that interfaces directly with the EdgeTech SSS systems via a dedicated Ethernet connection. Each instance of the software was installed and operated on the SSS acquisition PC running the Windows 7 64-bit operating system. 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.

According to the equipment manufacturer, Discover 4125D and 4200-MP are identical versions of the same Discover program. The different name suffix is applied during the software installation depending on which EdgeTech sonar system folder the installer accesses on the manufacturer's FTP site. One advantage to running two versions of the same program is that the data from each system (4125 and 4200) is written to independent folders if a single acquisition computer is employed as was the case during Project OPR-J377-KR-15. On occasion the two SSS systems were operated concurrently.

Both instances of Discover received fish position information from the HYPACK SURVEY program via discrete serial connections to the HYPACK computer. For this reason, all navigation offset settings within each instance of Discover were set to zero.

For the rigid pole-mount configuration, HYPACK SURVEY calculated and transmitted fish position based upon the fixed physical offsets of the EdgeTech 4125 SSS relative to the vessel RP.

When the towed side scan configuration was implemented, HYPACK SURVEY calculated and transmitted fish position based on required and recorded inputs such as tow sheave position relative to the vessel RP, "cable out," and fish depth as transmitted in the form of a NEMA "DPT" message by the EdgeTech 4200. Fish altitude, another required parameter, is calculated by HYPACK SURVEY based on water depth and fish depth.

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 each instance of Discover over a serial connection. The software used this timing message to sync its time and the EdgeTech 4125/4200 TPU time to UTC.

All SSS scrolling waterfall data displays 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.

Each instance of 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 Version 7.1.2 for 64-bit processors.

All SSS data were converted from raw JSF format line files to HDCS format and processed using the CARIS SIPS software Version 7.1.2 for 64-bit processors.

HIPS/SIPS Version 7.1.2 was also utilized to process MBES and SSS calibration data, which included MBES patch and performance tests, and SSS position confidence tests.

A.8.2.5 CARIS Notebook

Notebook 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 in Notebook and exported using Notebook in the NOS Hydrographic Specifications and Deliverables (HSSD)-specified format, an S-57 .000 file. Field investigation assignments were conveyed to the field team using, among other tools, HOB files created in Notebook.

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

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 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 daily/weekly sound speed comparisons. All sound speed instrumentation used on this project measures sound speed directly, i.e. the HSSD-imposed prohibition on Wilson's sound speed equation, used by Velocwin to process CTD casts, does not apply.

A.8.2.9 AML Oceanographic SeaCast

Comparison sound speed cast data were acquired using an AML Oceanographic Base-X system. Also, as mentioned previously, the Base-X was used on one occasion (for seven casts) when the primary sound speed profiling device, the ODIM MVP, malfunctioned. 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, convert the pressure data to depths, 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. The workbook was also used to export a HYPACK-format .VEL file which was used infrequently during data acquisition when the ODIM MVP was not functional.

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 weekly comparison cast utility.

A.8.2.11 ODIM Brooke Ocean MVP Controller

A dedicated laptop computer was used to operate the ODIM MVP30 Controller Software. The System Configuration Window was used to interface the MVP towfish, MVP winch and the navigation and depth data strings output from HYPACK. Position, depth and vessel speed data were received from HYPACK and sound speed profiles were 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 nearly once per day with the vessel at rest, 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

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 navigation and acquisition stations. Visual alarms were configured to alert the operator in the event that attitude, position, velocity, heading or heave accuracy was degraded.

A.8.2.13 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 strong network of shore-based CORS stations. As a result the IAPPK solution is not expected to be considerably better than the Differential GPS (DGPS) position data acquired in real-time. However, POSPac MMS *was* used to process the post-survey confirmation patch test and fixed-mount SSS positioning test. In this case a "single base" IAPPK solution was used.

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 SSS 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. This process was not repeated for the towed SSS as there was no observable improvement in image quality when doing so.

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 Hydrographic Consultants, Ltd. CALLOAD

CALLOAD was installed on the HYPACK acquisition computer and used to calibrate and configure the SCC Smart Cable Counter. Sheave circumference, quantity of magnets and preset cable out values were input into CALLOAD to reset the cable counter. Once the hardware had been configured via the CALLOAD software the “cable out” value was reset, as needed, by means of hardware controls, i.e. buttons on the cable counter display unit. This process was completed frequently throughout side scan sonar operations between data acquisition runs.

A.8.2.17 Trimble MS Controller

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

A.8.2.18 Trimble ProBeacon

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

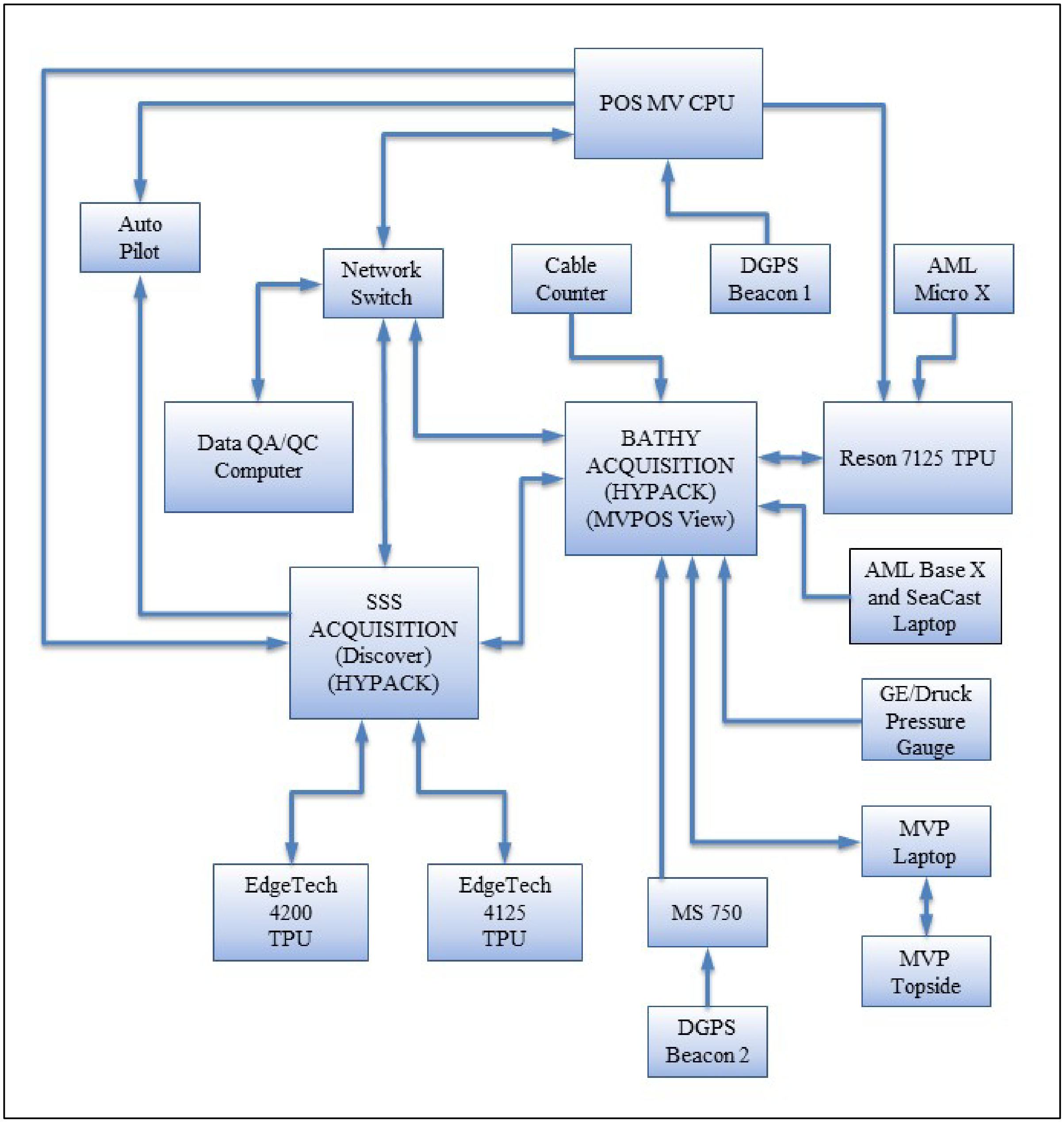
A.8.2.19 Trimble GPS Configurator

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.8.2.20 NGS OPUS-RS

The NGS' online OPUS-RS 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.8.2.21 Acquisition System Block Diagram



B. QUALITY CONTROL

B.1 Data Acquisition

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

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

Line plans were created to achieve 100% SSS coverage with concurrent MBES, with lines planned for side scan acquisition as follows:

- 75-meter SSS range – 130-meter line spacing resulting in 20 meters of outer range overlap; SSS nadir coverage provided by the MBES

- 50-meter SSS range – 80-meter line spacing resulting in 20 meters of outer range overlap; SSS nadir coverage provided by the MBES

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

B.1.1 Bathymetry: Multibeam Echosounder (MBES)

Transducer offsets for the Reson 7125 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 May 6, 2015 (DN 126) full static survey of the *R/V Ocean Explorer* which was completed using standard optical survey equipment and techniques. The transducer mounting orientation as relates to the vessel's fore/aft centerline and the POS MV IMU orientation was set using a portable gyroscopic compass mounted on a square plate. In practice, 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. 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. A patch test was used to determine minor residual misalignments for any transducer deployment modification. In the case of this project, there were two instances where patch testing was performed to determine these residuals: upon initial installation of the transducer pole and after one transducer draft change.

The POS MV IMU "bullseye" or reference point, located on the top of the IMU served as the vessel RP. The IMU mounting plate and key components of the transducer pole mounting apparatus are permanently installed hardware components of the survey vessel. For detailed information regarding system offsets refer to *Section C* Correction to Echo Soundings.

The Reson 7125 processor was interfaced with the POS MV such that UTC date and time information from the POS MV was used to accurately time stamp the Reson output data string. The Reson 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 recorded 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.

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

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

Prior to the start of data collection using the Reson 7125, the vessel 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 Reson 7125 as returned from the acoustic target. A "spot check" was also completed which consisted of sounding the seafloor directly below the multibeam transducer with the lead line while simultaneously observing the multibeam nadir depth. Throughout the course of the survey bar checks were completed at least weekly. All bar checks and spot checks indicate that the multibeam sonar system was performing within expected accuracy limits.

The initial vessel and MBES calibration to establish the dynamic draft correction table (squat test), residual transducer alignment offsets (patch test), and a multibeam system performance test were completed on May 29-30 (DN 149-150). These tests were performed with the POS MV 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 and were only utilized for system acceptance testing.

After transiting to the project area a second set of patch test and performance test data were acquired. Specifically, patch test data were acquired in the Mississippi River on June 18, 2015 (DN 169) with the POS MV in RTK mode as the test area was within range of a RTK

GPS base station deployed by OSI. The performance test was completed within the assigned survey area on June 21, 2015 (DN 172) with the POS MV in DGPS mode. These datasets serve as the project start “calibrations of record.”

A “closeout” patch test was conducted on July 4, 2015 (DN 185). This test was performed to confirm offsets derived at the outset of the survey prior to making a necessary draft change to the transducer pole.

Another patch test was completed immediately after changing the draft of the transducer on July 5, 2015 (DN 186). The transducer draft change was not made for reasons related to the MBES system. Rather, the change was made to improve image quality of the fixed mount SSS which was mounted on the same pole as the multibeam. A system performance test for this multibeam draft configuration was performed on July 8, 2015 (DN 189).

Post-survey patch and performance tests were completed to ensure that the transducer alignment and system performance remained consistent over the course of the survey. Calibration results are presented in *Section C*. Correction to Echo Soundings.

The SeaBat display and user interface installed on the Reson 7125 TPU were used to configure MBES settings, to monitor sounding acquisition, and to adjust system parameters in real time. The Reson 7125 was operated in equidistant mode using 512 beams. During calibration, the system was operated at a swath of 140°. However, the swath was reduced to 130° at the start of 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. “Absolute” depth gates were conservatively employed to reject fliers during mainscheme and cross line data acquisition. Depth gate filters were used sparingly or turned off all together during item investigations.

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

Bathymetry, position, motion and heading data were logged in HYPACK SURVEY and HYSWEEP SURVEY. Position information from the primary and secondary DGPS receivers were continuously compared in HYPACK 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 three (3) meters would be reported by means of a visual alarm on the data acquisition screen.

The HYSWEEP SURVEY program allows for real-time monitoring of surface sound speed as transmitted by the transducer-mounted AML Micro-X. A utility in HYSWEEP SURVEY allows for real-time comparison of the Micro-X-reported surface sound speed to the surface sound speed recorded in the most recently acquired water column sound speed profile (as reported by the ODIM MVP). For this project the system was configured to provide a visual alarm if the difference between these surface sound speed values exceeded 2 meters per second. Due to the sometimes dynamic surface sound speed conditions surrounding the Mississippi River delta, it was impractical to acquire a sound speed profile each and every time the 2 meter per second threshold was exceeded; the ODIM MVP requires some amount of time to deploy and recover the freefall fish. Hydrographers endeavored to acquire sound speed casts at an interval ≤ 15 minutes. However, when a dynamic surface sound speed was noted, sound speed profile casts were acquired more frequently.

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, preliminary 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: 2015OC1692114_5.HSX/RAW, where "OC" stands for Ocean Explorer.

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. POSPac data were logged at least 5 minutes prior to and after MBES acquisition. POSPac TrueHeave file names include the project number, device (POS MV), year, day number, and date (ex: 15ES026_POS_2015_181_0630.000). 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.

The POS MV heave bandwidth filter was configured with a dampening coefficient of 0.707. The cutoff period of the high-pass filter was determined by estimating the swell period encountered during the project. A heave bandwidth filter of 10 seconds was employed for project OPR-J377-KR-15 data collection.

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), a new Applanix POSPac Trueheave file was begun, a bar check was performed (weekly) to verify echosounder draft offsets and system sounding accuracy, a sound speed profile comparison cast was performed nearly daily, and side scan sonar depth sensor function/accuracy was confirmed (as appropriate). A surface sound speed comparison (AML Micro X vs. ODIM MVP) was often recorded at this time via the Velocwin "Daily Comparison" utility. However, if conditions were too rough to make the aforementioned static vessel tests impractical the vessel was kept underway and the surface sound speed "Daily Comparison" was performed while underway.

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 USB drives, frequently throughout each survey day. These data were periodically transferred to OSI's home office via courier delivery.

B.1.2 Imagery: Side Scan Sonar

For the towed SSS configuration, prior to commencing survey operations, the location of the top of the side scan sonar sheave at its operational, deployed position was verified with respect to the vessel RP. The vertical offset between the SSS sheave reference point and the water line was also confirmed. The position of the sheave serves as the starting point for the cable out measurement used to calculate towfish layback. In practice, horizontal offsets entered into the HYPACK SURVEY data acquisition program (used to calculate towed fish position) were measured relative to the survey vessel "steering point" origin which was able to be accurately related to the vessel RP.

For the fixed mount side scan sonar configuration, the horizontal position of the SSS was measured in relation to the vessel RP. However, as with the towed configuration, horizontal offsets entered into the HYPACK SURVEY data acquisition program (used to calculate fixed mount fish position) were referenced to the survey vessel "steering point" origin which was able to be 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. Both instances of Discover received towfish position from HYPACK SURVEY and, in the case of the fixed mount system, ship heading, directly from the POS MV. SSS survey line names include date (YYYYMMDD) and UTC time (HHMMSS), for example: 20150702070129.jsf.

Over one hundred percent (100%) SSS coverage was attained employing line spacing and side scan sonar range scales tabulated in Table 4 below.

Table 4
SSS Line Spacing and Range Scales

Trackline Offset (meters)	SSS Range Scale (meters)
80	50
130	75

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

For the towed SSS configuration, cable out readings were verified and/or recalibrated at least once per survey line by observing measured index marks on the towfish cable with respect to the reference position at the top of the sheave. The calculated depth from the pressure sensor within the EdgeTech 4200-MP towfish was confirmed regularly throughout the survey day. The 4200-MP's pressure sensor was not observed to drift throughout the term of the survey. For the fixed mount configuration, the 4125 SSS towfish height was not adjustable. As such the towfish altitude varied based on water depth. Therefore, on any given trackline, the SSS altitude may have been marginally above or below the 8-20 percent range scale limit. Due to the relatively shallow water depths in these areas the fixed mount SSS was used primarily in Survey H12733 and sparingly in Survey H12734. The fixed mount SSS was not used in Surveys H12735 or H12736.

The towed fish height was adjusted to fly at 8-20 percent of the range scale, with a visual alarm setup to indicate when the fish was nearing the upper and lower limits of the height threshold. Refraction and surface noise effects were minimized by changing the depth/altitude at which the towfish was flown. On rare occasions, when searching for a clean, refraction-free image, the towfish dipped below the lower height threshold while flying the fish at the lower height limit. The towed SSS (4200-MP) was used in all survey areas. However, its use was limited in Survey H12733 due to the relatively shallow water depths in this area.

As a conservative measure, for both the towed and fixed-mount SSS systems, in order to only utilize the effective SSS swath range, all sonar imagery was trimmed to 12.5 times towfish height before being mosaicked. Due to the conservative SSS line spacing described above, 100% coverage was still easily accomplished.

Confidence checks observed across the full range (e.g. scour marks and bottom type changes) were recorded frequently throughout each survey day 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 was 7-9 knots.

B.1.3 Sound Speed

B.1.3.1 Sound Speed Profiles

Sound speed profile data were acquired with the ODIM MVP30 approximately every 15 minutes, except when 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 2 meters off the bottom when operating in freewheel mode. For the overwhelming majority of sound speed casts the MVP free fall fish reached a depth greater than 80% of water depth. At least once per day the MVP fish reached a depth of at least 95% of water depth. As a safety measure, there were occasions that the free fall fish did not make it to within 80% of the water depth, e.g. in very shallow reaches of the survey area or in the vicinity of charted or observed obstructions. All casts were acquired within the survey area. 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_DN202_0038.calc.

Frequently during the daily "UTC midnight" changeover, while the *R/V Ocean Explorer* was at a full-stop offshore, the MVP was manually deployed to near full seafloor depth while an AML Oceanographic Base-X sound speed profiler was simultaneously deployed for a comparison cast. This satisfied the HSSD-specified "independent sound speed measurement system confidence check" requirement. AML Base-X comparison casts were used for quality assurance only and were not utilized in sound speed correction of soundings.

B.1.3.2 Surface Sound Speed

The AML Micro-X sound speed sensor was installed within the bow fairing of the multibeam transducer essentially at the draft of the transducer phase center. Real-time surface sound speed values were transmitted to the Reson 7125 topside unit and subsequently recorded with multibeam echosounder data in the raw HYPACK .HSX data files. Sound speed data were also utilized by HYSWEEP SURVEY which was configured to display a visual alarm if the surface sound speed changed +/- 2 m/s. Variations in surface sound speed were monitored and evaluated as an indicator of surface water temperature/salinity fluctuation and potential water column variation which would necessitate additional sound speed profile measurements.

Daily sound speed quality assurance (DQA) checks were performed using NOAA's Velocwin software by comparing the AML Micro-X surface sound speed to the surface sound speed of a MVP manual cast (stopped offshore) or an automated cast (underway).

B.1.4 Horizontal and Vertical Control

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

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

Position confidence checks of the POS MV were accomplished at the start of survey and during provisioning stops in Venice, LA. The distance between the vessel reference point and the horizontal control point computed by the navigation system was compared to the distance between the vessel reference point and the horizontal control point as measured with a steel tape. In all cases, dockside navigation system accuracy testing demonstrated that the POS MV, employing USCG correctors, had an accuracy of better than 1.0 meter. A tabulation of navigation system performance checks is included in DAPR Appendix III.

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 POS MV to the position reported by the Trimble MS750. For the purposes of the comparison the physical, shipboard position of the MS750 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 3-meters.

The alarm threshold was exceeded occasionally when the DGPS beacon receiver interfaced with the Trimble MS750 and configured to use the Eglin, FL station, lost signal. The primary positioning system, the POS MV, lost signal from the English Turn, LA DGPS beacon only twice: one time July 7, 2015 (DN188) during USCG-scheduled maintenance of the English Turn station and once during a period of thunderstorm activity that was located between the survey boat and the station. Project data acquired during these periods were not retained but were reacquired at a later time. New data were not acquired during the English Turn station outages.

The position integrity alarm proved very useful in quickly detecting faults in the positioning solution of the POS MV when the solution was occasionally corrupted as described in Section A.4.1. As mentioned in the aforementioned DAPR section, all project data acquired during the infrequent periods of corrupted positioning were discarded.

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 876-0922, Pilots Station East, SW Pass, 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 Pilots Station East station were downloaded and reviewed for data gaps. Verified tides were downloaded and reviewed when available.

The Verified tide curve contains numerous short period "data spikes" of relatively large magnitude, with some spikes measuring over 50% of the total range of tide on a given day. While the true cause of the data spikes is unknown it is suspected that wakes caused by passing ships are to blame. As noted in the Project HVCR, with CO-OPS approval, OSI removed the spurious tide data via application of a fourth-order, zero-lag, Butterworth low-pass filter using a sampling frequency of 120 with a cut-off frequency of 5.

Final project data are delivered with filtered, verified tides applied using the zoning file "J377KR2015RevCORP.zdf" provided by CO-OPS and verified by OSI.

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 and to meet the Object Detection Coverage specification in the HSSD (Section 5.2.2.1). 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 CARIS Notebook HOB file

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 balls, 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-J377-KR-15 Project Instructions. A sediment sampler was deployed from the A-frame located on the stern of the vessel to acquire seafloor sediment samples. Bottom sample locations were logged in a target file in HYPACK SURVEY. Once the sample was on deck it was photographed and classified based on the criteria outlined in Appendix H, Bottom Classification, in the HSSD.

B.1.7 Other

B.1.7.1 Autopilot

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

B.1.7.2 Digital Acquisition Logs

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

- Daily operations and locations
- Weather and sea state observations
- MBES and SSS survey line ID and start time
- Date and Time of MVP and TrueHeave (POSPac) files
- Navigation System Performance Checks, Bar Check Table, Vessel Water Level Tabulation and Sound Speed Comparison Table
- Systematic changes (i.e. SSS range scale change, equipment repairs or replacements)
- SSS Confidence Checks
- Significant SSS contacts or Bathy features
- Excessive Noise in the SSS/MBES records due to fish, vessel traffic, or surface noise
- Deviations from planned tracklines or Data Gaps
- System “crashes” or Position Outages
- Line Miles and Survey Statistics
- 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 port calls. Using this approach the lag between acquisition and data check-in at the home office was about one week. Near the end of the field work as it became more critical for the lag between acquisition and processing to be minimized, data was forwarded to the land courier via an offshore courier who visited the survey vessel within the study area. Upon receipt of a data disk, 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 MVP sound speed profiles 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. 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 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, cross lines, 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.

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

1. Convert the HSX and RAW data to the HDCS data format.
2. Load zoned, predicted tides or preliminary tides, if available.
3. Load daily TrueHeave files.
4. Load and apply concatenated sound speed profile data. Sound speed profiles were loaded with the CARIS <u>*nearest in distance within time*</u> correction method. During CARIS SVP Correction, the following correctors were applied: sound speed, heave, pitch, roll and waterline.
5. Merge data to apply vessel offsets/alignment, position, gyro, tide, and dynamic draft correctors to bathymetry. HIPS/SIPS computes the fully corrected depth and position of each sounding during the Merge process.

6. Compute TPU (Figure 6). Total Propagated Uncertainty (TPU) is calculated in CARIS HIPS from contributing uncertainties in the echosounder, positioning and motion sensor measurements as well as uncertainties associated with sound speed and water level correction. The standard CARIS devicemodel.xml was used to create the HVF. Tide uncertainty values for measured and zoned tides were provided in the OPR-J377-KR-15 Tides Statement of Work as 0.30 meters at the 95% Confidence Level, 0.15 meters at 1 standard deviation. 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. Despite the fact that the MVP was deployed for a cast approximately every 15 minutes a conservative sound speed profile uncertainty value of 2 m/s was chosen for the measured sound speed due to the relatively dynamic sound speed throughout the site.

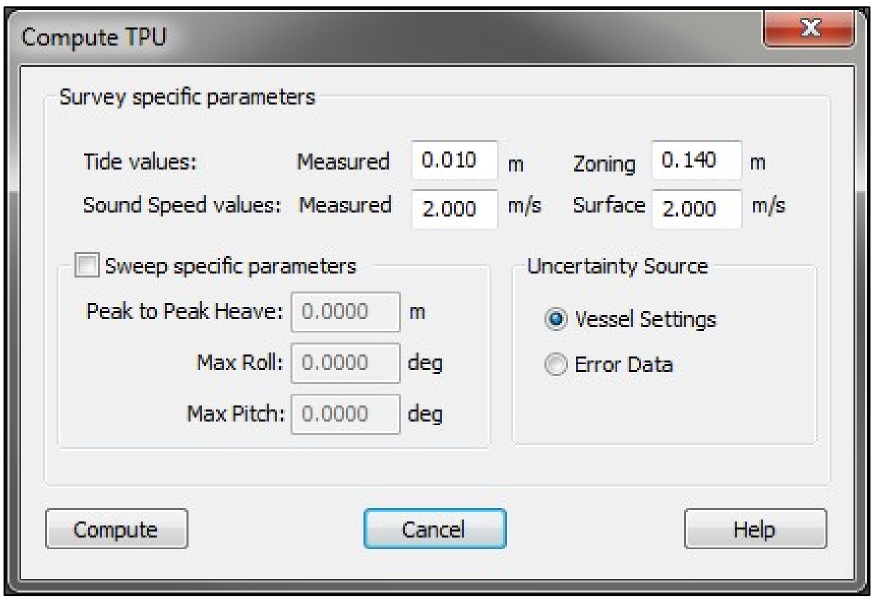


Figure 6. Uncertainty values entered into the Compute TPU process in CARIS HIPS & SIPS.

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 methodologies: Complete Multibeam, Set Line Spacing, and Object Detection. Depending on the MBES acquisition methodology employed and in consideration of water depth, various CUBE surfaces were created to evaluate coverage, e.g. 4-meter resolution CUBE for "Set Line Spacing" MBES coverage or 2-meter resolution CUBE for "Complete Multibeam" in water depths greater than 18 meters. Both in the field and during home office processing, 0.5-meter resolution CUBE surfaces were used to evaluate coverage for item investigations.

After the lines were run through the batch process, 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 cross lines, and to detect potential systematic position, motion, tide, or sound velocity errors. Highest standard deviation values were observed over obstruction features, seafloor depressions and in the vicinity of offshore platforms.

Coverage surfaces were reviewed for any data gaps in excess of 3 nodes while the Object Detection and Complete Coverage surfaces were reviewed with respect to the holiday definition described in Section 5.2.2.4 of the HSSD. All surfaces were reviewed to ensure that Object Detection Coverage was obtained over significant shoals and features. Density layers were reviewed to verify that 95% of all nodes in the Set Line Spacing coverage surfaces were populated with at least 3 soundings and that 95% of all nodes in the Object Detection and Complete Coverage surfaces were populated with at least 5 soundings.

III. Data Cleaning and Processing

Line attitude and navigation data were reviewed in their respective CARIS editors to ensure that there were no problems with the correctors, such as gaps in attitude data or navigation jumps.

The CARIS Swath Editor was used to clean noise, multipath returns, and gross fliers which are most easily reviewed and edited in this time-based (ping) display. Soundings were colored by depth and reviewed in multi-directional profile and 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. A complete final sounding review was performed for the entire survey coverage area using Subset Editor and tracked with subset tiles.

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.

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

"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 that 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. Section 5.2.1.2 of the HSSD offers the following guidance on the criteria for choosing designated soundings:

- Depths 20 meters and less: A designated sounding may be selected when the difference between the gridded surface and reliable shoaler sounding(s) is more than one-half the maximum allowable TVU at that depth (≤ 0.28 meters at 20 meters of water or less).

- Depths greater than 20 meters: A designated sounding may be selected when the difference between the gridded surface and reliable shoaler sounding(s) is more than the maximum allowable TVU at that depth (≤ 0.65 at 32 meters of water).

In the case of Project OPR-J377-KR2-15, the survey area depths ranged between approximately 3 meters and 50 meters. Therefore, with the HSSD criteria in mind, and taking a conservative approach, a designated sounding flag was applied to features taller than 0.25 meters for depths less than 20 meters and 0.50 meters for depths greater than 20 meters. Designating a sounding ensured that the least depth of all features insignificant or significant in height resolved with the MBES would be adequately represented in the final surfaces. Near nadir soundings were designated as least depths on features in lieu of outer beam soundings whenever possible. In the instance that soundings from multiple MBES lines suggested different least depths, the contact heights measured in side scan editor were reviewed to assist with least depth designation 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 Raster Nautical Charts (RNCs) and Electronic Nautical Charts (ENCs). The final chart comparison was completed using charts downloaded from the OCS website, nauticalcharts.noaa.gov, on September 11, 2015. CARIS Notebook and CARIS HIPS & SIPS were utilized to complete chart comparisons with the RNCS and ENCS. This was accomplished by overlaying surveyed depths in the form of finalized surface layers, sounding layers and S-57 features over the RNCs and ENCs. Surveyed data were compared to all charted depths, contours and features, with agreements, discrepancies and disprovals addressed in each survey's descriptive report.

B.2.1.1 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-terabyte, USB-3 hard drive numerous times each day. During each port call (and sometimes more frequently) 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 $\sqrt{2}$.

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

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

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

Example for a 4-meter BASE surface in depths less than 40 meters:

CDS = 0.005
CDM = 4 / (√2) = 2.83

The CDS radius maximum value (0.005 * 40 = 0.2 meters) will not exceed the CDM value (2.83 meters) for the maximum depth, and therefore the Density Attribute Layer will represent those soundings that lie within a fixed radial distance (2.83 meters) for all nodes.

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

Table 5
CUBE Parameters Applied in Surface Generation

Grid Resolution (m)	Capture Distance Scale (%)	Capture Distance Minimum (m)
0.5	0.5	0.35
2.0	0.5	1.41
4.0	0.5	2.83

Set Line Spacing Coverage requirements in Section 5.2.2.3 of the HSSD prescribes a grid resolution threshold of 4 meters to prove MBES coverage in water depths less than 40 meters. However, as mentioned earlier and shown in Table 5, due to the varying water depths and MBES acquisition methodologies employed during Project OPR-J377-KR-15, three grid sizes are included with the project deliverables. Project Instruction Coverage Requirements are included below:

- All waters in survey area less than 20 meters:
  - A) Complete MBES with backscatter, or
  - B) 100% SSS with concurrent set line spacing MBES with backscatter.

- Greater than 20 meters water depth:
  - Complete Multibeam with backscatter.

All significant features were developed with MBES to meet Object Detection coverage standards. Object detection surfaces were centered over the significant features and covered a minimum area of 400 m^2.

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 Set Line Spacing Coverage grids were "finalized" in CARIS according to depth. Per the CARIS HIPS & SIPS 7.1 Users Guide, a finalized BASE surface "is a finished version of the surface that is ready for export." Designated soundings were incorporated into the BASE surfaces when finalized making certain the least depth sounding was honored in the grid. Set Line Spacing and Complete MBES coverage surfaces were finalized according to depth, such that 4-meter resolution Set Line Spacing Surfaces honored a depth range from 0 to 20 meters and the 2-meter resolution Complete MBES coverage surfaces honored a depth range from 18 to 40 meters.

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

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.

CARIS HVFs were created to convert EdgeTech JSF data files. Different vessel files were created for the two collection configurations; towed and rigid pole mount. All Preprocess EdgeTech JSF data were converted to the HDCS data format in CARIS' Conversion Wizard. Unlike the EdgeTech Discover XTF format imagery the EdgeTech JSF format imagery does not record bottom tracking. As discussed below the JSF format imagery was bottom tracked in CARIS SIPS which is an additional step during data processing. The additional work was deemed worth the effort for the resultant imagery which experience has shown is superior to that recorded in EdgeTech's XTF format.

For the towed SSS configuration, towfish positions were converted from the JSF sensor position field and fish heading was computed from course made good (CMG) from vessel navigation. The towed SSS vessel file is a "zero" configuration because all tow point offset and layback calculations were performed real-time in HYPACK SURVEY; therefore, no additional towfish position calculations were necessary in CARIS HIPS/SIPS. Since HYPACK performed the layback calculation not all sensor data, i.e. cable out and ship position, were imbedded in the CARIS processed files. Therefore, post-conversion, position and sensor data were inserted into the SSS HDCS lines by parsing the sensor data from the HYPACK RAW files with the CARIS Generic Data Parser.

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.

The fixed mount SSS vessel file is <u>not</u> 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 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 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. Like the towed SSS configuration, the fixed mount bottom tracking and altitude field populating was accomplished using CARIS.

For the towed SSS (4200-MP) both the low and high frequencies were converted. For the fixed mount SSS (4125) only the low frequency was converted.

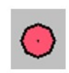
Navigation time stamp irregularities were edited and navigation data were reviewed in the CARIS Navigation Editor. Each side scan line was reviewed in CARIS Attitude Editor to ensure that the towfish attitude, depth, and cable out (if applicable) were properly represented and that there were no gaps or problems with these parameters.

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 possible and then correct any automated bottom tracking errors by manually re-digitizing the bottom trace.
2. Slant range correct the side scan lines with a resolution of 0.03 meters to convert the across track axis from time to distance and remove the water column from the imagery. Calculate and apply an average speed of sound value from sound speed casts acquired during the corresponding day of side scan acquisition. Sound speed values used for slant range correction varied between 1517 m/s and 1538 m/s. The slant range correction sound speed used for each day of side scan acquisition is noted in the processing log.
3. Lines were AVG corrected to normalize angular response across the swath.

During pre-survey planning, the CARIS HIPS and SIPS ContactFeatures.hcf file located in the CARIS\HIPS(x64)\System directory was modified by OSI to include additional Contact Feature types with which to classify contacts in Side Scan Editor. The additional contact types are included in Table 6 below, along with their graphical display in CARIS HIPS and a brief description of the conditions under which the contact type is selected. The OSI-modified ContactFeatures.hcf file is provided within the project deliverables Ancillary_Data directory for AHB's use during the survey acceptance review.

Table 6
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. (ask for 2nd opinion if unclear)	
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.	
Post/Pile/Dolphin (detached) **PILPNT** Dolphins, posts, or piles. Freestanding/detached from larger structure * Use for signs on posts – if charted use NAVAID; Do not use "pile" in remarks, use "piling"	
Navigational Aids (charted) **NAVAID** Navigation Aids that can be verified against raster chart, ENC, or CSF	
Flagged by QAQC **QAQC** * Do not use during contact picking, for review purposes only.	
Possible Gas Leak **BUOYS** A depression with possible gas bubbles (i.e. tall shadow, bubbles in water column); Confirm in MB	
Cable **NPCA** Linear features that are not a pipeline	
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. An example of an attributed contact selected in Side Scan Editor is displayed in Figure 7.

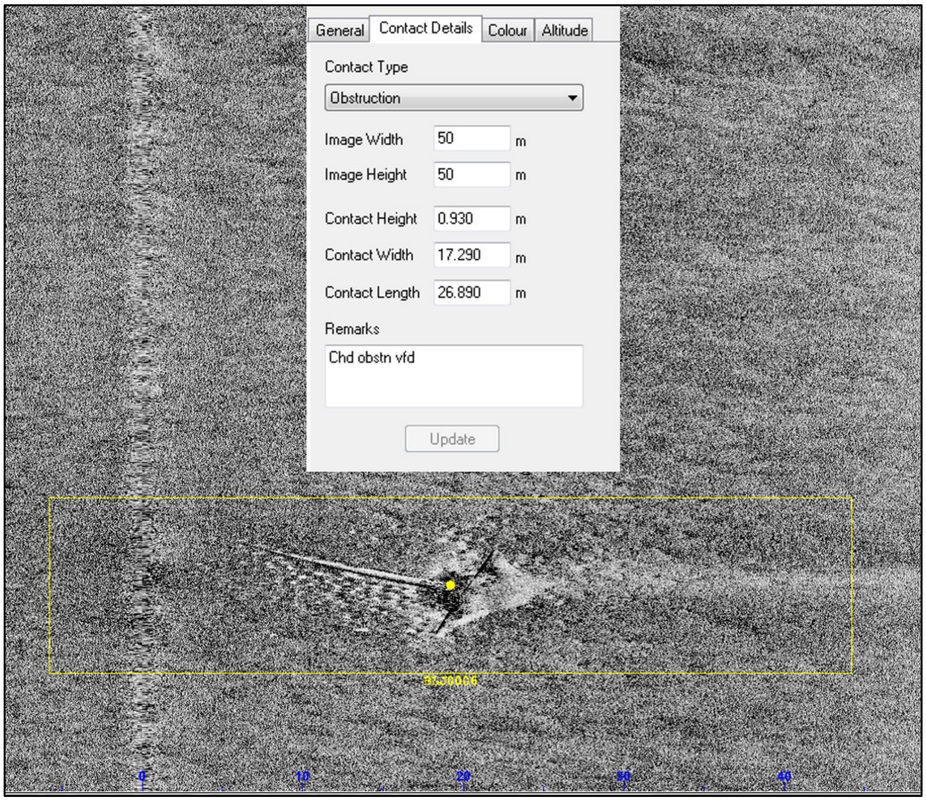


Figure 7. Attributed side scan contact selected in Side Scan Editor waterfall display.

SSS lines were reviewed a minimum of two times by more than one 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 & 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, especially in light of the 12.5 x towfish height image trimming discussed earlier and the fact that only 100 percent SSS coverage was required, the 100 percent coverage mosaic was generated frequently in CARIS HIPS and SIPS using the Mosaic Editor. First, all lines from the 100 percent coverage HVF were selected and GeoBars (Georeferenced Backscatter Rasters) were created for each line. The GeoBars were generated with a resolution of 0.15 meter and were saved in the HDCS line folder for each side scan line. With all the GeoBars loaded for the 100 percent side scan coverage, mosaics were generated with a 0.25-meter resolution.

During initial home office processing, the 100 percent coverage 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 initial mainscheme coverage. After the completion of survey and processing operations, the final 100 percent coverage mosaic was 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 Object Detection and Accuracy Requirements

As noted earlier, two SSS systems were employed on this project.

For the towed SSS, an EdgeTech 4200-MP, the “high speed” mode was utilized. In this mode the system has two pulses in the water during each ping cycle effectively doubling the ping rate of traditional side scan sonar systems. This system was operated at either the 50-meter or 75-meter range scale.

For fixed mount SSS operations utilizing an 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 with two minor exceptions noted below.

For the SSS systems and operating parameters described above, the limiting vessel speed of the “slowest” system, the EdgeTech 4125 single ping system, is calculated to be 9.72 knots. In only two instances did the vessel speed meet or exceed 9.72 knots when the EdgeTech 4125 was in operation. The period of these occurrences, both in Survey H12733, were of relatively short duration along the respective lines. These data are included in CARIS Vessel “OE_SSS_Mounted_JSF.” The files/lines discussed herein, both of which were acquired on July 2, 2015 (DN 183), include 20150702060537.jsf and 20150702070129.jsf and were converted into their like-named CARIS Day folder in the deliverable HDCS directory.

As mentioned earlier, at times, especially in Survey H12733, two SSS units were operated simultaneously. This was the case during the period described above. In order to meet the HSSD along track ping density specification, imagery from the EdgeTech 4200 was also reviewed. The EdgeTech 4200, operating in “Multi Pulse” mode, far exceeds the pulse repetition interval required to meet the HSSD ping density requirement. Review of the coincidental EdgeTech 4200-MP imagery did not reveal any feature that might have been “missed” during the period of non-compliant EdgeTech 4125 single pulse system runs. Redundant SSS coverage for the two runs discussed above is included with the project deliverables. However, only the EdgeTech 4125 imagery is used to populate the coverage mosaic in this area.

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 overlapping coverage of 20 meters. Given that the Autopilot maintained line steering within 2 meters of the planned line and the towfish was generally flown at a height as not to diminish the scanning range, full swath coverage was achieved on the majority of mainscheme lines. 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 Significant 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 7.

Table 7
Significant Contact Selection Criteria

Surrounding Depth or Area	Significant Contact Height
≤ 20 meters	1 meter
> 20 meters	10% of surrounding depth

During field operations OSI used a more conservative approach when selecting contacts, to make certain that significant features would not be overlooked for further investigation or correlation in the MBES record. All contacts with a minimum 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.

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 contacts in the HIPS display window was also helpful during editing of bathymetry as an indicator to the hydrographer to anticipate noisy data. Fish contacts were not assigned heights.

Most side scan contacts were symbolized as point features; however, sections of exposed 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.2.2.5 Compression Methods Used for Reviewing Imagery

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

B.2.3 Sound Speed

B.2.3.1 Sound Speed Profiles

As mentioned earlier an ODIM MVP was used as the primary sound speed profiling device. On two occasions the ODIM MVP malfunctioned requiring, in one case, that manual sound speed profiles were acquired using an AML Base-X profiler. All automated and manual 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 handful 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 using the AML Base-X, the profiles were downloaded with a dedicated laptop computer as they were acquired, plotted for comparison to recently acquired casts, converted to HYPACK .VEL format and, as with each MVP cast, incorporated to HYSWEEP SURVEY platform for use by the program in real time.

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 AML Micro-X sound speed sensor

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 SVP files.

For the automated cast data, the ASCII CALC files logged with each MVP 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 survey level SVP file (ex: H12734_Master.svp) for use in sound speed correction of survey lines in CARIS HIPS.

The manual sound speed cast data, which included position, date, and time, were exported using a customized macro within the daily sound speed workbook to generate individual CARIS compatible SVP files on a per cast basis. These casts were appended to the cumulative master project SVP file (H12736_Master.svp) that was kept up-to-date throughout the project.

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

The CARIS Profile selection method used to apply sound speed correction was the "Nearest in distance within time" option. 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.

The frequent AML Base-X and MVP comparison casts acquired during the "UTC midnight" changeover were converted in Velocwin to generate ZZQ files used to compare the sound speed profiles with the "Weekly DQA" tool. The SVP comparison casts were not appended to the CARIS SVP file used for sounding correction. A listing of DQA results is included in DR Separate II.

B.2.3.2 Surface Sound Speed

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

B.2.4 Horizontal and Vertical Control

B.2.4.1 Horizontal Control

RTK GPS positioning and water level determination were employed during pre- and interim-survey MBES patch testing, pre-survey 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.

B.2.4.2 Vertical Control

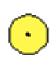
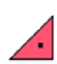
Predicted, Preliminary and Verified tides were downloaded from the CO-OPS SOAP web services website and were re-formatted as TID files to be used in CARIS HIPS tide correction. With OC-OPS approval OSI removed high-frequency noise in the tide curve via application of a fourth-order, zero-lag, Butterworth low-pass filter using a sampling frequency of 120 with a cut-off frequency of 5.

The preliminary tidal zoning file (ZDF) that was provided by CO-OPS with the OPR-J377-KR-15 Tides Statement of Work was used when applying the tide correctors from the Pilots Station East (876-0922) gauge in CARIS HIPS. The time and height corrections in the zoning file were used to extrapolate the water level measured at the tide gauge to each discrete tide zone. The zoned tide correctors were then applied to the soundings.

B.2.5 Feature Verification

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 8.

Table 8
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:

- Object Detection MBES coverage was obtained over significant SSS contacts.
- Charted soundings were verified or disproved with MBES coverage.
- 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 0.5 meters were created over the investigated features. The density layers were reviewed to verify that the Object Detection Coverage requirement of 5 soundings per node was met. Least depths were designated on all verified features and significant contacts.

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 were included in the FFF.

I. SSS Contact File

All SSS contacts, point and linear features, were exported from HIPS and SIPS to an ASCII file and imported into a Notebook HOB File. Individual contacts were correlated manually with respect to available overlapping SSS coverage, 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 Customized Attributes as specified in the "Side Scan Sonar Contact Points" table from Section 8.2 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: 201506221223110010.

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 in S-57 .000 format was created in CARIS Notebook beginning with the "Assigned" features from the OCS-provided CSF as its base. The FFF includes new survey features, updated and disproved charted features, and Meta-Objects. The FFF is submitted in the WGS84 datum, unlike all other project deliverables that are submitted in the NAD83 datum.

OSI followed the feature attribution guidance in Section 8.2, S-57 Format Features Deliverables, of the 2014 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)."

New or Updated point features' depths (VALSOU – value of sounding) and positions were imported into Notebook 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 8.2 and Appendix 8: Feature Attribution 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,H12733. 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, AWOIS 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 8.2 of the HSSD. The required attributes vary with S-57 object class (i.e. OBSTRN, OFSPLF, SBDARE), but may include:

- WATLEV (Water Level Effect) – updated for OBSTRN features
- VALSOU (Value of Sounding) – updated for OBSTRN features
- CATOBS (Category of Obstruction) – updated for OBSTRN features (when applicable)
- TECSOU (Technique of Sounding Measurement)

- QUASOU (Quality of Sounding Measurement)
- NATSUR (Nature of Surface) – updated for SBDARE features
- NATQUA (Nature of Surface, Qualifying terms) – updated for SBDARE features
- COLOUR (Color) – updated for SBDARE features

The required S-57 Meta-Object, M_COVR (Coverage) is also included in the FFF, with the required attributes updated as specified in Section 8.2 of the HSSD.

B.2.6 Bottom Samples

Bottom sample positions were imported into CARIS Notebook from the HYPACK target file into the FFF. The bottom samples were classified as SBDARE (Seabed area) objects and attributed as instructed in Sections 7.1 and 8.2 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 cross line sounding data set was acquired at the start of acquisition, prior to collection of mainscheme coverage. Cross lines were run nominally perpendicular to mainscheme lines. Soundings from mainscheme lines and cross lines were compared periodically throughout survey operations using preliminary CUBE surfaces and using CARIS HIPS Subset Editor. Cross line 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).

The planned cross line mileage was > 8% of mainscheme mileage required in the HSSD for Set Line Spacing coverage and > 4% of mainscheme mileage required in the HSSD for Complete Multibeam coverage.

Statistical quality control information was generated periodically during data acquisition by comparing the beams of each cross line 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 only from mainscheme MBES data and a surface compiled only from cross line MBES data. The results from the difference surface creation and the statistical analyses are discussed in the descriptive reports for each survey.

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

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

Sound speed profiles were plotted by day to visualize the variation over time and space (Figure 8). Rapid increases or decreases in sound speed in the top 5 meters of the water column generally correlated with higher error in the sounding position, as evidenced by a “smile” or “frown” effect across the MBES swath. Surface sound speed logged in the raw HYPACK files was extracted and plotted for every line. High deviation and rapid changes in the surface sound speed over a line, were also an indicator of increased sound speed error in sounding correction, which was most severe in the outer beams (Figure 9). Lines that exhibited high variability in the surface sound speed were reviewed in the CUBE surface layers and in Subset Editor for excessive sound speed error. CARIS beam filters were used on lines that exhibited larger than acceptable uncertainty in the outer beams due to increased error in sound speed data. The beam filters were applied on a line-by-line basis.

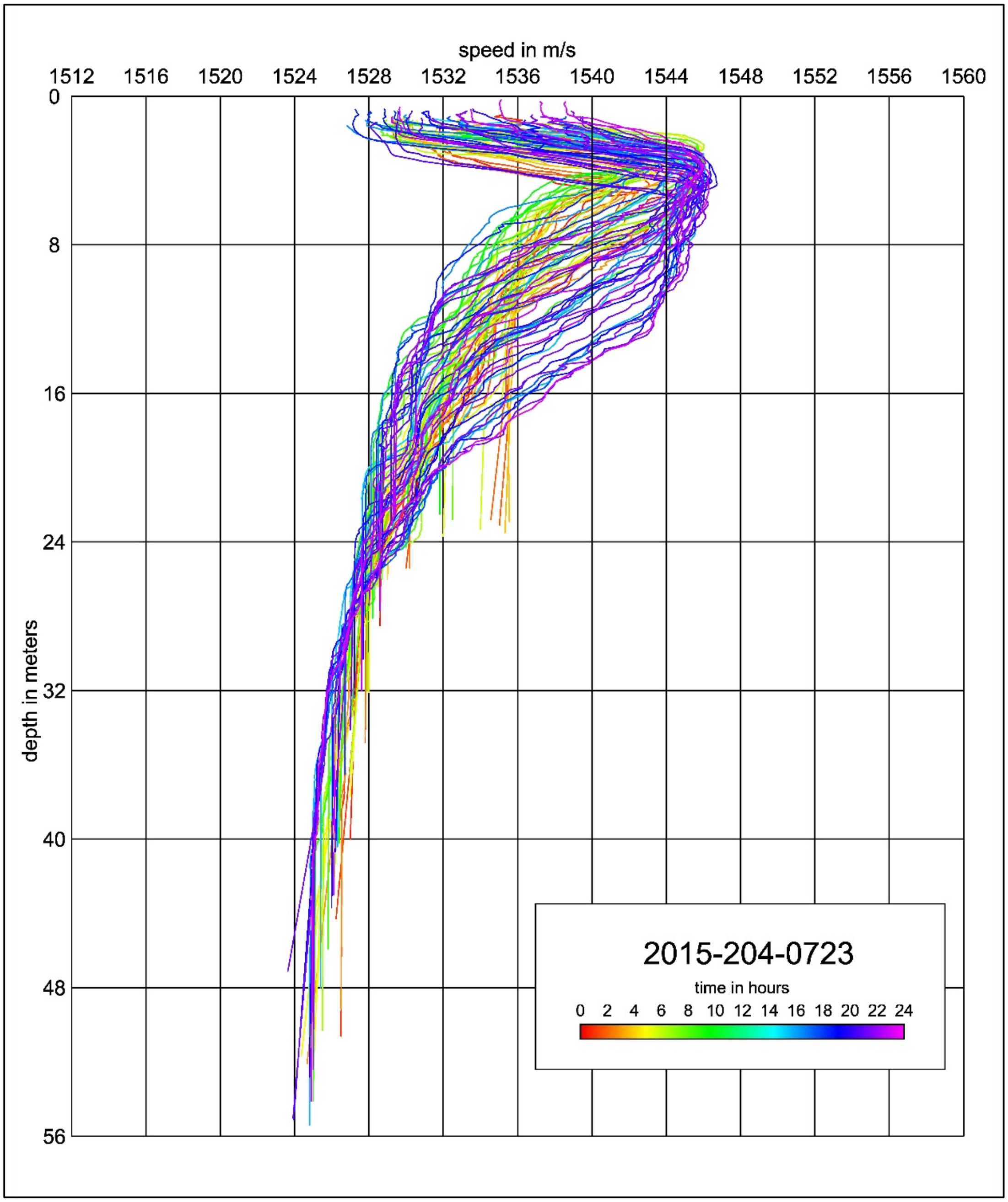


Figure 8. Plot of sound speed casts for July 23, 2015 (DN 204).

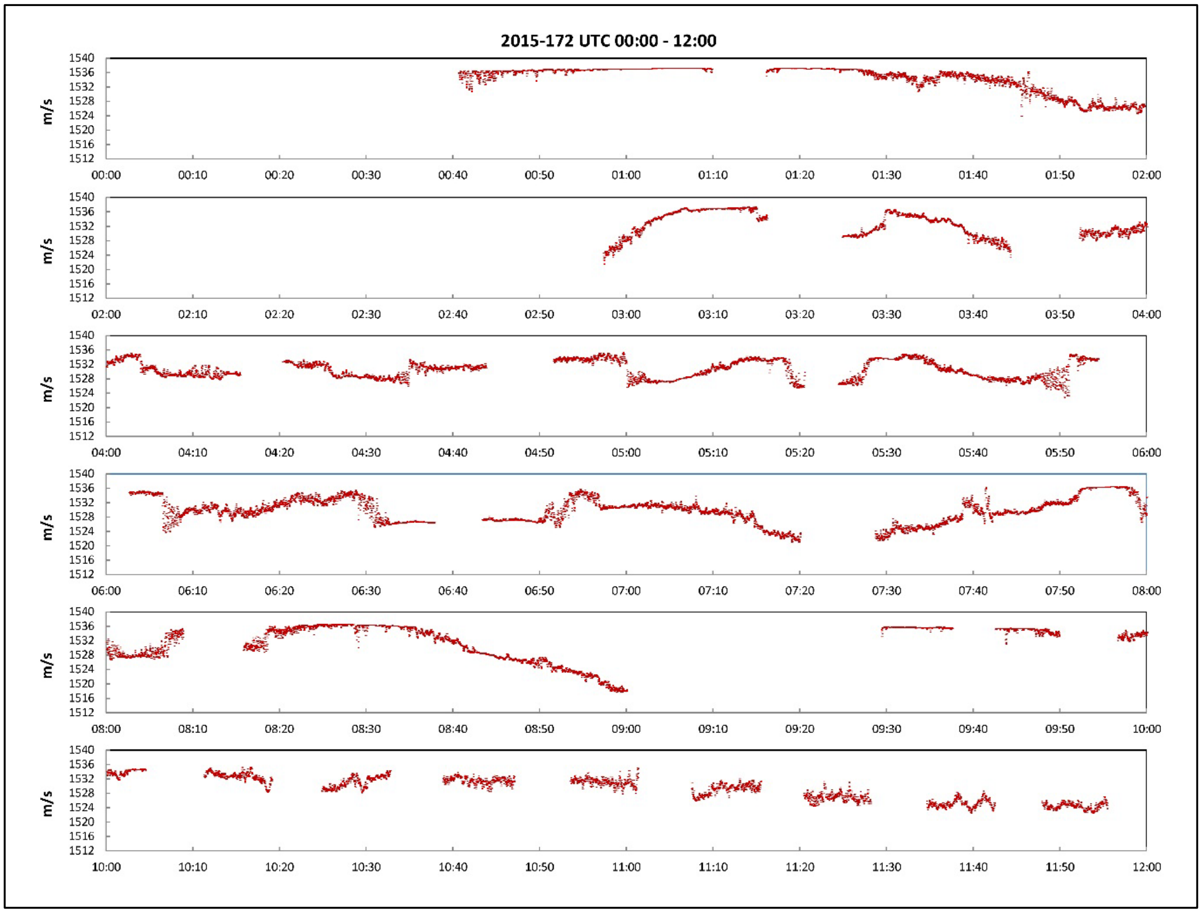


Figure 9. Surface sound speed plot by survey line for June 21, 2015 (DN 172) spanning 00:00 to 12:00 UTC.

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

B.4 Uncertainty and Error Management

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

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

The combined uncertainty value per sounding, or the Total Propagated Uncertainty (TPU), was calculated using CARIS HIPS. Standard deviation values for vessel offsets, motion, draft and alignment measurements were entered into the vessel HVF "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 9 lists the standard deviation and uncertainty estimates used for all measurements incorporated into the TPU estimates for the Reson 7125 echo soundings.

Table 9
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)	1.030
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)	0.14
Pitch Timing σ (sec)	0.01	Sound Speed Error Measured (m/s)	2.00
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.

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.

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.

A sound speed measurement uncertainty of 2 m/s was used in the TPU model. This is a conservative value considering that the overwhelming majority of project sound speed casts were acquired at a frequency of ≤ 15-minute intervals. Table 4-9 in the FPM recommends a value of 1m/s when casts are taken at this frequency. However, in consideration of the relative complexity of the sound speed profile in the project area and the few instances when manual profile casts were taken at a frequency of ≥ 15-minute intervals, the value of 2 m/s was chosen.

The surface sound speed uncertainty, 2 m/s, a conservative number per the FPM, was estimated from the surface speed of sound variability measured with the AML Micro-X.

C. CORRECTIONS TO ECHO SOUNDINGS

C.1 Vessel Configuration and Offsets

C.1.1 Description of Correctors

Vessel configuration parameters and offsets are measures of the location of the integrated survey systems in respect to an established vessel Reference Point (RP) that serves as XYZ point 0, 0, 0 within the vessel's reference frame. The RP on the *R/V Ocean Explorer* was the phase center or "bullseye" of the POS MV IMU. 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, the distance from the fixed mount SSS to the RP, and the distance from the top of the side scan sheave and the RP.

C.1.2 Methods and Procedures

As mentioned in prior sections, a total station was used to complete a full survey of the *R/V Ocean Explorer* prior to mobilizing the instrumentation for this survey. The POS MV IMU was mounted on a permanent plate close to the vessel's center of rotation (Figure 10). The total station was used to measure the offsets from the IMU bullseye to the POS MV GPS port and starboard antenna mounts, the Trimble 750 GPS antenna mount, the top of the towed SSS sheave and multiple port/starboard reference points including draft measurement points. When the multibeam/fixed mount SSS pole mount was fully deployed, the offsets between the MBES and fixed mount SSS transducers were related to the RP 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 the starboard side reference points allowing for an unobstructed measurement path.

The IMU and transducer mounting hardware were co-aligned employing a gyrocompass while the survey vessel was firmly secured to the dock in flat calm conditions. The vessel was made stable by pushing ahead with the engines against taut dock lines.

C.1.3 Vessel Offset Correctors

Instrument offsets input to the CARIS vessel configuration files are included in Table 10 below.

Table 10
***R/V Ocean Explorer* Sensor Offsets (see Figure 10)**

***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 Center 0,0,0	0.000	0.000	0.000	-0.480
POS MV GPS Antenna Phase Center Port	4.900	-1.200	5.730	5.250
POS MV GPS Antenna Phase Center Starboard	4.883	1.239	5.723	5.243
Positioning Integrity Comparison GPS Antenna Phase Center	2.713	0.948	7.972	7.492
7125 Transducer Phase Center Before Draft Change	0.629	2.870	-1.097	-1.577
7125 Transducer Phase Center After Draft Change	0.629	2.870	-1.400	-1.880
Fixed Mount SSS (EdgeTech 4125) Before Draft Change	1.139	2.870	-0.670	-1.150
Fixed Mount SSS (EdgeTech 4125) After Draft Change	1.139	2.870	-0.973	-1.453
Towed SSS (EdgeTech 4200) Top Of Sheave (Cable at top of sheave)	-4.073	1.156	3.160	2.680
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

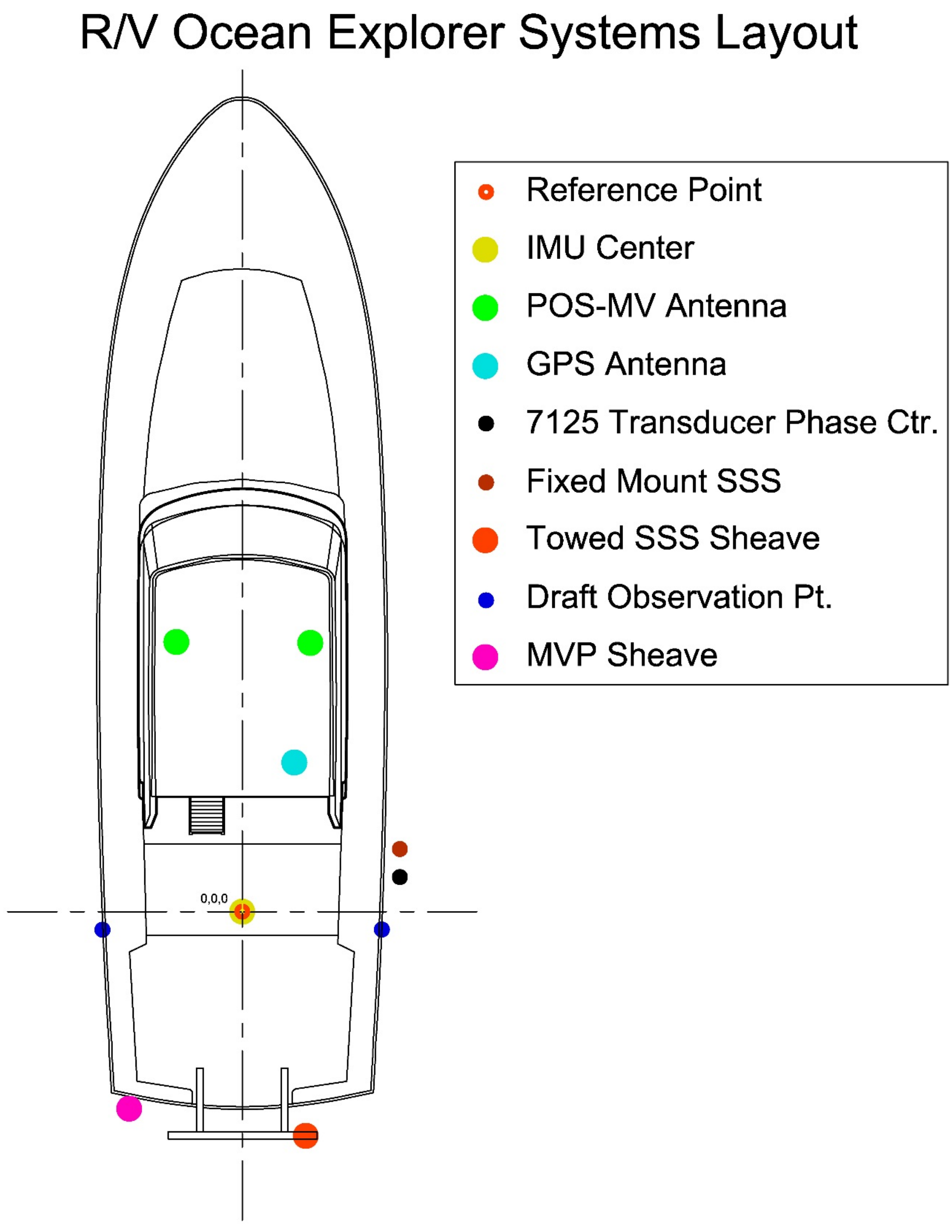


Figure 10. *R/V Ocean Explorer* systems layout.

C.1.4 Layback

C.1.4.1 Towed Configuration

Towed side scan sonar fish positioning was accomplished in real-time using HYPACK SURVEY configured using the Towfish device (towfish.dll). The Towfish device calculates fish position based on fixed sheave offsets relative to the RP, real-time ship position, cable out value, and towfish depth. The real-time calculation incorporates the Pythagorean Theorem and a multi-segmented cable discretization approach to predict how the towfish follows the main vessel. The layback calculation can be empirically fine-tuned by adjusting the number of cable segments and modifying the catenary factor. Field testing conducted prior to this survey indicated a 5-segmented cable model and a catenary factor of 1.0 were appropriate for this particular setup.

The real-time calculated towfish positions were output from HYPACK SURVEY and delivered to Discover via a serial cable connection. Discover then stored this position in the SSS data files. Since all required offsets and parameters were already incorporated into the stored position, the data were imported into a zeroed vessel file for CARIS SIPS processing.

Side scan sonar positioning accuracy 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 ranges and distances from the feature to confirm overall system accuracy. Test results are presented in DAPR Appendix II.

C.1.4.2 Fixed Mount Configuration

When operating the side scan in the rigid, fixed-mount configuration, 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 the vessel 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.

Like the towed SSS, 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 ranges and distances from the feature to confirm overall system accuracy. 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. A vertical offset to account for the distance from the RP to the water surface was updated nearly once a day into the Waterline Height field in the HVF. The Z-value and the waterline corrector added together equaled the static draft of the echosounder transducer phase center.

C.2.1.2 Methods and Procedures

Static draft measurements were taken during mobilization, prior to the start of the survey (June 18, 2015, DN 169), 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 fiberglass stadia rod or 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.

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 approximately 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.

The waterline height measurement was calculated nearly daily using the pressure sensor water level gauge method and the measure down values were acquired when the vessel was moored dockside and offshore during extremely calm conditions. The waterline height measurement was corrected to the vessel reference point and recorded in the acquisition log. Waterline height values calculated from physical measurement, “measure downs,” or the 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 the echosounder static draft.

C.2.2 Dynamic Draft

C.2.2.1 Description of Correctors

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

C.2.2.2 Methods and Procedures

Dynamic draft was measured on May 29, 2015 (DN 149) with the *R/V Ocean Explorer* configured for data acquisition with an average loading weight and vessel trim. Calibration test lines were acquired in water with a nominal depth of 12-21 meters; the sea-state was calm during collection. Data were acquired along tracklines approximately 2,000 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. Testing was conducted around the time of slack tide and 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. 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.

Table 11 summarizes the as-measured results of the settlement test. In populating the CARIS HVF draft table the settlement curve generated using the values shown in Table 11 was smoothed and densified using a 4^{th} Order polynomial curve fit in EXCEL. Settlement values entered into the CARIS HVF were taken from the smooth curve at regular speed intervals. These values are shown in Table 12.

C.2.2.3 Dynamic Draft Correctors

Table 11
***R/V Ocean Explorer* As-Measured Dynamic Draft Correctors**

RPM Both Engines	Speed M/S	Speed Knots	Dynamic Draft Meters
Static	0	0	0
Troll Setting 1	1.30	2.53	-0.010*
Troll Setting 2	2.14	4.16	-0.018
Troll Setting 3	2.70	5.26	-0.031
600	3.66	7.11	-0.045
700	4.11	7.99	-0.056
800	4.52	8.80	-0.100
900	5.20	10.11	-0.175

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

Table 12
***R/V Ocean Explorer* - Polynomial Curve Fit Dynamic Draft Correctors**
As entered into CARIS HVFs

Speed M/S	Speed Knots	Dynamic Draft Meters
1.03	2.00	0.006
1.29	2.50	0.010
1.54	3.00	0.013
1.80	3.50	0.017
2.06	4.00	0.020
2.31	4.50	0.023
2.57	5.00	0.025
2.83	5.50	0.028
3.09	6.00	0.032
3.34	6.50	0.037
3.60	7.00	0.043
3.86	7.50	0.052
3.99	7.75	0.057
4.12	8.00	0.064
4.24	8.25	0.072
4.37	8.50	0.080
4.50	8.75	0.091
4.63	9.00	0.102
4.76	9.25	0.115
4.89	9.50	0.131
5.02	9.75	0.148
5.14	10.00	0.167

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. The initial patch test of record was performed in Venice, LA on June 18, 2015 (DN 169). Data were acquired in accordance with HSSD April 2014 Section 5.2.4.1. Initial and interim patch testing of record was conducted in either Tiger Pass or the Mississippi River nearby Venice, LA in areas with relatively large relief or discrete bed forms respectively. The discrete bed forms consist of sand waves oriented nominally perpendicular to the Mississippi River flow. These areas were chosen in lieu of a traditional patch test area because an optimal patch test area, described in the HSSD as a “500-1000 meter long, 10-20 degree smooth slope perpendicular to the depth curve” is not readily available in the vicinity of the project area.

Throughout the course of the survey the multibeam pole was occasionally recovered (pivoted out of the water for transit and docking). Upon returning the pole to its deployed position an abbreviated patch test was performed. Specifically, a set of reciprocal lines were collected such that the patch test roll offset could be confirmed. Often the reciprocal lines consisted of mainscheme lines that were acquired during the course of the day that the multibeam pole was redeployed. As expected, due to the design of the substantial, indexed, multibeam mounting apparatus, the roll values were generally repeatable. However, on two occasions, a small change was detected in the roll offset. These changes are reflected in the Reson 7125 HVFs.

On July 5, 2015 (DN 186) the draft of the multibeam transducer was changed (made deeper). Prior to the draft change a verification patch test was performed to confirm the values in use at the time. Upon changing the transducer draft another patch test was completed to establish new angular offset values. These pre- and post-draft change patch tests were performed on July 4-5, 2015 (DN 185-186). Finally, verification patch testing was performed at the completion of the project on July 28, 2015 (DN 209). Patch test results of record are presented in DAPR Appendix II.

Pre- and interim-survey patch test calibrations were accomplished employing RTK GPS positioning. Interim roll check lines were acquired with the POS MV in DGPS mode. The close out patch test was conducted with the POS MV in DGPS mode. However, these data were processed using “single base” IAPPK positioning.

For each 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 11) was primarily used to determine offset values. All patch test values were verified with the HYPACK HYSWEEP patch test routine (Figure 12).

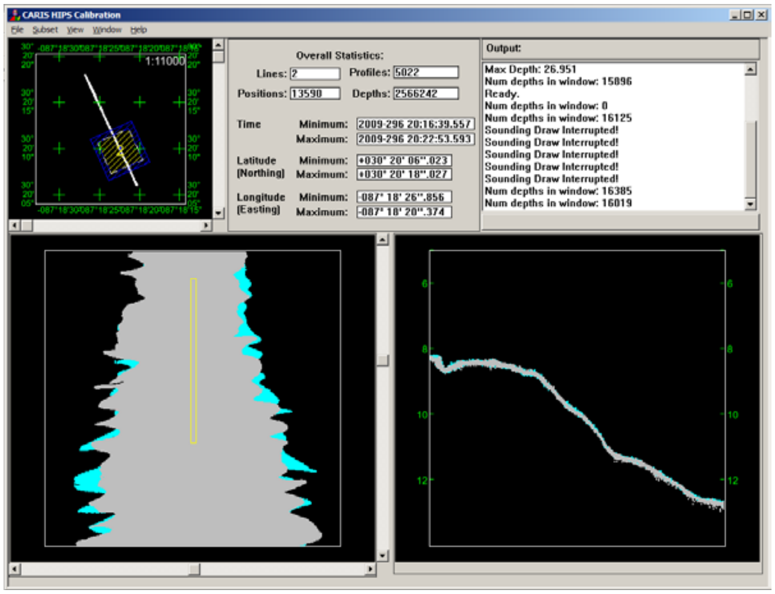


Figure 11. CARIS HIPS Calibration Tool.

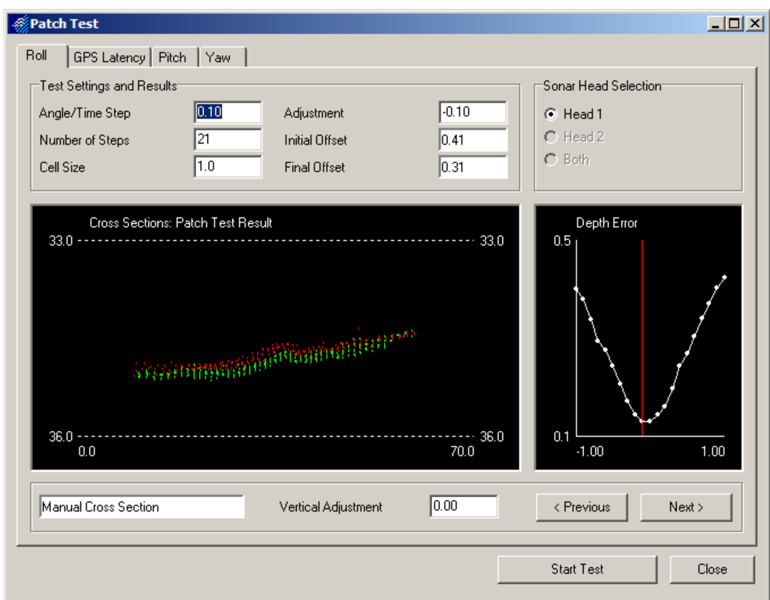


Figure 12. HYPACK HYSWEEP Patch Test Utility.

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 13. The patch test results were of high quality and repeatability.

The initial performance test of record was performed within the survey area on June 21, 2015 (DN 172). On July 5, 2015 (DN 186) the draft of the multibeam transducer was changed (made deeper). A performance test of the deeper draft configuration was completed on July 8, 2015 (DN 189). Finally, verification performance testing was performed at the completion of the project on July 28, 2015 (DN 209).

In practice a performance surface was created from a high density, near nadir sounding set collected with the Reson 7125. Ten MBES lines were acquired over a flat section of seafloor and processed in CARIS HIPS with the patch test bias values for timing, pitch, roll and yaw entered into the HVF. A port and starboard beam filter of 45 degrees was applied to the performance surface lines and a 1 m x 1 m Uncertainty Surface was generated from the processed soundings. Two performance check lines that were run perpendicular across the center of the surface were processed in CARIS HIPS as well; however, no beam filter was applied. The CARIS HIPS QC Report Utility was used to compare the beams of each performance check line to the performance surface to verify system accuracy. Performance test results of record are presented in DAPR Appendix II.

C.3.3 System Alignment Correctors

Table 13
MBES Patch Test Alignment Correctors

CARIS Patch Test Results	
Latency	0.00 sec
Pitch	-0.80°
Roll (DN 169 to DN 174)	-0.18°
Roll (DN 174 to DN 184)	-0.28°
Roll (DN 184 to DN 185)	-0.25°
Roll (DN 185 to DN 209)	-0.28°
Yaw (heading)	0.00°

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 was employed for motion, heading, and position determination. Manufacturer’s stated accuracy and resolution values are tabulated below.

Table 14
POS MV Specifications

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

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

C.5 Tides and Water Levels

C.5.1 Description of Correctors

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

C.5.2 Methods and Procedures

The water level station at Pilots Station East, LA (876-0922), is the reference station for predicted, preliminary observed, and verified tides for all hydrography for this project. The time and range ratio correctors for applicable zones were applied to all tide correctors in CARIS HIPS during the preliminary and final processing phases of this project. Predicted and preliminary observed zoned tides were applied to sounding data for preliminary processing. Verified tide data were downloaded from the NOAA CO-OPS internet page and applied with final zoning for all final soundings and BASE surfaces.

As mentioned previously the verified tide curve contains numerous short period "data spikes" of relatively large magnitude, e.g. some spikes were over 50% of the total range of tide on a given day. With OC-OPS approval OSI removed the spurious tide data via application of a fourth-order, zero-lag, Butterworth low-pass filter using a sampling frequency of 120 with a cut-off frequency of 5.

C.6 Sound Speed

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

C.6.1 Sound Speed Profiles

The sound speed profiles used to correct the echo soundings were primarily acquired with an ODIM MVP30 equipped with two sensors: a sensor that measured sound speed directly at 10Hz during its descent through the water column and a pressure sensor for profile depth measurement. Due to a depth sensor failure in the primary MVP sensor package, two sensor packages were employed during the course of the project (primary and spare). The primary MVP sensors (sound speed and depth) were calibrated May 12-13, 2015 (DN 132-133). The spare MVP sensors were calibrated on June 1-2, 2015 (DN 152-153).

As mentioned earlier an AML Base-X sound speed profiler was used to acquire sound speed profile casts for a short period during Project OPR-J377-KR-15. The sound speed and pressure sensors for this unit were calibrated May 12-13, 2015 (DN132-133). 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

Surface sound speed correctors were sent directly from the AML Micro-X sensor to the Reson 7125 TPU in real time to facilitate beam steering in equidistant mode and roll stabilization, a feature used throughout the survey. The AML Micro-X sound speed sensor was calibrated by the manufacturer on May 13, 2015 (DN 133).

D. APPROVAL SHEET

LETTER OF APPROVAL

REGISTRY NOS.
H12733, H12734, H12735, AND H12736

This report and the accompanying data are respectfully submitted.

Field operations contributing to the accomplishment of Surveys H12733, H12734, H12735, and H12736 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: 2015.11.17 17:33:52 -05'00'

George G. Reynolds
Ocean Surveys, Inc.
Chief of Party
November 19, 2014