U.S. Department of Commerce

National Oceanic and Atmospheric Administration

DATA ACQUISITION & PROCESSING REPORT

Type of Survey	*Field Examination*
Project No.	*S-K924-NRT4-19*

LOCALITY

Time Frame	*September*
State	*Texas*
Gen Locality	*Galveston*

2019

Chief of Party

LT John Kidd

Library and Archives

DATE	***October, 2019***

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service

Data Acquisition & Processing Report

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State(s):	Texas
General Locality:	San Jacinto River at the I-10 bridge

2019

CHIEF OF PARTY
LT John Kidd

LIBRARY & ARCHIVES

Date:

Table of Contents

List of Figures

Data Acquisition and Processing Report

NRT1
Chief of Party: LT John Kidd
Year: 2019
Version: 1
Publish Date: 2019-09-18

A. System Equipment and Software

A.1 Survey Vessels

A.1.1 S3005

<table>
<tr><td>Vessel Name</td><td colspan="2">S3005</td></tr>
<tr><td>Hull Number</td><td colspan="2">S3005</td></tr>
<tr><td>Description</td><td colspan="2">Aluminum Hydrographic Survey Vessel</td></tr>
<tr><td rowspan="3">Dimensions</td><td>LOA</td><td>31 ft</td></tr>
<tr><td>Beam</td><td>8.5 ft</td></tr>
<tr><td>Max Draft</td><td>1.5 ft</td></tr>
<tr><td rowspan="2">Most Recent Full Static Survey</td><td>Date</td><td>2018-01-29</td></tr>
<tr><td>Performed By</td><td>Joshua Bergeron & Alex Ligon</td></tr>
<tr><td rowspan="2">Most Recent Full Offset Verification</td><td>Date</td><td>2018-01-29</td></tr>
<tr><td>Method</td><td>NRT1 performed the survey of S3005 (Figure 1) by placing the launch within the network of established bolt landmarks located at the University of Southern Mississippi's facility on Stennis Space Center. Using a Leica TS02 Total Station, the bolt positions were established by a closed traverse survey. Critical equipment positions aboard S3005 were surveyed in a reference frame independent of that of the vessel from no less than three different established bolt positions. This method produced precise positions with known standard deviations. The reference frame was then shifted and rotated using the Leica software to several different origins, such as the phase center of the MB transducer.</td></tr>
</table>

Most Recent Partial Offset Verification	*Date*	2019-03-20
	Method	The offset between the Primary GPS and IMU was verified, using a steel tape, independently by three different members of NRT1. Measured values for the x, y, and z were then averaged and compared to the values obtained during the Offset Survey in 2018. All measurements and standard deviation were within acceptable limits.

Figure 1: S3005 in canal at Stennis Space Center

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Kongsberg EM2040C

S3005 is equipped with a hull-mounted Kongsberg 2040C, which operates at sonar frequencies in the 200 to 400 kHz range. The system has an output sample rate up to 60 kHz. Maximum angular coverage is 130 degrees allowing coverage of 4.3 times water depth. The system is roll and pitch stabilized. The system has water column logging capabilities.

<table>
<tr><td>Manufacturer</td><td colspan="3">Kongsberg</td></tr>
<tr><td>Model</td><td colspan="3">EM2040C</td></tr>
<tr><td rowspan="6">Inventory</td><td rowspan="6">S3005</td><td>Component</td><td>Sonar Head</td></tr>
<tr><td>Model Number</td><td>EM2040C</td></tr>
<tr><td>Serial Number</td><td>1127</td></tr>
<tr><td>Frequency</td><td>330</td></tr>
<tr><td>Calibration</td><td>2019-03-19</td></tr>
<tr><td>Accuracy Check</td><td>2019-03-21</td></tr>
</table>

Figure 2: Kongsberg EM2040C

A.2.2 Single Beam Echosounders

No single beam echosounders were utilized for data acquisition.

A.2.3 Side Scan Sonars

A.2.3.1 Edgetech 4125

The 4125 utilizes Edgetech’s Full Spectrum® CHIRP technology which provides higher resolution imagery. Operated at 400 and 900 kHz to collect imagery and detect obstructions on the sea floor.

Manufacturer	Edgetech		
Model	4125		
Inventory	*S3005*	*Component*	Tow Fish
		Model Number	4125
		Serial Number	N/A
		Frequency	400
		Calibration	2019-03-21
		Accuracy Check	2019-03-21

Figure 3: Edgetech 4125

A.2.4 Phase Measuring Bathymetric Sonars

No phase measuring bathymetric sonars were utilized for data acquisition.

A.2.5 Other Echosounders

No additional echosounders were utilized for data acquisition.

A.3 Manual Sounding Equipment

A.3.1 Diver Depth Gauges

No diver depth gauges were utilized for data acquisition.

A.3.2 Lead Lines

No lead lines were utilized for data acquisition.

A.3.3 Sounding Poles

No sounding poles were utilized for data acquisition.

A.3.4 Other Manual Sounding Equipment

No additional manual sounding equipment was utilized for data acquisition.

A.4 Horizontal and Vertical Control Equipment

A.4.1 Base Station Equipment

No base station equipment was utilized for data acquisition.

A.4.2 Rover Equipment

No rover equipment was utilized for data acquisition.

A.4.3 Water Level Gauges

No water level gauges were utilized for data acquisition.

A.4.4 Levels

No levels were utilized for data acquisition.

A.4.5 Other Horizontal and Vertical Control Equipment

No other equipment were utilized for data acquisition.

A.5 Positioning and Attitude Equipment

A.5.1 Positioning and Attitude Systems

A.5.1.1 Applanix POS MV-320 V-4

The POS MV V5 is a GNSS-aided inertial navigation system, which provides a blended position solution derived from both an Inertial Motion Unit (IMU) and an integrated GNSS receiver. The IMU and GPS receiver are complementary sensors, and data from one are used to filter and constrain errors from the other. This inter-dependence results in higher position accuracy and fewer errors. Position accuracy is displayed in real time by the POS MV software and is monitored to ensure that positioning accuracy requirements as outlined in the NOS Hydrographic Surveys Specifications and Deliverables (HSSD) were not exceeded.

In addition to position, the POS MV also provides accurate navigation and attitude data to correct for the effects of heave, pitch, roll and heading. When using differential correctors, the POS MV generates attitude data in three axes (roll, pitch and heading) to an accuracy of 0.02° or better. Heave measurements supplied by the POS MV maintain an accuracy of 5 cm or 5% of the measured vertical displacement (whichever is greater) for movements that have a period of up to 20 seconds

Manufacturer	Applanix				
Model	POS MV-320 V-4				
Inventory	*S3005*	*Component*	IMU	Primary Antenna	Secondary Antenna
		Model Number	7	GA830	GA830
		Serial Number	2425	11726	13473
		Calibration	2019-04-04	2019-10-01	2019-10-01

Figure 4: POS MV-320 V-4 GNSS-aided inertial navigation system

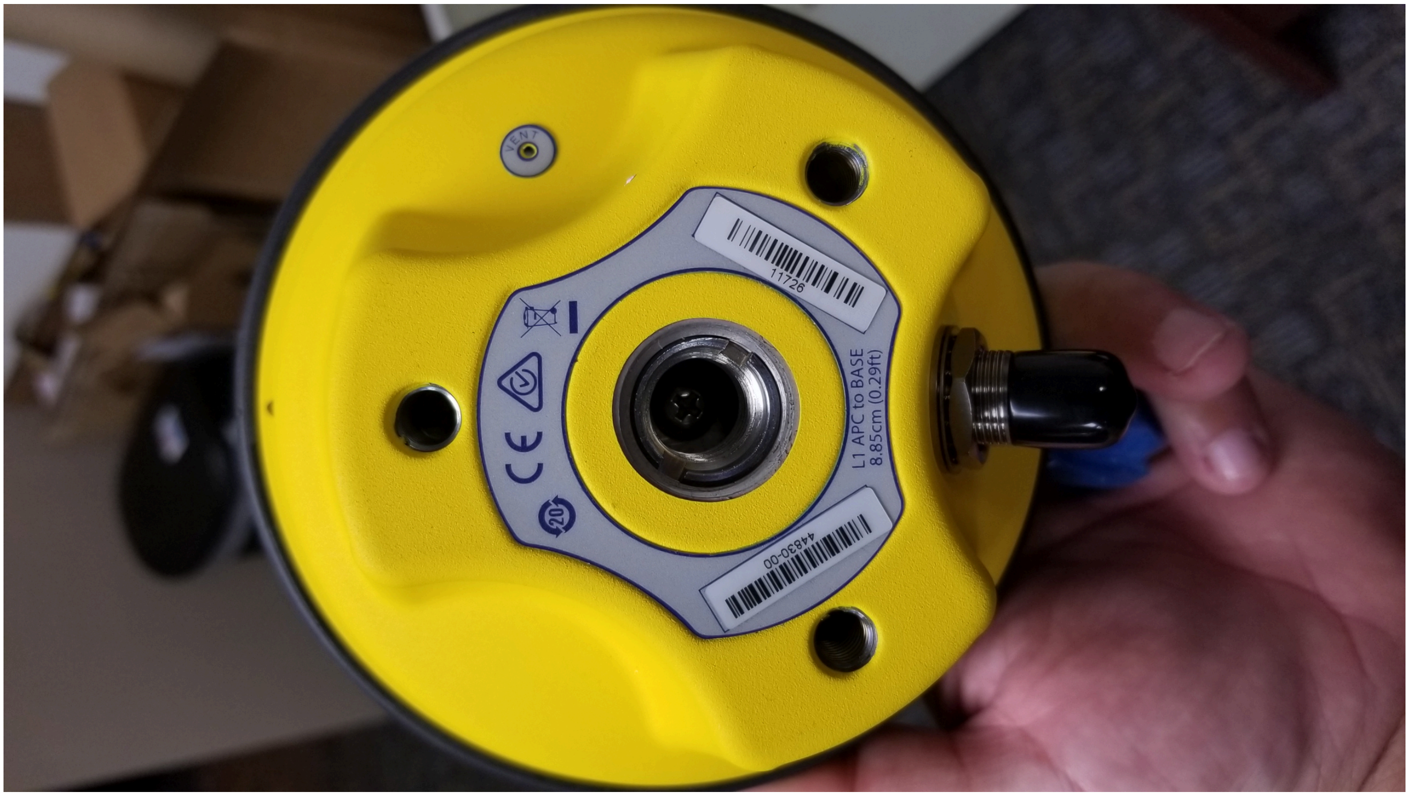


Figure 5: Primary Antenna Trimble GA830

Figure 6: Secondary Antenna Trimble GA830

A.5.2 DGPS

A.5.2.1 Trimble SPS 361

Auxiliary DGPS

<table>
<tr><td>Manufacturer</td><td colspan="3">Trimble</td></tr>
<tr><td>Model</td><td colspan="3">SPS 361</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">S3005</td><td>Component</td><td>Receiver</td></tr>
<tr><td>Model Number</td><td>SPS-361</td></tr>
<tr><td>Serial Number</td><td>5330K63691</td></tr>
<tr><td>Calibration</td><td>N/A</td></tr>
</table>

Figure 7: Trimble SPS-361

A.5.3 GPS

GPS equipment was not utilized for data acquisition.

A.5.4 Laser Rangefinders

Laser rangefinders were not utilized for data acquisition.

A.5.5 Other Positioning and Attitude Equipment

No additional positioning and attitude equipment was utilized for data acquisition.

A.6 Sound Speed Equipment

A.6.1 Moving Vessel Profilers

No moving vessel profilers were utilized for data acquisition.

A.6.2 CTD Profilers

A.6.2.1 Sontek Castaway

Measures conductivity and temperature of seawater versus pressure in depths up to 100 meters. GPS enabled for positioning, data is uploaded via bluetooth to an onboard laptop. Primary sound speed measurement device.

<table>
<tr><td>Manufacturer</td><td>Sontek</td></tr>
<tr><td>Model</td><td>Castaway</td></tr>
<tr><td>Inventory</td><td><table>
<tr><td>Component</td><td>CTD</td></tr>
<tr><td>Model Number</td><td>Castaway</td></tr>
<tr><td>Serial Number</td><td>CC1433005</td></tr>
<tr><td>Calibration</td><td>2018-05-22</td></tr>
</table></td></tr>
</table>

Figure 8: Sontech Castaway

A.6.3 Sound Speed Sensors

A.6.3.1 AML Oceanographic Micro-X

Used in real time for Kongsberg EM2040C beam steering based on surface sound speed.

Manufacturer	AML Oceanographic		
Model	Micro-X		
Inventory	*S3005*	*Component*	SSP
		Model Number	Micro-X
		Serial Number	10296
		Calibration	2019-03-04

Figure 9: AML Micro-X SV

A.6.4 TSG Sensors

No surface sound speed sensors were utilized for data acquisition.

A.6.5 Other Sound Speed Equipment

No surface sound speed sensors were utilized for data acquisition.

A.7 Computer Software

Manufacturer	*Software Name*	*Version*	*Use*
Caris	Base Editor	4.3	Processing
Caris	HIPS and SIPS	10.4 / 11.1 (project dependant)	Processing
NOAA	Pydro Charlene	v3.1.4 (r10246)	Processing
NOAA	Pydro Sound Speed Manager	v.2019.2.3	Processing
NOAA	PydroExplorer	v19.4 (r10246)	Processing / Acquisition
Trimble	POS View	9.91	Acquisition
Applanix	POSPAC MMS	8.4	Acquisition
Kongsberg	SIS	4.3.2	Acquisition
Edgetech	Discover	37.0.1.108	Acquisition

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

A.8.1.1 Custom Clam Shell

4" penetration grab sampler designed to collect unconsolidated bottom material.

Figure 10: NRT1 Bottom Sampler

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

B.1.1 Vessel Offsets

The MBES phase center is defined as the Reference Point (RP). Vessel offsets were surveyed to 0.0001 meter accuracy using a Leica Total Station during a Static Survey and are verified annualy through a verification survey. The Vessel Survey Results, listed in the table below, reflect the values used for the Reference to IMU Target and Reference to Primary GNSS Lever Arms in the MS POSView Lever Arms & Mounting Angles. The offsets and associated standard deviation were transformed into the Caris HVF Reference Frame for input into the S3005 Caris HVF TPU data table. Additional detailed information is available in the Vessel Offset Report within the Appendices.

Vessel	S3005						
Echosounder	Kongsberg EM2040C						
Date	Sept 1, 2017						
Vessel Survey Results TRA ORIGIN — **North positive, East positive, Down positive**							
Vector	Northing	VCS Easting	DOWN	Ortho	Sd North	Sd East	Sd Height
TRA to NAV	4.1864	-0.8110	-3.1889	3.1889	0.0032	0.0029	0.0027
TRA to MRU (REF to IMU)	-0.0147	-0.0187	-0.3971	0.3971	0.0034	0.0030	0.0028
TRA	0.0000	0.0000	0.0000	0.0000	0.0032	0.0026	0.0024
HVF Reference Frame TRA ORIGIN — **(Y) North positive, (X) East positive, (Z) Down positive**							
Vector	Easting (X)	Northing (Y)	DOWN (Z)	Ortho	Sd North	Sd East	Sd Height
TRA to NAV	-0.8110	4.1864	-3.1889	3.1889	0.0032	0.0029	0.0027
TRA to MRU	-0.0187	-0.0147	-0.3971	0.3971	0.0034	0.0030	0.0028
TRA	0.0000	0.0000	0.0000	0.0000	0.0032	0.0026	0.0024
HVF TPU value Offsets — **(Y) North positive, (X) East positive, (Z) Down positive**							
Vector	Easting (X)	Northing (Y)	DOWN (Z)	Ortho	Sd North	Sd East	Sd Height
NAV to TRA	0.8110	-4.1864	3.1889	-3.1889	0.0032	0.0029	0.0027
MRU to TRA	0.0187	0.0147	0.3971	-0.3971	0.0034	0.0030	0.0028

Figure 11: Vessel Static Offset Survey Results

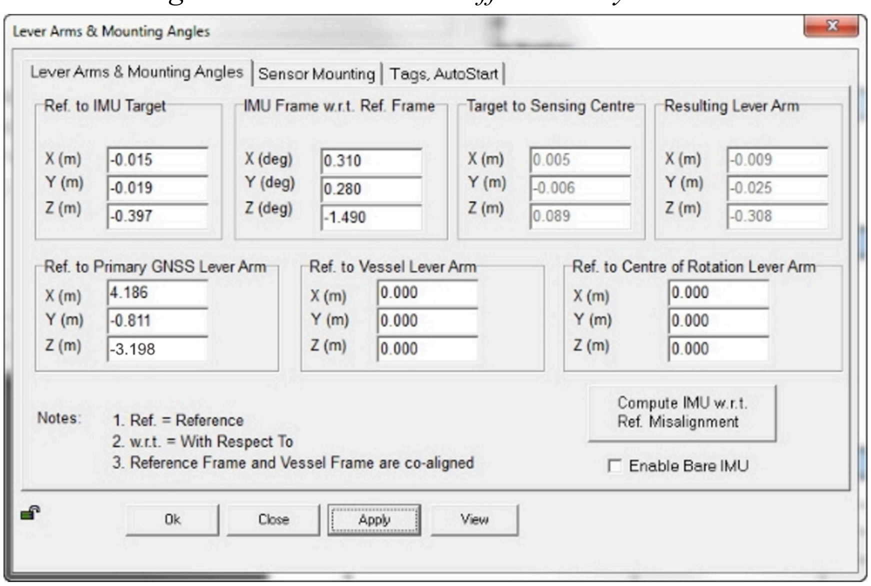


Figure 12: POS offsets as of September 19, 2019

B.1.1.1 Vessel Offset Correctors

Vessel offset correctors were not applied.

Survey Offsets were verified through independant repetition during the 2019 HSRR with an average standard deviation of 0.018 m and an average difference of 0.028 m between the 2019 verification survey results and the 2018 vessel configuration survey. Additional detailed information is available in the Vessel Offset Report within the Appendices.

2019 HSRR Verification Survey Results

	Primary GPS Phace Center to IMU target						
	Colin	Alex	Josh	AVG	STD	dif	VCS 2018
x	4.260	4.263	4.230	4.251	0.018	0.051	4.2005
y	0.800	0.809	0.800	0.803	0.005	-0.007	0.7960
z	2.750	2.746	2.800	2.765	0.030	0.026	2.7918

Verification survey results of longest lever arm

On September 19, 2019, we upgraded both of the POS antenna to the above specified Trimble GA830. The new POS offsets reflect the 0.0089 m (Z value) phase difference between the old GA530 and the new GA830. A new GAMS was completed after instalation.

	Phase center to antenna reference point (cm)	Antenna reference point to S3005 mount (cm)	Total distance from S3005 mount to antenna phase center (cm)	Difference in antenna phase center hieght (cm)	
GA530					
port	3.96	14.4	18.36		
star	3.96	14.7	18.66		
GA830					
port	8.85	10.4	19.25	0.89	0.0089 meters
star	8.85	10.7	19.55	0.89	0.0089 meters

GA830 installation offsets.

B.1.2 Layback

NRT1 pole mounts their 4125 using a Universal Sonar Mount attached to the port side of S3005. Position of the towfish is adjusted in the Caris HVF for corrected position.

SSS Offsets

	Applanix ref frame	Colin	Alex	Josh	AVG	STD
bow/stern	x	-0.996	-0.949	-0.900	-0.948	0.048
port/stbd	y	-1.633	-1.653	-1.615	-1.634	0.019
waterline		0.916	0.863	0.900	0.893	0.027

Figure 13: SSS Offsets

Layback correctors were not applied.

B.2 Static and Dynamic Draft

B.2.1 Static Draft

A tidestaff gauge positioned at a marked location alongside S3005 was referenced in height to the face of the multibeam transducer by calculating the difference between the measured height of the tidestaff gauge and the transducer to leveled ground while the vessel was trailered. This offset represented the distance from the bottom of the tidestaff to the transducer's face. The vessel was then launched fully fueled, equipped with its survey gear, and normally crewed for survey. The tidestaff gauge was then positioned at its marked position and independently read at the waterline by each member of the crew -taking care to level the boat by sight to the horizon. These measurements were averaged and added to the gauge / transducer offset in order to estimate the static waterline offset.

Figure 14: Static Draft Gauge made from tide staff

	2019 HSRR Static Survey Results						
	Colin	Alex	Josh	AVG	STD	DIF	Original Waterline
Waterline in ft	0.7500	0.7400	0.7500				
Waterline in m	0.2286	0.2256	0.2286				
Gauge Offset	0.3220	0.3220	0.3220				
Waterline	0.5506	0.5476	0.5506	0.550	0.0018	0.0266	0.523

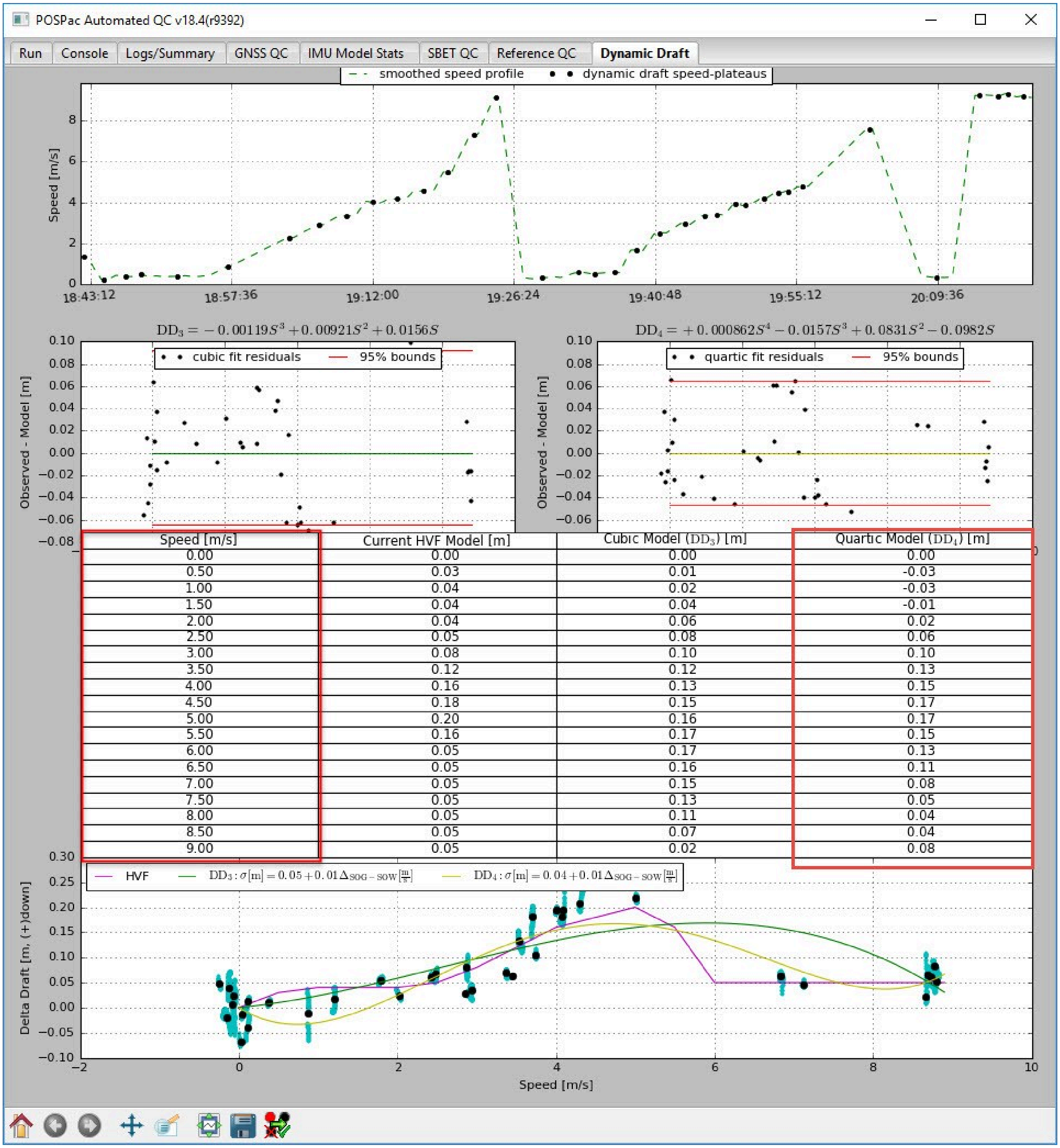
Figure 15: Static Survey Results

B.2.1.1 Static Draft Correctors

Vessel		S3005
Date		2019-03-20
Loading		0.010 meters
Static Draft	*Measurement*	-0.550 meters
	Uncertainty	0.0018 meters

B.2.2 Dynamic Draft

Two lines of data were acquired for this test. The general orientation of the main lines were East and West. Course azimuth was approximately 240 degrees for the first line, and 60 degrees for its reciprocal.
The vessel was positioned at the start of the line and allowed to record Dead in Water (DIW) for five minutes. A five minute DIW occurred at each end of the lines. After the initial 5 minute DIW, S3005 set both engines to clutch ahead, approximately 650 RPM, for 2 minutes. Vessel speed was monitored in coordination with engine RPM. Engine RPM were increased by approximately 250-300 every 2 minutes, until a speed 17 of knots was achieved. This RPM and speed encompasses the entire vessel’s operational survey range.
The data was then processed using Charlene to create an SBET. Once made, that data was loaded into Pydro’s Auto QC tool which assesses the quality of the SBET and creates an ERDDM table. The statistics derived from this ERDDM table were examined, found to be of good quality, and entered in the 2019 HVF for S3005



Speed [m/s]	Current HVF Model [m]	Cubic Model (DD_3) [m]	Quartic Model (DD_4) [m]
0.00	0.00	0.00	0.00
0.50	0.03	0.01	-0.03
1.00	0.04	0.02	-0.03
1.50	0.04	0.04	-0.01
2.00	0.04	0.06	0.02
2.50	0.05	0.08	0.06
3.00	0.08	0.10	0.10
3.50	0.12	0.12	0.13
4.00	0.16	0.13	0.15
4.50	0.18	0.15	0.17
5.00	0.20	0.16	0.17
5.50	0.16	0.17	0.15
6.00	0.05	0.17	0.13
6.50	0.05	0.16	0.11
7.00	0.05	0.15	0.08
7.50	0.05	0.13	0.05
8.00	0.05	0.11	0.04
8.50	0.05	0.07	0.04
9.00	0.05	0.02	0.08

Figure 16: Results from 2019 ERDDM of S3005

B.2.2.1 Dynamic Draft Correctors

Vessel	S3005	
Date	2019-03-25	
Dynamic Draft	*Speed (m/s)*	*Draft (m)*
	0.00	0.00
	0.50	-0.03
	1.00	-0.03
	1.50	-0.01
	2.00	0.02
	2.50	0.06
	3.00	0.10
	3.50	0.13
	4.00	0.15
	4.50	0.17
	5.00	0.17
	5.50	0.15
	6.00	0.13
	6.50	0.11
	7.00	0.08
	7.50	0.05
	8.00	0.04
	8.50	0.04
	9.00	0.08
Uncertainty	*Vessel Speed (m/s)*	*Delta Draft (m)*
	0.10	0.01

B.3 System Alignment

B.3.1 System Alignment Methods and Procedures

S3005's patch test was run in accordance with Field Procedure Manual section 1.5.5.1.2 and the Hydrographic Specifications & Deliverables documentation section 5.2.4.1. Additional detailed information is available in the Echosounder Confidence Check Report within the Appendices.

Figure 17: Patch values applied to the "IMU Frame w.r.t. Ref. Frame" in MS POSView Lever Arms & Mounting Angles. Values are transformed from a Caris Patch Results reference frame to MS POSView reference frame.

2019 HSRR Patch Test Results

	Alex	Colin	Josh	AVG	STD
Timming	0.00	0.07	0.00	0.023	0.040
Pitch	-0.35	-0.20	-0.30	-0.283	0.076
Roll	-0.31	-0.32	-0.35	-0.310	0.021
Yaw	1.37	1.60	1.50	1.490	0.115

Figure 18: Results from Caris Patch Calibration

B.3.1.1 System Alignment Correctors

Vessel	S3005		
Echosounder	Kongsberg EM2040C		
Date	2019-03-20		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.010 seconds
	Navigation Time Correction	0.000 seconds	0.010 seconds
	Pitch	0.280 degrees	0.020 degrees
	Roll	0.310 degrees	0.020 degrees
	Yaw	-1.490 degrees	0.020 degrees
	Pitch Time Correction	0.000 seconds	0.010 seconds
	Roll Time Correction	0.000 seconds	0.010 seconds
	Yaw Time Correction	0.000 seconds	0.010 seconds
	Heave Time Correction	0.000 seconds	0.010 seconds

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

NRT1's Kongsberg EM2040C acquisition of MB data was monitored in real time with the SIS acquisition software. Data were displayed using 2-D and 3-D data display windows. Traditional line planning using Hypack guides NRT1's acquisition of MBES data, usually based on 200% SSS coverage. Adjustable parameters common for the 2040C are range scale, power, gain and pulse width.

Data Processing Methods and Procedures

Following acquisition, MB sonar data were processed using CARIS HIPS and SIPS. The steps below are the standard procedure for MBES data processing.
Convert the “raw” data to the HDCS data format.
Load Delayed Heave
Load SBETs and RMS
Compute GPS Tides (ERS)

Correct for Sound Speed and apply heave
"Merge" data to apply position, attitude, and dynamic draft correctors to bathymetry and compute the corrected depth and position of each sounding.
Compute Total Propagated Uncertainty (TPU).
Create CUBE surface.

Preliminary data cleaning is performed in Subset editor as well as Swath editor. Surfaces are then reviewed by the team lead and any final cleaning or re acceptance of soundings is performed. Surfaces are examined for holidays and any additional line planning is done at this time.

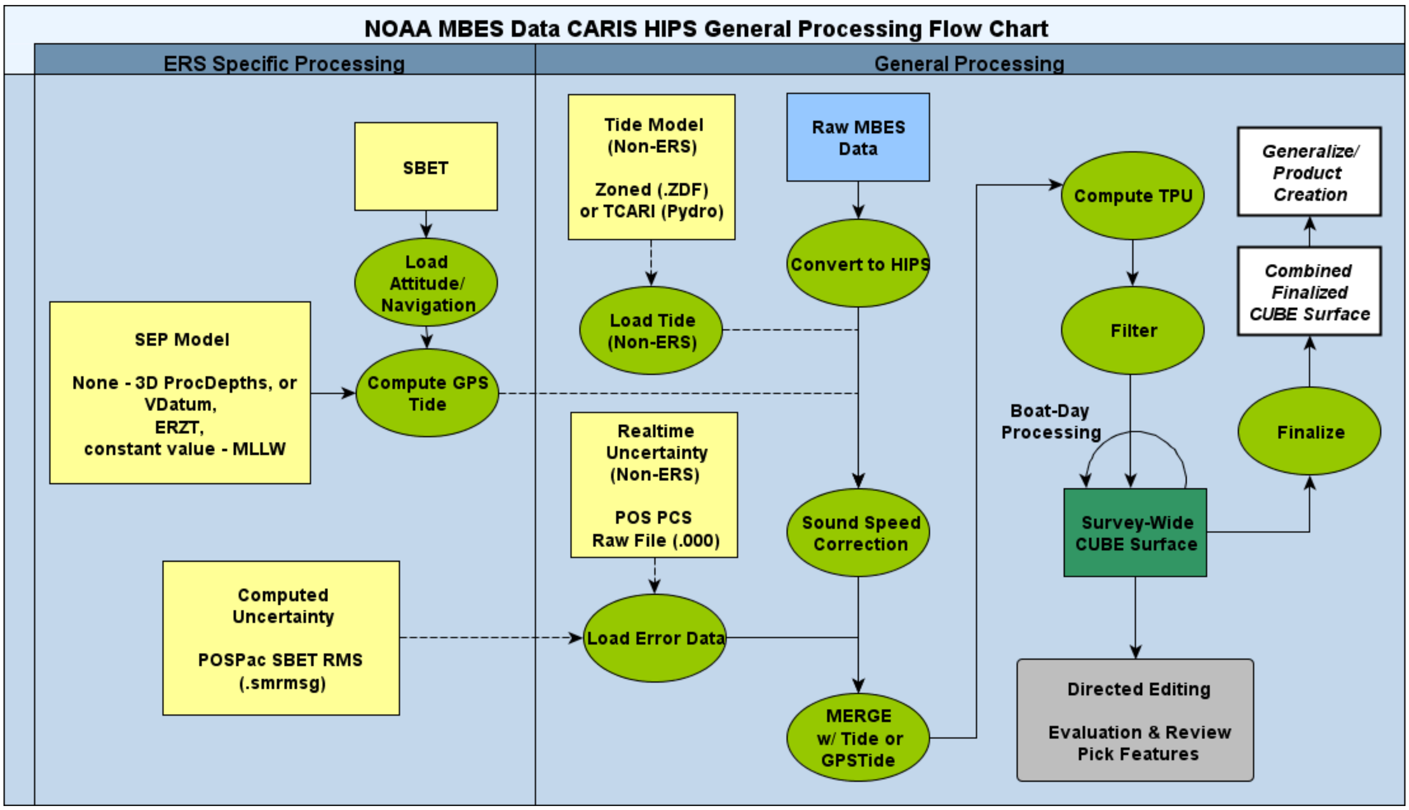


Figure 19: MBES Workflow

C.1.2 Single Beam Echosounder

Single beam echosounder bathymetry was not acquired.

C.1.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar bathymetry was not acquired.

C.1.4 Gridding and Surface Generation

C.1.4.1 Surface Generation Overview

The following options are selected in surface creation:
Surface Type – CUBE
IHO S-44 Order – Order 1a
Include status – check Accepted, Examined and Outstanding
Disambiguation method - Density & Locale (this method selects the hypothesis that contains the greatest number of soundings and is also consistent with neighboring nodes).
NRT1 rarely surveys in depths greater than 20m and therefore always uses a base surface resolution of 0.5 to 1m.

C.1.4.2 Depth Derivation

NRT1 does not employ any cleaning filters.

C.1.4.3 Surface Computation Algorithm

NRT1 uses the CARIS CUBE BASE surface algorithms for the generation of all surfaces generated for final submission. The exact behavior of CUBE is determined by the values set in the CUBE parameters file, an xml file which can be selected by the user in the CARIS Tools --> Options --> Environment tab. The NOAA Office of Coast Survey (OCS) has created and provided a customized CUBE parameters file (CubeParams_NOAA.xml) with new CUBE parameters that are required for each grid resolution. During the creation of CUBE surfaces, the user is given the option to select parameter configurations based upon surface resolution which have been tuned to optimize the performance of the CUBE algorithm. The advanced options configuration is manipulated based on the grid resolution of the CUBE surface being generated.

C.2 Imagery

C.2.1 Multibeam Backscatter Data

<u>Data Acquisition Methods and Procedures</u>

Backscatter is acquired through the Kongsberg SIS and is automatically burned into the .all file.

<u>Data Processing Methods and Procedures</u>

NRT1 does not currently process backscatter.

C.2.2 Side Scan Sonar

Data Acquisition Methods and Procedures

The Edgetech 4125 SSS towfish is deployed from a port side mounted Universal Sonar Mount (hydro) Foil Z pole. Line spacing for side scan sonar (SSS) operations is determined by range scale. The range scales of the Edgetech 4125's high and low frequencies can be set independently. Confidence checks are performed daily by observing changes in linear bottom features extending to the outer edges of the digital side scan image, features on the bottom in survey area, and by passing aids to navigation. Daily rub tests are also conducted.

Data Processing Methods and Procedures

Following acquisition, side scan sonar data were processed either using CARIS HIPS & SIPS manually, or by using the automated Pydro Explorer application, Charlene, to perform the same steps. The standard data processing steps are as follows:

1. Convert raw Edgetech JSF data to the HDCS data format
2. Check Attitude and Navigation for spikes. Interpolate as allowed.
3. Recompute towfish navigation to compute the position of the towfish in relation to the vessel
4. Review each line for contacts, proper towfish altitude tracking, gain, intensity and beam pattern corrections
5. Create mosaics and evaluate for coverage gaps

C.2.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar imagery was not acquired.

C.3 Horizontal and Vertical Control

C.3.1 Horizontal Control

C.3.1.1 GNSS Base Station Data

GNSS base station data was not acquired.

C.3.1.2 DGPS Data

Data Acquisition Methods and Procedures

NRT1 is equipped with a Trimble DGPS Beacon Receiver that acts as an auxiliary DGPS source to the Applanix POS/MV. The POS/MV PCS will only use the data from the auxiliary GNSS receiver if its quality is better than that of the primary GNSS receiver of the POS/MV. The POS/MV will acquire DGPS if a better solution is not available.

Data Processing Methods and Procedures

DGPS Data is processed using the POSPAC software. The processing method may vary by survey.

C.3.2 Vertical Control

C.3.2.1 Water Level Data

Water level data was not acquired.

C.3.2.2 Optical Level Data

Optical level data was not acquired.

C.4 Vessel Positioning

Data Acquisition Methods and Procedures

Attitude and Heave data were measured with the sensors described in Section A.5, and applied in post-processing during SVP Correct and Merge in CARIS HIPS.

S3005 utilizes a heave filter integration method known as “TrueHeave” as described in Section 3.4.1.2 of the 2014 Field Procedures Manual. This filter almost completely eliminates the need for steadying up on lines before logging can begin.

TrueHeave data were logged throughout the day via the POS MV's USB logging feature. Data was logged via an Ethernet connection to the PC in preset file size increments. Each file has a unique identifier for the year, Julian day number, and the vessel number (ex. 2017_214_S3007.000). The multiple POS files that are created from logging in this way are each distinguished by the numbering found in the file type (e.g, 000, 001, 002, etc.). After regular CARIS data conversion, the TrueHeave file was separately loaded into HIPS, replacing the unfiltered heave values recorded in the raw data. TrueHeave is actually applied to the data, if the checkbox is marked, during the sound velocity correction process.

It is standard procedure to begin logging the POS MV Applanix .000 file at least 5 minutes before starting bathymetric data acquisition and letting it run for at least 5 minutes afterward. Although the filter that produces the true heave values by looking at a long series of data to create a baseline needs only 3 minutes before and after the acquisition of bathymetric data, SBET processing which uses the same .000 file, requires logging for 5 minutes before and after bathymetric acquisition.

Data Processing Methods and Procedures

NRT1 utilizes Post Processed Kinematic (PPK) methods for the horizontal positioning of bathymetric data. The exact method selected is based upon the availability, or lack thereof, of Continually Operating Reference Stations (CORS) near the project area. The three methods available in order of preference are 1) Smart Base, 2) Single Base, and finally 3) Precise Point Positioning (PPP).

Smart Base is the preferred method when a minimum of four (six recommended) CORS stations are available for selection near the project area. In situations with a maximum baseline of 70 km, an optimal horizontal accuracy of 3-10 cm should be achieved. Applanix POSPac software is used to produce a Smoothed Best Estimate of Trajectory (SBET) file. The SBET file consists of GPS position and attitude data corrected and integrated with inertial measurements and reference station correctors, exported into WGS84. The SBET is created using the Applanix proprietary “SmartBase” algorithm, which generates a Virtual Reference Station (VRS) on site from a network of established reference stations surrounding the project area, generally the Continually Operating Reference Station (CORS) network. Reference station data is downloaded with the POSPac MMS download tool and usually available within 24 hours. These SBET navigation and attitude files are applied to all lines in CARIS and supersede initial positioning and attitude data. For further details on the CORS network stations utilized in addition to processing methodology, refer to the HVCR of the appropriate project.

Single Base is the preferred method when there are not enough CORS stations to form a SmartBase network. In a short baseline situation with a maximum baseline
of 20-30 km to the control station, an optimal horizontal accuracy of <10 cm should be achieved. The Single Base solution of processing SBETs requires the input of attitude data acquired by the POS/MV in addition to simultaneously collected base station data. Vessel kinematic data is post-processed using Applanix POSPac processing software, POSGNSS processing software and Single Base processing methods. These SBET navigation and attitude files are applied to all lines in CARIS and supersede initial positioning and attitude data.

Precise Point Positioning (PPP) is used as a last resort when Smart Base or Single Base is not available.

Single Base Station Processing
Open Applanix POSPac™ Mobile Mapping Suite and set up the project
Load the Applanix .000 file
Load the satellite data logged by the base station
Once the coordinate manager window opens, the true ITRF coordinates from the OPUS report is input. The same ITRF coordinates are used throughout the project and are checked against "new" OPUS solutions to maintain consistency.
Both the SBET (in ITRF format) and smrmsg error data files are created.

Smart Base Processing

Open Applanix POSPac™ Mobile Mapping Suite and set up the project
Load the Applanix .000 file
Select the "Find Base Stations" option which will generate a list of nearby CORS stations and then click on the "Smart Select" button.

POSPac will need the Internet to access and download the base station data it finds as the best option to import. It will need a minimum of 4 stations as well as adequate ephemeris data to continue. This process is done automatically.
Once the base stations and ephemeris data have been downloaded, the Raw Data Check-In window will appear automatically, click OK. Once you click OK, POSPac will create a triangulated network of all the base stations it has chosen for processing.
Next run the SmartBase Quality Check. POSPac will run the quality check to see if the data downloaded is good enough for processing and generate a Results Summary. If the data is inferior, it will recommend to Re-run the SmartBase Quality Check processor or that there is not enough adequate data to continue.
Occasionally you have to override the system and see if the SBET generated is up to spec. This is done by running the Applanix SmartBase processor.
Once the Applanix SmartBase processor has finished, the outline of the triangulated network will be highlighted in yellow. This means that you are ready for processing and that the appropriate base stations have been designated and set.

POSPac SBET Quality Control -- Once the POSPac project has completed processing successfully, quality control of the SBETs (Smoothed Best Estimated Trajectories) is performed.
Exporting Custom SBET -- Once the QC is complete and the processing log updated, the next step is to export a custom SBET in WGS84.

For both a Single Base or Smart Base solution, SBETs are applied in CARIS by loading both the SBET files and error data files in smrmsg format. For every SBET file generated during single base station processing there is an associated smrmsg file.

Process --> Load Attitude/Navigation data… Load the WGS84 SBET files. Import data for Navigation, Gyro, Pitch, Roll, and GPS Height are all selected for vessel.
Process --> Load Error data… Load the smrmsg error data file. Import data for Position RMS, Roll RMS, Pitch RMS, and Gyro RMS are selected for the vessel. Vertical RMS is not selected since HIPS will default to using the trueheave RMS values.

C.5 Sound Speed

C.5.1 Sound Speed Profiles

<u>Data Acquisition Methods and Procedures</u>

Sound velocity profiles are acquired with the YSI Castaway CTD. Casts are taken approximately every 2 hours or when there is a noticeable change in environment or survey area. Realtime surface sound speed is also monitored and additional casts are taken if the value varies by more than 2 m/s. SIS also monitors changes in the surface sound speed vs. the value obtained with the last cast in real-time. The user is then warned for the need of a new cast by highlighting both the “SV Profile” and “SV Used” numerical displays in yellow with a difference greater than 3 m/s and red for a difference greater than 5 m/s.

Data Processing Methods and Procedures

Cast data is processed via Velocipy and the cast data is extended using "most probable slope" method. The cast to be used for the survey data is then exported to a Caris SVP file, concatenated and applied within Caris process " Apply SVP". Each Survey has one SVP file named as the master file such as " H12345.SVP" which would contain all SVP cast for that survey.

C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

Surface sound speed is acquired by the AML Oceanographic Micro-X sensor. The original configuration of the sensor was in a PVC tube attached to the stern, extended below the water line, between the two outboards. This configuration proved to be less than ideal due to the nature of S3005's hull and cavitation from the motors. Many surface sound speed blow outs were observed during the first few trials of the vessel. In the short term the sensor is being placed in a bucket of seawater, freshened after every line. This solution is not ideal as the water may heat above the actual sea surface temperature quickly over time. NRB is actively seeking a resolution for this issue and this document will be updated when that occurs.

Data Processing Methods and Procedures

Surface sound speed data is not processed.

C.6 Uncertainty

C.6.1 Total Propagated Uncertainty Computation Methods

TPU values for all motion, navigation position and timing values are taken directly from Appendix IV (Uncertainty values for use in CARIS with vessels equipped WITH an attitude sensor) of the Field Procedures Manual. All timing values were set to 0.01 seconds as outlined for setups with Ethernet connections and precise timing.

C.6.2 Uncertainty Components

C.6.2.1 A Priori Uncertainty

Vessel		S3005
Motion Sensor	*Gyro*	0.02 degrees
	Heave	5.00% 0.05 meters
	Roll	0.02 degrees
	Pitch	0.02 degrees
Navigation Sensor		1.00 meters

C.6.2.2 Real-Time Uncertainty

Real-time uncertainty was not applied.

Entry in HVF		1 Sigma Recommended Value (Units)
	Attitude	
Gyro error (heading)	for POS/MV 320	0.02 deg
Heave (amplitude)*	for POS/MV 320	5 %
Heave *	for POS/MV 320	0.05 m
Roll	for POS/MV 320	0.02 deg
Pitch	for POS/MV 320	0.02 deg
Nav. position	0.5 to 2.0 depending on differential quality	1 m
	Sonar timing	
Nav. Timing**	Integration dependent	.01 (.005)s
Gyro Timing**	Integration dependent	.01 (.005)s
Heave Timing**	Integration dependent	.01 (.005)s
Pitch Timing**	Integration dependent	.01 (.005)s
Roll Timing**	Integration dependent	.01 (.005)s
	Vessel variables	

Figure 20: Table 4-9. Uncertainty values for use in CARIS with vessels equipped with an attitude sensor. Field Procedures Manual, 2014, pg. 482

C.7 Shoreline and Feature Data

<u>Data Acquisition Methods and Procedures</u>

Source shoreline data is typically supplied by NRB Project Manager in a single Composite Source file (CSF) in both S-57 .000 and .hob formats. The CSF is delivered with the Project Instructions and is to be used as the only shoreline data for use in the field. The composite source file is compiled from all available source shoreline files (i.e. ENC, Geographic Cells, lidar, RNC, and Prior Surveys) into a single file in an S-57 .000

format. Additionally, a Project Reference file (PRF) is supplied containing sheet limits, maritime boundary points, and recommended bottom sample sites.

Shoreline verification is performed using several different methods, depending on the nature of the feature. Underwater features are verified or disproven using MBES and SSS. Above water features such as platforms or piers are verified using Hypack detached positions.

In the absence of direction to the contrary, the NALL was the furthest offshore of the following:
The 4m depth contour at MLLW.
A line seaward of the MHW line by the ground distance equivalent to 0.8mm at the scale of the largest scale raster chart of the area.

Features are addressed in the following manner:
Offshore of the NALL:
A feature found within 2mm at survey scale of the composite source position has its height/depth determined.
A feature outside 2mm at survey scale of the composite source position has its field position revised in addition to a heights/depth determination.
Features with any linear dimension greater than 1mm at survey scale are treated as an area and delineated.
New features not in the Composite Source file.
Maritime boundary points and other features specifically identified for investigation.

Inshore of the NALL:
Assigned maritime boundary points only if they are safe to approach.
Navigationally significant features as defined below.

Navigationally Significant features were defined as the following:
All features within the limits of safe navigation (i.e., offshore of the NALL).
Features inshore of the NALL which:
Are sufficiently prominent to provide a visual aid to navigation (landmarks). Note that rocks awash are almost never landmarks, but distinctive islets or other features visible at MHW can be useful for visual navigation.
Are significantly (a ground unit distance equivalent to 0.8mm at the scale of the largest scale chart of the area) deflect this limit. Common examples of these features include foul areas and large reef/ledge structures.
Are man-made permanent features connected to the natural shoreline (such as piers and other mooring facilities) larger than the resolution specified for the survey. Seasonal features will be evaluated by the Command.
Are man-made permanent features disconnected from the shoreline, such as stakes, pilings, and platforms, regardless of size

Small, private mooring facilities (piers and buoys) suitable for pleasure craft are not generally considered navigationally significant. Areas with a high density of mooring buoys for these vessels are delineated, but the features themselves not individually positioned.

Data Processing Methods and Procedures

Following a day of shoreline verification, NRT1 copies the HXXXXX_Final_Features_File.hob used on the vessel in addition to any digital photos taken and the trackline hob file. These file are then placed in the appropriate locations in the working projects directory.

S-57 Attribution

With the advent of custom CARIS support files supplied by OCS, Bathy DataBASE now supports feature flags previously available only in Pydro. All feature flagging can now be accomplished in BDB while Pydro used for generating reports and performing QC. Features are selected for investigation by NRB OPS based on distance from MHW. Project Instructions require that “All features with attribute asgnmt populated with 'Assigned' shall be verified even if they are inshore of NALL.”

NRT1 will not venture inshore of the NALL, even for assigned investigation items, if there is a question of safety or potential equipment damage. If the feature in question is exposed, time and height attributes are assigned while driving past. If the feature is not evident while driving the NALL during shoreline verification, a remark of “inshore of NALL not investigated” is made with a recommendation of "Retain as charted".

Feature attribution is completed for all 'Assigned' and any newly discovered items. Unassigned features are left untouched. Submerged features, such as wrecks and submerged piles designated in CARIS HIPS are also be brought into
BDB for attribution.

All features marked as “primary” are edited to have their object/attribute instances describe each feature as completely as possible. Object attributes assigned to each feature conform to direction located within both the 2016 HSSD and the CARIS “IHO S-57/ENC Object and Attribute Catalogue”. S-57 attribution is not required for those features flagged as "secondary" nor for unassigned features.

NOAA specific attribution in BDB includes “descrp” with a drop-down menu which is edited to reflect the hydrographer recommendations as follows:

descrp - new -- A new feature is identified during survey operations. The hydrographer recommends adding the feature to the chart. Also, in cases in which the geographic position of an existing point feature is modified; the newly proposed feature is characterized as "new", while the original feature
is flagged as "delete".
descrp - update -- The feature was found to be portrayed incorrectly on the chart. Update is also used in the case where the feature was found to be attributed incorrectly or insufficiently and is modified to reflect the additional or corrected attribution. Also, for cases in which the geographic extents/position of an existing line feature are modified; the newly proposed feature is characterized as "update".
descrp - delete -- The feature is disproved using approved search methods and guidelines. The hydrographer recommends removing it from the chart. Also, for cases in which the geographic position of an existing point object is modified; the newly proposed feature is characterized as "new", while the original feature was flagged as "delete".

descrp - retain -- The feature is found during survey operations to be positioned correctly and no additional attribution was required. The hydrographer recommends retaining the feature as charted.
descrp – not addressed -- The feature is not investigated during shoreline acquisition, typically because it is either inshore of the NALL or unsafe to approach. The hydrographer recommends retaining the feature as charted.

Features described as "new" and "update" are updated with the SORIND/SORDAT attribution of the current survey.

Features described as "delete", "retain", and "not addressed" have their SORIND/SORDAT attribution remain unchanged.

C.8 Bottom Sample Data

Data Acquisition Methods and Procedures

The clam shell style bottom sampler is set for deployment by placing the attached pin between the hinge. The device is allowed to free fall to the bottom and upon contact the line is jerked up sharply to snap the jaws shut. Bottom material is transferred from the clam shell into a plastic bin where it is examined for type, color and texture.

Data Processing Methods and Procedures

Typically NRB Operations provides the field unit with a number of recommended bottom sample sites included as part of the shoreline project reference file (PRF). These proposed sample sites, which are encoded as S-57 SPRINGS. In the event that no sample is obtained after three attempts, the sample site's NATSUR is characterized as “unknown”. The observations are recorded to the boat notebook or directly to the .hob file. Samples are then discarded after field analysis is complete.

D. Data Quality Management

D.1 Bathymetric Data Integrity and Quality Management

D.1.1 Directed Editing

Depth, Standard Deviation, Hypothesis Strength and Hypothesis Count models derived from the surface are viewed with appropriate vertical exaggeration and a variety of sun illumination angles to highlight potential problem areas.

D.1.2 Designated Sounding Selection

In some instances, due to the nature of the weighting algorithm, a BASE surface does not accurately represent the least depth of a navigationally significant feature (typically a fine item such as a tall, narrow coral head or a shipwreck's mast). In such cases, a sounding can be flagged as Designated to force the nearest BASE surface grid node to honor the depth of the designated sounding.

Since the calculated depth at each grid node of a BASE surface is influenced by multiple soundings, the least depth of a feature may not always be accurately represented in the gridded data. Prior to creating a finalized BASE surface collection, the hydrographer must systematically review significant feature least depths to ensure they are accurately portrayed by the BASE surface. If a specific least depth sounding is preferred over the weighted mean-depth calculation for the associated BASE surface grid node, that sounding should be flagged Designated. The Designated flag can be applied in either HIPS or Pydro. If a sounding is made Designated in one software package, this flag will automatically carry through to the other application. Designated soundings shall be selected in accordance with section 5.2.1 and 5.2.2 of the HSSD.

A common area of confusion is the preferred spatial density of designated soundings. It is easy to lose ones sense of scale when viewing data in subset editor. Sand ripples can look like mountains and small rocks appear like house sized boulders. The hydrographer shall take a holistic view of the surrounding bathymetry to help determine the hydrographic significance of a feature before designating a sounding. When there are a group of features near each other (e.g. they would be shown as a single sounding or charted feature at the scale of the survey), only the shoalest sounding on the feature with the most representative shoal depth shall be selected.

As discussed in the Specifications and Deliverables section 5.2.1.2, the hydrographer should use discretion in designating soundings on features.

D.1.3 Holiday Identification

Holidays are defined as gaps in main scheme data or areas where accuracy requirements have not been met. Holidays may be caused by various events, such as vessel maneuvering, survey equipment problems, unexpected shoals, or rejection of poor quality data during post-processing. Holiday line plans are typically developed to address these data gaps as main scheme acquisition progresses, rather than at the end of main scheme operations. This practice will minimize transit time required to revisit each area of the survey with a holiday and the time required to acquire, process, and manage additional sound speed profiles. If the field unit uses a real- time coverage map during main scheme data acquisition, most holidays can be identified and addressed prior to ceasing operations that day, thus increasing survey efficiency. NRT1 makes every effort to identify potential holidays during acquisition. Upon initial office review of the data holidays are identified visually by examining the surface or by using the Pydro QC tools "Holiday Finder".

D.1.4 Uncertainty Assessment

NRT1's primary bathymetric data review and quality control tool are the CARIS CUBE (Combined Uncertainty and Bathymetry Estimator) BASE surfaces as implemented in CARIS HIPS. The CUBE algorithm generates a surface consisting of multiple hypotheses that represent the possible depths at any given position. The BASE surface is a grid of estimation nodes where depth values are computed based on the horizontal and vertical uncertainty of each contributing sounding as follows:

Soundings with a low vertical uncertainty are given more influence than soundings with high vertical uncertainty
Soundings with a low horizontal uncertainty are given more influence than soundings with a high horizontal uncertainty.
Soundings close to the node are given a greater weight than soundings further away from the node.

As soundings are propagated to a node, a hypothesis representing a possible depth value is developed for the node. If a sounding's value is not significantly different from the previous sounding then the same or modified hypothesis is used. If the value does change significantly, a new hypothesis is created. A node can contain more than one hypothesis. As node-to-node hypotheses are combined into multiple surfaces through methodical processing, a final surface that is the best representation of the bathymetry is created.

Any individual sounding’s uncertainty, or Total Propagated Uncertainty (TPU), is derived from the assumed uncertainty in the echo sounder measurement itself, as well as the contributing correctors from sound speed, water levels, position, and attitude. TPU values for tide and sound velocity must be entered for each vessel during TPU computation, unless using TCARI, where uncertainty is added directly to survey lines by Pydro.

Tide values measured uncertainty value error ranges from 0.01m to 0.05 m dependent upon the accuracy of the tide gauge used and the duration of their deployment. NRT1 is using a value of 0.0 since the Tide Component Error Estimation section of the Hydrographic Survey Project Instructions now includes the estimated gauge measurement error in addition to the tidal datum computation error and tidal zoning error.

Tide values zoning is unique for each project area and typically provided in Appendix II of the Hydrographic Survey Project Instructions, Water Level Instructions. In section 1.3.1.1 of the Water Level Instructions, Tide Component Error Estimation, the tidal error contribution to the total survey error budget is provided at the 95% confidence level, and includes the estimated gauge measurement error, tidal datum computation error, and tidal zoning error. Since this tidal error value is given for two sigma, the value must be divided by 1.96 before it can be entered into CARIS (which expects a one sigma value). If TCARI grids are assigned to the project area, this value is set at 0.0 since TCARI automatically calculates the error associated with water level interpolation and incorporates it into the residual/harmonic solutions.

Measured sound speed value error ranges from 0.5 to 4 m/s, dependent on temporal/spatial variability. FPM recommends a value of 4 m/s when 1 cast is taken every 4-hours.

Surface sound speed value is dependent on the manufacturer specifications of the unit utilized to measure surface SV values for refraction corrections to flat-faced transducers.

All other error estimates are read from the Hydrographic Vessel File (HVF) and Device Model file. The HVF contains all offsets and system biases for the survey vessel and its systems, as well as error estimates for latency, sensor offset measurements, attitude and navigation measurements, and draft measurements. The HVF specifies which type of sonar system the vessel is using, referencing the appropriate entry from the Device Model file.

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

Cross line data are used to identify any systematic data problems by comparing it to main scheme data acquired at different times, water levels, and line azimuths. Ideally, cross lines should be acquired prior to main scheme data, in areas of gently sloping bottom, and when water levels are as close to survey datum (MLLW) as practicable. Two separate surfaces are created for main scheme and cross lines. These surfaces are then differenced in Caris HIPS and SIPS. The resulting difference surface is examined for statistical variations.

D.1.5.2 Junctions

Junctioning surveys are evaluated by differencing the overlapping surfaces and examined for statistical variations.

D.1.5.3 Platform to Platform

NRT1 rarely has the opportunity to compare data across platforms

D.2 Imagery data Integrity and Quality Management

D.2.1 Coverage Assessment

NRT1 performs 200% coverage SSS regularly. To achieve this coverage careful line planning, taking into account the water depth and range scale, is required. 10 meter overlap of SSS coverage is the goal in each percentage to ensure adequate coverage. Any SSS holidays are discovered by turning on a bright red background in Caris and overlaying each percentage's mosaic.

D.2.2 Contact Selection Methodology

Imagery data is reviewed twice using CARIS SIPS Side Scan Editor. The initial review process is referred to as “scanning” the data. The second review is performed by a different person and is called “check scanning.” The initial reviewer should identify any object that warrants further investigation, often referred to as a “significant contact”, and record these items into the digital data. The second review serves as a quality control, and should add any significant contacts that were overlooked during the initial check. SIPS provides several tools to assist in determining if a contact is significant. Two of the most frequently used are “Measure Shadow” and “Measure Distance.”

“Measure Shadow” can be used to determine the height of an object by measuring its acoustic shadow and calculating the object’s approximate elevation off the seafloor. This tool can only be used when viewing data in slant range corrected mode. “Measure Distance” is used to measure the distance between two points. This tool is helpful in determining the overall size of contacts, which may determine significance. For example, a very large item, even if it does not protrude significantly from the seafloor, may be listed in the AWOIS database and should therefore be investigated. The Measure Distance tool can be used when viewing both "raw" (i.e., not slant range corrected) and slant range corrected data.

All significant contacts are recorded in the digital data by creating a contact in SIPS. The general NRT1 practice for determining significance of an imagery contact is stated in the HSSD. The hydrographer must always consider the location of a contact when determining significance. For example, in a major channel where vessels transit with minimal under keel clearance, a contact less than one meter high could be significant.

When a contact is recorded in SIPS, the item is geo-coded and attributes are attached to it in the Side Scan Editor. Each contact should be attributed as thoroughly as possible. A contact file is created for each survey line and is stored in the line folder within the Project directory structure.

E. Approval Sheet

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

Survey adequacy is provided in the individual survey Descriptive Reports.

Approver Name	Approver Title	Date	Signature
LT. John Kidd	Chief of Party	11/14/2019	

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	S3005_Wiring_Diagram_2019.pdf
Sound Speed Sensor Calibration	S3005_Castaway_2019.pdf AML_Cal.pdf
Vessel Offset	2018 NRT1 Component Spatial Relationship Survey.pdf S3005_2019_Verification_Survey.pdf
Position and Attitude Sensor Calibration	S3005_2019_POSMV_Calibration.pdf
Echosounder Confidence Check	S3005_2019_Multibeam_Echosounder_Calibration.pdf
Echosounder Acceptance Trial Results	N/A

Additional Report	***File***
Ellipsoidally Referenced Dynamic Draft Model 2019	S3005_2019_ERDDM_Report.pdf
S3005 SSS Calibration Test 2019	S3005_75mRS_SSS_Calibration_Analysis.pdf