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

Data Acquisition & Processing Report

Type of Survey:	Navigable Area Habitat Mapping
Project Number:	OPR-H355-KR-21
Time Frame:	April - November 2021

LOCALITY

State(s):	Florida
General Locality:	Key West

2021

CHIEF OF PARTY
David J. Bernstein, CH, PLS, GISP

LIBRARY & ARCHIVES

Date:

NOAA FORM 77-28
(11-72)

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

HYDROGRAPHIC TITLE SHEET

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

REGISTRY No

H13427
H13428
H13429
H13430
H13431
H13432

FIELD No

Geodynamics LLC

State	**Florida**
General Locality	**Key West**
Sub-Locality	**Eastern Outer Band, Western Outer Band, East of Key West, West of Key West, Seven Mile Bridge, South of Marquesas**
Scale	**1:5,000 1:10,000 1:20,000**
Date of Survey	**April - June 2021**
Instructions Dated	**February 17, 2021**
Project No.	**OPR-H355-KR-21**
Vessel	**R/V Benthos, R/V Chinook, R/V Substantial**
Chief of Party	**David J. Bernstein, CH, PLS, GISP**
Surveyed by	**Geodynamics LLC**
Soundings by echo sounder	**Kongsberg 2040C**
Graphic record scaled by	**N/A**
Graphic record checked by	**N/A**
Automated Plot	**N/A**
Verification by	**Atlantic Hydrographic Branch**
Soundings in	**Meters at Mean Lower Low Water (MLLW)**

REMARKS:

NAD83 (2011), UTM Zone 17 North
Times are in UTC
The purpose of this contract is to provide NOAA with modern, accurate hydrographic survey data to update the nautical charts of the assigned area.

SUBCONSULTANTS:

eTrac Inc., 637 Lindaro, Suite 100, San Rafael, CA 94901
Ocean Operators LLC, 848 N. Rainbow Blvd. #4755, Las Vegas, NV, 89107

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

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Data Acquisition and Processing Report

Geodynamics LLC
Chief of Party: David J. Bernstein, CH, PLS, GISP
Year: 2021
Version: 1
Publish Date: 2021-09-30

A. System Equipment and Software

A.1 Survey Vessels

A.1.1 R/V Benthos

Vessel Name	R/V Benthos	
Hull Number	ACD28CATA212	
Description	Geodynamics LLC supplied the R/V Benthos for hydrographic survey operations on OPR-H355-KR-21. The R/V Benthos is a 9.14 meter catamaran built by Armstrong Marine and conducted 12-hour day operations. The R/V Benthos has the following specifications:	
Dimensions	*LOA*	9.14 m
	Beam	3.20 m
	Max Draft	0.61 m
Most Recent Full Static Survey	*Date*	2021-03-09
	Performed By	Mike Ulmer, 3Space Inc
Most Recent Full Offset Verification	*Date*	2021-03-09
	Method	The R/V Benthos offset survey was verified / conducted by measurement specialists Mike Ulmer of 3Space Inc and a team of Geodynamics hydrographers prior to the start of field operations for OPR-H355-KR-21. Survey instrument offsets were measured using a Leica 402 Laser Tracker with Spatial Analyzer software. All measurements were performed multiple times and in varying combinations to reduce uncertainty and blunders.

Figure 1: R/V Benthos

A.1.2 R/V Chinook

Vessel Name	R/V Chinook	
Hull Number	IAR28CATJ607	
Description	Geodynamics LLC supplied the R/V Chinook for hydrographic survey operations on OPR-H355-KR-21. The R/V Chinook is a 9.44 meter catamaran built by Armstrong Marine and conducted 12-hour day operations. The R/V Chinook has the following specifications:	
Dimensions	*LOA*	9.44 m
	Beam	3.20 m
	Max Draft	0.61 m
Most Recent Full Static Survey	*Date*	2021-04-10
	Performed By	Mike Ulmer, 3Space Inc

Most Recent Full Offset Verification	*Date*	2021-04-10
	Method	The R/V Chinook offset survey was verified / conducted by measurement specialists Mike Ulmer of 3Space Inc and a team of Geodynamics hydrographers prior to the start of field operations for OPR-H355-KR-21. Survey instrument offsets were measured using a Leica 402 Laser Tracker with Spatial Analyzer software. All measurements were performed multiple times and in varying combinations to reduce uncertainty and blunders.

Figure 2: R/V Chinook

A.1.3 R/V Substantial

<table>
<tr><td>Vessel Name</td><td colspan="2">R/V Substantial</td></tr>
<tr><td>Hull Number</td><td colspan="2">USZ00221D013</td></tr>
<tr><td>Description</td><td colspan="2">Geodynamics LLC supplied the R/V Substantial for hydrographic survey operations on OPR-H355-KR-21. The R/V Substantial is a 16.15 meter Seaton designed mono-hull vessel built by Marks Marine and conducted 24-hour operations. The R/V Substantial has the following specifications:</td></tr>
<tr><td rowspan="3">Dimensions</td><td>LOA</td><td>16.15 m</td></tr>
<tr><td>Beam</td><td>5.48 m</td></tr>
<tr><td>Max Draft</td><td>1.89 m</td></tr>
<tr><td rowspan="2">Most Recent Full Static Survey</td><td>Date</td><td>2021-03-08</td></tr>
<tr><td>Performed By</td><td>Mike Ulmer, 3Space Inc</td></tr>
<tr><td rowspan="2">Most Recent Full Offset Verification</td><td>Date</td><td>2021-03-08</td></tr>
<tr><td>Method</td><td>The R/V Substantial offset survey was verified / conducted by measurement specialists Mike Ulmer of 3Space Inc and a team of Geodynamics hydrographers prior to the start of field operations for OPR-H355-KR-21. Survey instrument offsets were measured using a Leica 402 Laser Tracker with Spatial Analyzer software. All measurements were performed multiple times and in varying combinations to reduce uncertainty and blunders.</td></tr>
</table>

Figure 3: R/V Substantial

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Kongsberg EM2040C Dual

The R/V Benthos and R/V Chinook were each equipped with a dual-head Kongsberg EM2040C Multibeam Echo Sounder System (MBES) with sonar heads pole mounted with a bracket holding the sonar heads at 35°/-35°. On each vessel, two Kongsberg processing units (PU) were combined to enable dual swath mode. The R/V Substantial was equipped with a dual-head Kongsberg EM2040C MBES with sonar heads hull mounted at 35°/-35°, again equipped with dual swath capabilities. The dual-head EM2040C utilizes 512 discretely formed beams of a selectable sector up to 200° in equidistant operation mode. At 300 kHz, the EM2040C focuses an across-track and along-track beam width of 1° and 1° respectively. The EM2040C operates at a maximum ping rate of 50 Hz and is designed to comply with International Hydrographic Organization (IHO) standards for depth measurements to a maximum range of 450 meters.

Manufacturer	Kongsberg
Model	EM2040C Dual

Inventory

R/V Benthos

Component	Port Sonar Head	Stbd Sonar Head	Processing Unit 1	Processing Unit 2	Hydrographic Workstation (Start-05/22/21)	Hydrographic Workstation (05/23/21-end)
Model Number	EM2040C	EM2040C	385406	385406	Cincoze DS-1202	Cincoze DS-1202
Serial Number	2549	2548	20188	20159	U726920	U743018
Frequency	300 kHz	300 kHz	N/A	N/A	N/A	N/A
Calibration	2021-04-13	2021-04-13	N/A	N/A	N/A	N/A
Accuracy Check	2021-04-16	2021-04-16	N/A	N/A	N/A	N/A

R/V Chinook

Component	Port Sonar Head	Stbd Sonar Head	Processing Unit 1	Processing Unit 2	Hydrographic Workstation
Model Number	EM2040C	EM2040C	385406	385406	Cincoze DS-1202
Serial Number	2566	2565	20190	20193	U743019
Frequency	300 kHz	300 kHz	N/A	N/A	N/A
Calibration	2021-04-13	2021-04-13	N/A	N/A	N/A
Accuracy Check	2021-04-16	2021-04-16	N/A	N/A	N/A

R/V Substantial

Component	Port Sonar Head	Stbd Sonar Head	Processing Unit 1	Processing Unit 2	Hydrographic Workstation
Model Number	EM2040C	EM2040C	385406	385406	Cincoze DS-1202
Serial Number	2513	2532	20043	30067	U756909
Frequency	300 kHz	300 kHz	N/A	N/A	N/A
Calibration	2021-05-14	2021-05-14	N/A	N/A	N/A
Accuracy Check	2021-05-14	2021-05-14	N/A	N/A	N/A

Figure 4: Kongsberg EM2040C dual-head sonar on a pole mount

Figure 5: Kongsberg EM2040C dual-head sonar hull mounted on the R/V Substantial with each transducer labeled

Figure 6: Kongsberg EM2040C hull mount on the R/V Substantial

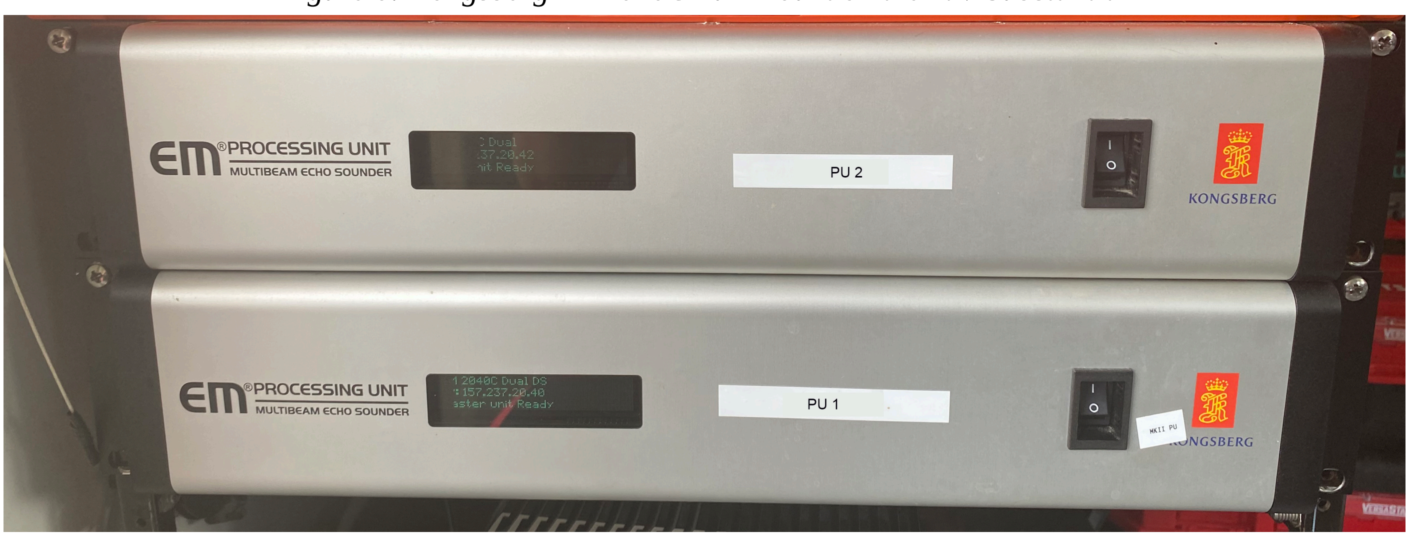

Figure 7: Kongsberg Slim Processing Units (PU) setup in dual swath configuration

A.2.2 Single Beam Echosounders

No single beam echosounders were utilized for data acquisition.

A.2.3 Side Scan Sonars

No side scan sonars were utilized for data acquisition.

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 V5 OceanMaster

Each survey vessel deployed on OPR-H355-KR-21 utilized an Applanix POS MV system for positioning, attitude, and precise timing of sonar data. The POS MV is a Global Navigation Satellite System (GNSS) aided inertial navigation system that provides georeferencing and motion compensation for hydrographic surveys. The POS MV is comprised of four main components: POS Computer System (PCS), Inertial Measurement Unit (IMU), Primary GNSS Antenna, and the Secondary GNSS Antenna.

On the R/V Benthos, R/V Chinook, and R/V Substantial, positioning and heading were transmitted from the POS MV at 10 Hz and attitude was transmitted at 100 Hz to the Kongsberg sonar over RS232 serial connections. These data were also broadcast to QPS Qinsy software over Ethernet/UDP at 50 Hz for vessel navigation and real-time quality control (QC).

The POS MV provided precise timing for sonar data to the Kongsberg PU via BNC Pulse Per Second cable. Additionally, a NMEA ZDA message was transmitted at 1 Hz from the POS MV to QPS Qinsy and Kongsberg SIS.

The R/V Benthos and R/V Chinook utilized POS MV firmware version 10.21 and POSView software version 10.2. The R/V Substantial utilized POS MV firmware version 10.50 and POSView software version 10.5.

During pre-survey calibrations, and when required (equipment failure/change), a POS MV calibration was performed. This calibration included a GNSS Azimuth Measurement System (GAMS) calibration and details can be found in the DAPR Appendix IV.

Manufacturer	Applanix					
Model	POS MV V5 OceanMaster					
Inventory	*R/V Benthos*	*Component*	PCS	Primary GNSS Antenna	Secondary GNSS Antenna	IMU
		Model Number	PCS-100	540AP	540AP	IMU 65
		Serial Number	11164	17985	17989	3250
		Calibration	2021-04-12	2021-04-12	2021-04-12	2021-04-12
	R/V Chinook	*Component*	PCS	Primary GNSS Antenna	Secondary GNSS Antenna	IMU
		Model Number	PCS-100	540AP	540AP	IMU 65
		Serial Number	11165	17980	17992	5272
		Calibration	2021-04-12	2021-04-12	2021-04-12	2021-04-12
	R/V Substantial	*Component*	PCS	Primary GNSS Antenna	Secondary GNSS Antenna	IMU
		Model Number	PCS-100	GA830	GA830	IMU 89
		Serial Number	12029	16886	17034	4947
		Calibration	2021-05-15	2021-05-15	2021-05-15	2021-05-15

Figure 8: POS MV V5 OceanMaster system

A.5.2 DGPS

DGPS equipment was not utilized for data acquisition.

A.5.3 GPS

Additional 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

A.5.5.1 Fugro Marinestar Satellite-Based Augmentation System (SBAS)

Each survey vessel deployed on OPR-H355-KR-21 received G2+ GNSS satellite corrections from the Marinestar worldwide correction system. SBAS settings in the POS MV were configured to receive the G2+ correction at a frequency of 1545.9375 MHz and bit rate of 1200 bits/second.

Manufacturer	Fugro		
Model	Marinestar Satellite-Based Augmentation System (SBAS)		
Inventory	*R/V Benthos*	*Component*	Marinestar SBAS
		Model Number	N/A
		Serial Number	N/A
		Calibration	N/A
	R/V Chinook	*Component*	Marinestar SBAS
		Model Number	N/A
		Serial Number	N/A
		Calibration	N/A
	R/V Substantial	*Component*	Marinestar SBAS
		Model Number	N/A
		Serial Number	N/A
		Calibration	N/A

A.6 Sound Speed Equipment

A.6.1 Moving Vessel Profilers

A.6.1.1 AML Oceanographic MVP30-350

The R/V Substantial was outfitted with an AML Oceanographic Moving Vessel Profiler (MVP) used to obtain sound speed profiles at a greater frequency without stopping the survey vessel. The AML MVP30-350 system consists of a sensor free fall fish, an integrated winch and power unit, an overboard towing sheave, and a remote system controller with dedicated operating station running the MVP Controller software. Sound speed profiles acquired with the MVP were imported into HydrOffice Sound Speed Manager (SSM) via ethernet/UDP and then broadcast directly to SIS. The AML MVP30-350 was the primary instrument collecting sound velocity profiles on the R/V Substantial, however, damage to the data cable led to the use of a secondary sound speed profiler, AML Minos•X (described in the Sound Speed Sensors section A.6.3.2), from 05/27/21-05/29/21. The MVP cable was then re-terminated, and the MVP was again functional from 05/29/21 until the end of the project.

Manufacturer	AML Oceanographic				
Model	MVP30-350				
Inventory	*R/V Substantial*	*Component*	Sound Speed Profiling Instrument	SV Sensor	Pressure Sensor
		Model Number	MVP30-350	SV•Xchange	P•Xchange
		Serial Number	M12540	209207	306273
		Calibration	N/A	2021-01-23	2021-01-22

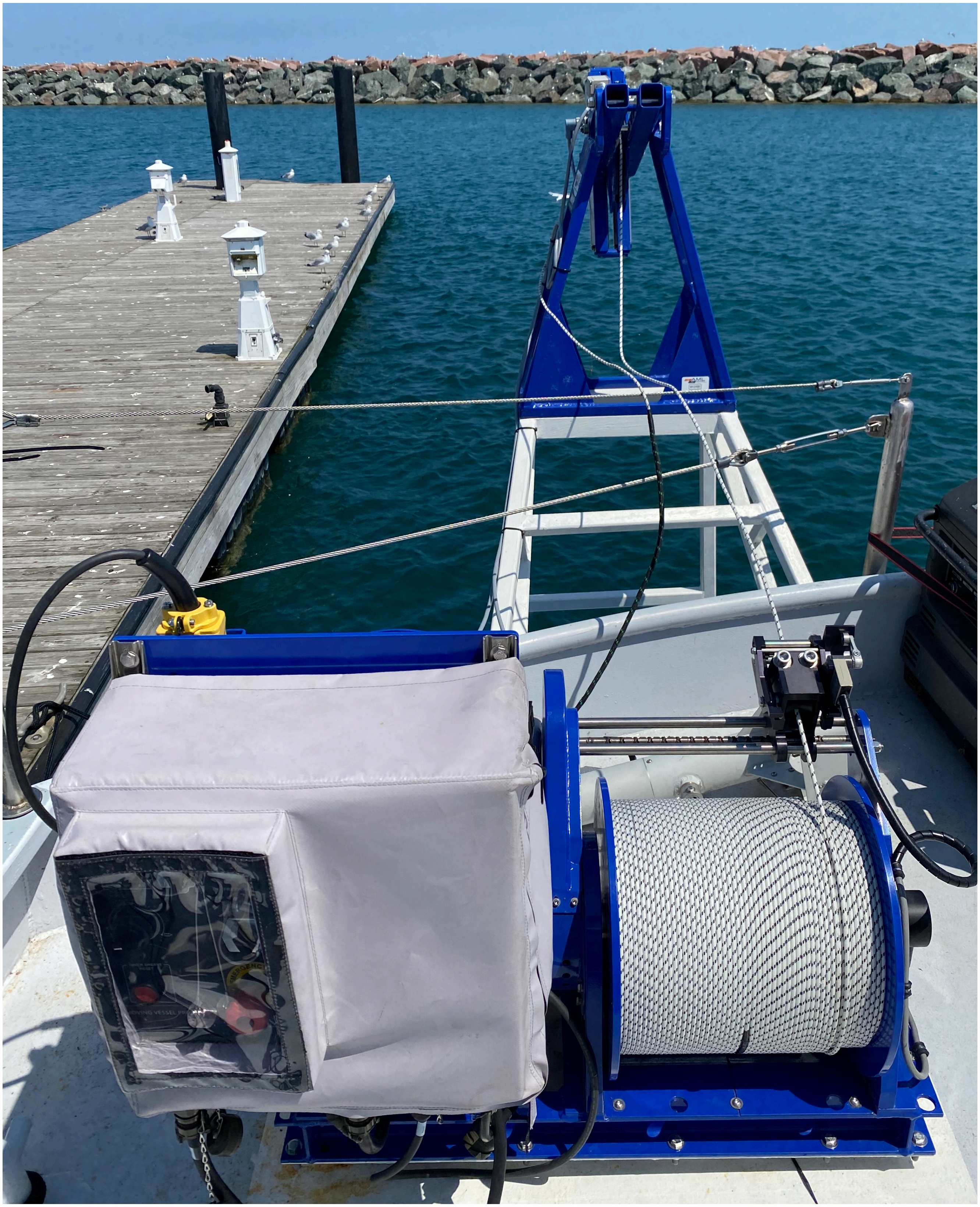

Figure 9: AML Oceanographic MVP30-350

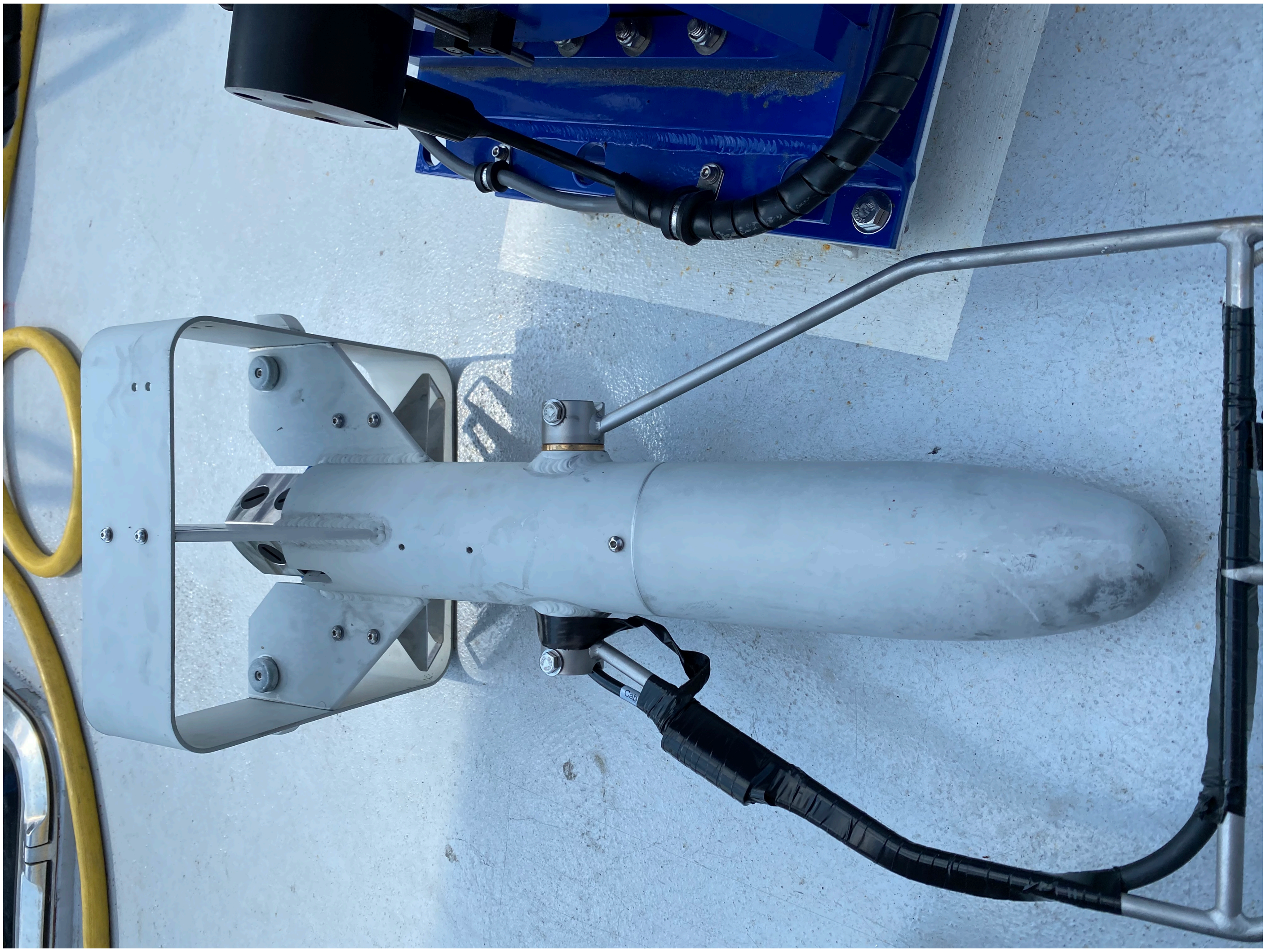

Figure 10: MVP Sensor free fall fish

A.6.2 CTD Profilers

No CTD profilers were utilized for data acquisition.

A.6.3 Sound Speed Sensors

A.6.3.1 AML Oceanographic AML Micro•X with SV•Xchange

Each survey vessel deployed on OPR-H355-KR-21 utilized an AML Oceanographic Micro•X with SV•Xchange to provide surface sound speed to the Kongsberg PU at 1 Hz over RS232 serial connection. The sensor, installed on the sonar head mount, was powered from a 12 volt power source.

<table>
<tr><td>Manufacturer</td><td colspan="4">AML Oceanographic</td></tr>
<tr><td>Model</td><td colspan="4">AML Micro•X with SV•Xchange</td></tr>
<tr><td rowspan="12">Inventory</td><td rowspan="4">R/V Benthos</td><td>Component</td><td>Surface Sound Speed Instrument</td><td>SV Sensor</td></tr>
<tr><td>Model Number</td><td>Micro•X</td><td>SV•Xchange</td></tr>
<tr><td>Serial Number</td><td>7762</td><td>204291</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2021-01-23</td></tr>
<tr><td rowspan="4">R/V Chinook</td><td>Component</td><td>Surface Sound Speed Instrument</td><td>SV Sensor</td></tr>
<tr><td>Model Number</td><td>Micro•X</td><td>SV•Xchange</td></tr>
<tr><td>Serial Number</td><td>12031</td><td>209306</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2021-01-23</td></tr>
<tr><td rowspan="4">R/V Substantial</td><td>Component</td><td>Surface Sound Speed Instrument</td><td>SV Sensor</td></tr>
<tr><td>Model Number</td><td>Micro•X</td><td>SV•Xchange</td></tr>
<tr><td>Serial Number</td><td>12854</td><td>209320</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2020-11-22</td></tr>
</table>

Figure 11: AML Oceanographic Micro•X with SV•Xchange

A.6.3.2 AML Oceanographic AML Base•X2 / Base•X / Minos•X with SV•Xchange

The AML Base•X2, Base•X, and Minos•X are sound speed profiling instruments integrated with time of flight sound speed sensors and pressure sensors to collect sound speed profiles. The Base•X2 and Base•X transferred sound speed profile data to AML Seacast over Wireless Local Area Network (WLAN) connection and RS232 serial cable when needed. The Minos•X, the secondary profiling instrument on the R/V Substantial, transferred sound speed profile data to AML Seacast via RS232 serial cable. On the R/V Chinook and the R/V Benthos, the Base•X2 was the primary profiling system. The backup profiler, Base•X, was utilized on the R/V Benthos from 05/13/21 to 06/01/21 due to power issues with the primary profiler. These power issues were resolved and the AML Base•X2 was then re-employed on the R/V Benthos from 06/02/21 to the end of the project.

<table>
<tr><td>Manufacturer</td><td colspan="2">AML Oceanographic</td></tr>
<tr><td>Model</td><td colspan="2">AML Base•X2 / Base•X / Minos•X with SV•Xchange</td></tr>
<tr><td rowspan="3">Inventory</td><td>R/V Benthos</td><td>
<table>
<tr><td>Component</td><td>Sound Speed Profiling Instrument</td><td>SV Sensor</td><td>Pressure Sensor</td><td>Sound Speed Profiling Instrument (secondary)</td><td>SV Sensor</td><td>Pressure Sensor</td></tr>
<tr><td>Model Number</td><td>Base•X2</td><td>SV•Xchange</td><td>P•Xchange</td><td>Base•X</td><td>SV•Xchange</td><td>P•Xchange</td></tr>
<tr><td>Serial Number</td><td>26045</td><td>206265</td><td>306187</td><td>25101</td><td>200936</td><td>304496</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2021-01-23</td><td>2021-01-22</td><td>N/A</td><td>2021-01-23</td><td>2021-01-22</td></tr>
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<tr><td>R/V Chinook</td><td>
<table>
<tr><td>Component</td><td>Sound Speed Profiling Instrument</td><td>SV Sensor</td><td>Pressure Sensor</td></tr>
<tr><td>Model Number</td><td>Base•X2</td><td>SV•Xchange</td><td>P•Xchange</td></tr>
<tr><td>Serial Number</td><td>26005</td><td>209304</td><td>306129</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2021-01-23</td><td>2021-01-22</td></tr>
</table>
</td></tr>
<tr><td>R/V Substantial</td><td>
<table>
<tr><td>Component</td><td>Sound Speed Profiling Instrument (Secondary)</td><td>SV Sensor</td><td>Pressure Sensor</td></tr>
<tr><td>Model Number</td><td>Minos•X</td><td>SV•Xchange</td><td>P•Xchange</td></tr>
<tr><td>Serial Number</td><td>8234</td><td>200826</td><td>146220</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2021-01-23</td><td>2021-01-22</td></tr>
</table>
</td></tr>
</table>

Figure 12: AML Oceanographic Base•X2

Figure 13: AML Oceanographic Minos•X

A.6.4 TSG Sensors

No TSG sensors were utilized for data acquisition.

A.6.5 Other Sound Speed Equipment

No other surface sound speed sensors were utilized for data acquisition.

A.7 Computer Software

Manufacturer	*Software Name*	*Version*	*Use*
QPS	Qinsy	9.3.1	Acquisition
AML Oceanographic	Seacast	4.4.0	Acquisition
AML Oceanographic	MVP Controller	4.3.1	Acquisition
Applanix	POSView	10.20	Acquisition
Applanix	POSView	10.50	Acquisition
Applanix	POS MV Firmware	10.21	Acquisition
Applanix	POS MV Firmware	10.50	Acquisition
Kongsberg	Seafloor Information System (SIS)	4.3.2	Acquisition
Kongsberg	Kongsberg Firmware	1.6	Acquisition
HydrOffice	Sound Speed Manager	2021	Acquisition
Microsoft	Office 365	2021	Acquisition and Processing
Google	Google Drive	2021	Acquisition and Processing
NOAA (HSTB)	Pydro Explorer	19.4	Acquisition and Processing
ESRI	ArcGIS Online	2021	Acquisition and Processing
ESRI	ArcGIS Enterprise	10.8	Acquisition and Processing
ESRI	ArcPro	2.7.3	Processing
Teledyne CARIS	HIPS Professional	11.3.14	Processing
Teledyne CARIS	BASE Editor	5.5.5	Processing
QPS	Qimera	2.1.0	Processing (Patch Test)
QPS	FMGeocoder Toolbox (FMGT)	7.9.3	Processing
Applanix	POSPac MMS with Trimble Centerpoint RTX	8.6	Processing
Adobe	Acrobat DC	2021.005	Processing
TechSmith	Snagit	2020.1.5	Processing

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

No bottom sampling equipment was utilized for data acquisition.

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

B.1.1 Vessel Offsets

Static vessel surveys were performed to determine offsets on each vessel deployed on OPR-H355-KR-21 prior to survey operations. Measurement Specialist, Mike Ulmer of 3Space Inc, performed the most recent static surveys of each vessel. The R/V Benthos and R/V Substantial's static surveys were performed near Geodynamics Headquarters in Beaufort, NC on March 8-9, 2021. The R/V Chinook's static survey was performed on April 10, 2021, in Key West, Florida prior to survey operations. These static surveys were performed identically in survey scheme and when possible, the static survey re-occupied a variety of previous vessel reference punch marks to ensure quality of the vessel offsets and reference frame measurements. Additionally, the 3Space Inc team are experts in Metrology and have vigorous QC procedures that were employed throughout the survey to ensure accuracy of the calculated vessel offsets. For the static surveys, all sensor locations were surveyed, as well as several pre-determined punch mark locations across the vessel frame. The static surveys were conducted with a Leica 402 Laser Scanner and Spatial Analyzer software.

The R/V Benthos, R/V Chinook, and R/V Substantial are each configured such that position and attitude are output from the POS MV at the sonar reference point. The sonar reference point is defined as the tangent point between each sonar head in the dual-head configuration. The location and angular offsets from the tangent reference point to each sonar head, and also the waterline, are entered into SIS. Identical vessel offsets were input in the Qinsy vessel template database (.DB) file for real-time display of corrected sonar data during acquisition.

Figure 14: Static survey of R/V Substantial

B.1.1.1 Vessel Offset Correctors

Vessel offset correctors were not applied.

B.1.2 Layback

Not applicable as side scan sonar was not acquired.

Layback correctors were not applied.

B.2 Static and Dynamic Draft

B.2.1 Static Draft

This project incorporated an Ellipsoid Referenced Survey (ERS) workflow and as a result, static draft was accounted for in the soundings by using post-processed ellipsoid-based corrections in addition to the real-time corrections. The combined correctors work to factor out the static draft, squat, and settlement of the survey vessel.

B.2.1.1 Static Draft Correctors

Static draft correctors were not applied.

B.2.2 Dynamic Draft

This project incorporated an ERS workflow and as a result, dynamic draft was accounted for in the soundings by using post-processed ellipsoid-based corrections in addition to the real-time corrections. The combined correctors work to factor out the static draft, squat, and settlement of the survey vessel.

B.2.2.1 Dynamic Draft Correctors

Dynamic draft correctors were not applied.

B.3 System Alignment

B.3.1 System Alignment Methods and Procedures

Multibeam patch tests were performed on each survey vessel to establish installation mounting biases between the attitude reference frame and the sonar reference frame. The patch tests also determined any latency bias between the sonar systems and positioning systems. Patch tests were conducted on each vessel prior to the start of data acquisition and whenever a major system hardware change was made. Patch tests were conducted in accordance with section 5.2.4.1 of the April 2021 Hydrographic Survey Specifications and Deliverables (HSSD). Patch test data were assessed in QPS Qimera by multiple hydrographers to issue an uncertainty associated with the patch test biases. Patch test biases for the R/V Benthos, R/V Chinook, and R/V Substantial were entered into SIS as well as the Qinsy .DB file. Additionally, these patch test biases are entered into the appropriate locations in the CARIS HVF. To ensure quality in system alignment and the integrity of the sonar data, daily roll lines were collected on the R/V Benthos and R/V Chinook since these vessels utilized a deployable over-the-side pole mount. For the R/V Benthos, an improved roll value was determined from a multi-day assessment of the daily roll lines and on 05/07/21, this value was then entered into SIS instead of the HVF. This is reflected in the HVF and SIS offsets appropriately.

B.3.1.1 System Alignment Correctors

Vessel	R/V Benthos		
Echosounder	Kongsberg EM2040C Dual		
Date	2021-04-13		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.001 seconds
	Navigation Time Correction	0.000 seconds	0.001 seconds
	Pitch	-0.494 degrees	0.110 degrees
	Roll	34.187 degrees	0.110 degrees
	Yaw	359.695 degrees	0.189 degrees
	Pitch Time Correction	0.000 seconds	0.001 seconds
	Roll Time Correction	0.000 seconds	0.001 seconds
	Yaw Time Correction	0.000 seconds	0.001 seconds
	Heave Time Correction	0.000 seconds	0.001 seconds
Date	2021-04-13		
Patch Test Values (Transducer 2)		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.001 seconds
	Navigation Time Correction	0.000 seconds	0.001 seconds
	Pitch	-0.507 degrees	0.110 degrees
	Roll	-35.853 degrees	0.110 degrees
	Yaw	359.850 degrees	0.189 degrees
	Pitch Time Correction	0.000 seconds	0.001 seconds
	Roll Time Correction	0.000 seconds	0.001 seconds
	Yaw Time Correction	0.000 seconds	0.001 seconds
	Heave Time Correction	0.000 seconds	0.001 seconds

Vessel	R/V Chinook		
Echosounder	Kongsberg EM2040C Dual		
Date	2021-04-13		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.001 seconds
	Navigation Time Correction	0.000 seconds	0.001 seconds
	Pitch	0.488 degrees	0.101 degrees
	Roll	36.122 degrees	0.101 degrees
	Yaw	0.020 degrees	0.120 degrees
	Pitch Time Correction	0.000 seconds	0.001 seconds
	Roll Time Correction	0.000 seconds	0.001 seconds
	Yaw Time Correction	0.000 seconds	0.001 seconds
	Heave Time Correction	0.000 seconds	0.001 seconds
Date	2021-04-13		
Patch Test Values (Transducer 2)		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.001 seconds
	Navigation Time Correction	0.000 seconds	0.001 seconds
	Pitch	0.570 degrees	0.101 degrees
	Roll	-34.228 degrees	0.101 degrees
	Yaw	0.113 degrees	0.120 degrees
	Pitch Time Correction	0.000 seconds	0.001 seconds
	Roll Time Correction	0.000 seconds	0.001 seconds
	Yaw Time Correction	0.000 seconds	0.001 seconds
	Heave Time Correction	0.000 seconds	0.001 seconds

Vessel	R/V Substantial		
Echosounder	Kongsberg EM2040C Dual		
Date	2021-05-14		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.001 seconds
	Navigation Time Correction	0.000 seconds	0.001 seconds
	Pitch	-1.290 degrees	0.086 degrees
	Roll	37.260 degrees	0.086 degrees
	Yaw	0.520 degrees	0.118 degrees
	Pitch Time Correction	0.000 seconds	0.001 seconds
	Roll Time Correction	0.000 seconds	0.001 seconds
	Yaw Time Correction	0.000 seconds	0.001 seconds
	Heave Time Correction	0.000 seconds	0.001 seconds

Date	2021-05-14		
Patch Test Values (Transducer 2)		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.001 seconds
	Navigation Time Correction	0.000 seconds	0.001 seconds
	Pitch	0.200 degrees	0.086 degrees
	Roll	-34.950 degrees	0.086 degrees
	Yaw	2.390 degrees	0.118 degrees
	Pitch Time Correction	0.000 seconds	0.001 seconds
	Roll Time Correction	0.000 seconds	0.001 seconds
	Yaw Time Correction	0.000 seconds	0.001 seconds
	Heave Time Correction	0.000 seconds	0.001 seconds

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

All data planning, calibrations, acquisition, processing, QC, quality assurance (QA), and reporting were performed under the direct supervision of the Chief of Party. Field data collection and processing were done under the supervision of a highly qualified team including the Chief of Party, Lead Hydrographer, Senior Hydrographer, and Data Processing Manager. Chief of Party David Bernstein and Lead Hydrographer Ben Sumners are both ACSM-NSPS-THSOA Certified Hydrographers.

Prior to the start of data acquisition, and following static vessel surveys and verification measurements, a series of calibrations and tests took place on each vessel to prepare and validate the setup and integration of all survey systems across all vessels. These procedures included navigation/GAMS calibrations, patch tests, performance checks, echo sounder bar/lead line checks, and a water level float test.

Line plans were developed based on optimal multibeam coverage and quality. Data acquisition used survey lines for tracking, however, lines were mostly used as a reference for data-driven acquisition, in which case captains used ~25% overlap sectors in the helm map to guide navigation. Features identified in the field and during on-site data processing were further investigated with additional MBES data coverage when deemed necessary, to adequately develop the feature. Bathymetric data acquisition around engineered shoreline, structures, reefs, and shoals were collected with special care and safety to provide the most accurate least depths and required coverage. All vessels utilized Qinsy for navigation, monitoring of system health, data logging, real-time progress tracking, and QC assessments. Using a custom NMEA output driver and

Wireless Wide Area Network (WWAN) connection, vessel tracking information was streamed over an ESRI GeoEvent Server to a Survey Information Management System (SIMS) hosted through ArcGIS Online. This combined progress tracker and dashboard system provided real-time situational awareness of each vessel and calculated various project tracking metrics, providing critical guidance for management and hydrographers in real-time. Each vessel and survey system were optimized for data collection to meet the requirements of the Project Instructions (PI) and HSSD. The R/V Benthos and R/V Chinook operated on a 12-hour day operation schedule while the R/V Substantial operated on a 24-hour schedule. The R/V Benthos, R/V Chinook, and R/V Substantial were configured with dual-head, dual swath EM2040C systems by synchronizing two Kongsberg PUs to provide approximately twice the along-track data density. Sonar systems were aided by the POS MV, which provided real-time QC of position and attitude data, and logged ancillary POSPac data (.000 files) for post-processing. All Kongsberg systems were controlled with SIS software and operated at 300 kHz. Additionally, all Kongsberg systems had absorption coefficients adjusted for saltwater in SIS and operated in "Normal" mode with "Auto" pulse width. Multibeam bathymetry data collected with the Kongsberg EM2040C systems were stored in the .ALL file.

Throughout the survey, a series of QC measures were taken to ensure that the survey data met the specifications of the PI and HSSD. Hydrographers on day operation vessels collected a daily set of "roll lines" to assess any potential biases ensued from daily deployment of the over-the-side sonar mount. Vessel speed and sonar coverage were monitored and adjusted when environmental conditions negatively impacted data quality. Vessel to vessel overlap was accomplished whenever possible for additional QC and crosslines were collected by multiple vessels.

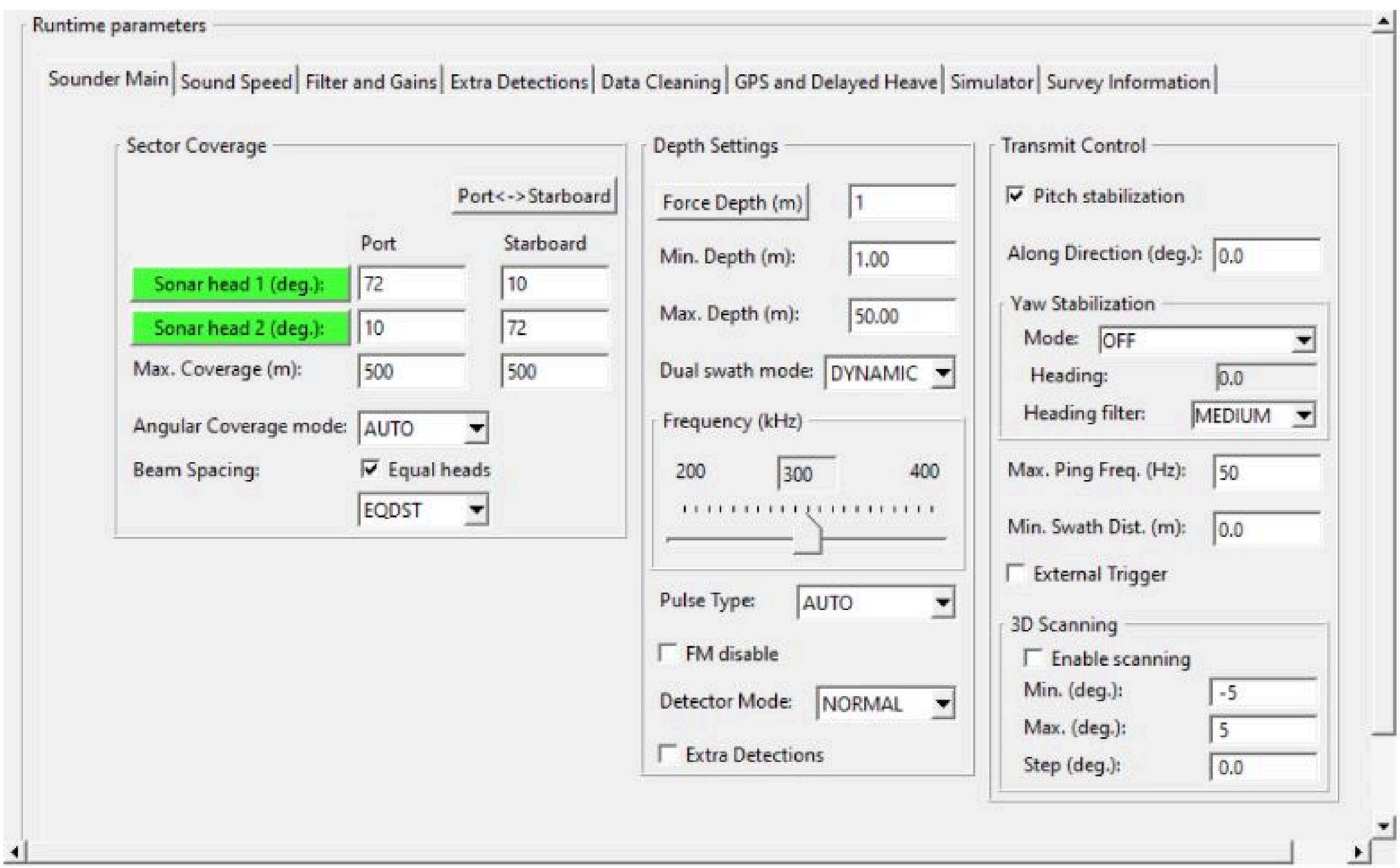

Figure 15: General SIS Runtime parameters window

Data Processing Methods and Procedures

Multibeam data processing were accomplished with Charlene, CARIS HIPS, and POSPac MMS. Initial data processing consisted of data transfer, file conversion, georeference bathymetry (application of GPS Tide, sound velocity corrections, and TPU calculation), CUBE surface generation, and SBET/SMRMSG creation (Phase 1). Immediately following acquisition, data were transferred via Charlene from portable solid-state drives (SSD) to the network attached server (NAS) hosting an array of SSDs. Charlene is an automated file transfer and batch data processing utility within Pydro Explorer developed by the National Oceanic and Atmospheric Administration (NOAA) Hydrographic Systems and Technology Branch (HSTB). Charlene automated the Phase 1 processing steps such that an initial surface and related QC data were generated before the next survey day. Phase 1 QC included assessing initial QC Tools results, SBET QC, surface inspection, assessment of data quality and system performance, and daily survey reporting.

Phase 2 processing began with application of SBET and SMRMSG data and re-running the georeferenced bathymetry process in CARIS HIPS. Another CUBE surface was then generated, and a thorough review of data quality was conducted along with data cleaning and feature identification/designation.

Phase 3 processing included QC and finalization of features/designations and bathymetric surfaces. During this stage, rigorous QC was performed to ensure completeness and adequacy of the final deliverables and associated reporting.

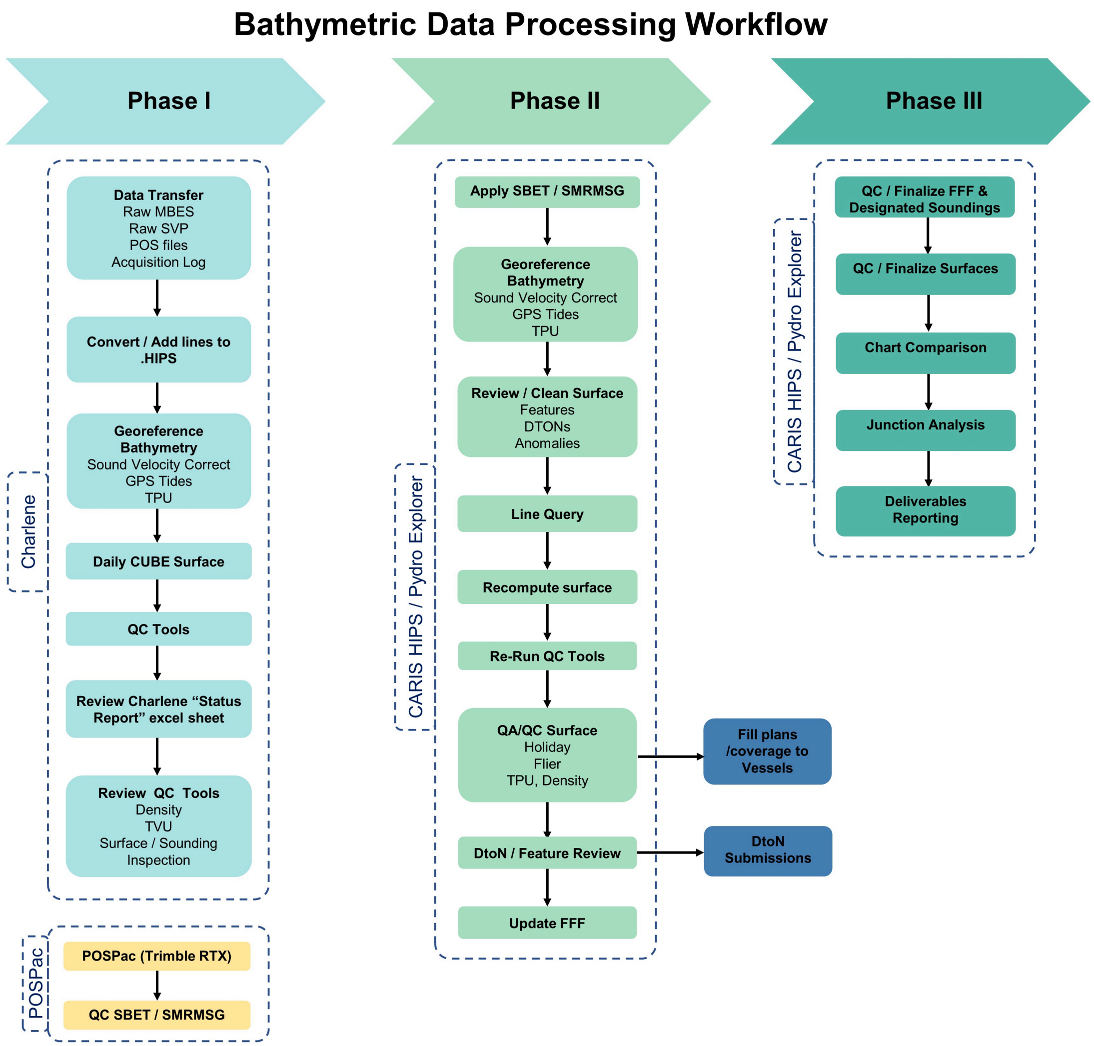

Figure 16: Bathymetric data processing workflow

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

All bathymetric surfaces were computed from fully corrected data in CARIS HIPS using CUBE algorithms specified in the CUBEParams_NOAA_2021.xml and standards specified in section 5.2.2 of the HSSD. Parent surfaces and depth controlled finalized surfaces were provided in CSAR format for each survey.

C.1.4.2 Depth Derivation

Prior to finalizing surfaces, data were thoroughly and redundantly reviewed for completeness and adherence to specifications in the HSSD. Outer beam clipping filters and manual data cleaning were utilized to clean erroneous swath data that adversely affected the surface. Some portions of lines were clipped in the Navigation Editor if the data were unnecessary or recovered. Processed soundings and features were reviewed in Subset Editor using both 2D and 3D views to ensure accurate designation of critical soundings were performed. Line queries were performed to ensure all data had consistent and complete correctors applied. Finalized surfaces were computed utilizing the "Apply Designated Sounding" function such that the surface represented each designated sounding depth. Uncertainty of the finalized surface was assigned from either uncertainty or standard deviation, whichever is greater.

C.1.4.3 Surface Computation Algorithm

The 2021 NOAA CUBE Parameters were used for CUBE surface computation. Surface generation used the following settings:

Gridding Method: CUBE
Bounding Polygon Type: Buffered
IHO Order: 1a
Disambiguation Method: Density and Local
Cube Configuration: NOAA_1m, NOAA_2m, NOAA_4m (with respect to depth range and coverage requirements)

C.2 Imagery

C.2.1 Multibeam Backscatter Data

Data Acquisition Methods and Procedures

Multibeam backscatter data collected with the Kongsberg EM2040C systems were stored in the .ALL file, which is directly importable into QPS FMGT. Data were acquired at 300 kHz with no major changes to settings. Hydrographers utilized real-time displays of backscatter and saturation to help assess any potential system-wide backscatter issues.

Data Processing Methods and Procedures

Although no processing or analysis of backscatter data were required, backscatter files were routinely processed for QA purposes in QPS FMGT and for the weekly progress reports. The mosaics were created to assure adequate coverage and quality of the backscatter. These mosaics were also submitted as a weekly deliverable in the progress reports during acquisition, which was an additional requirement outlined in the PI. SIMS ArcGIS Online Processing Manager Application (PMA) and ArcGIS Pro were utilized to review and combine the backscatter mosaics.

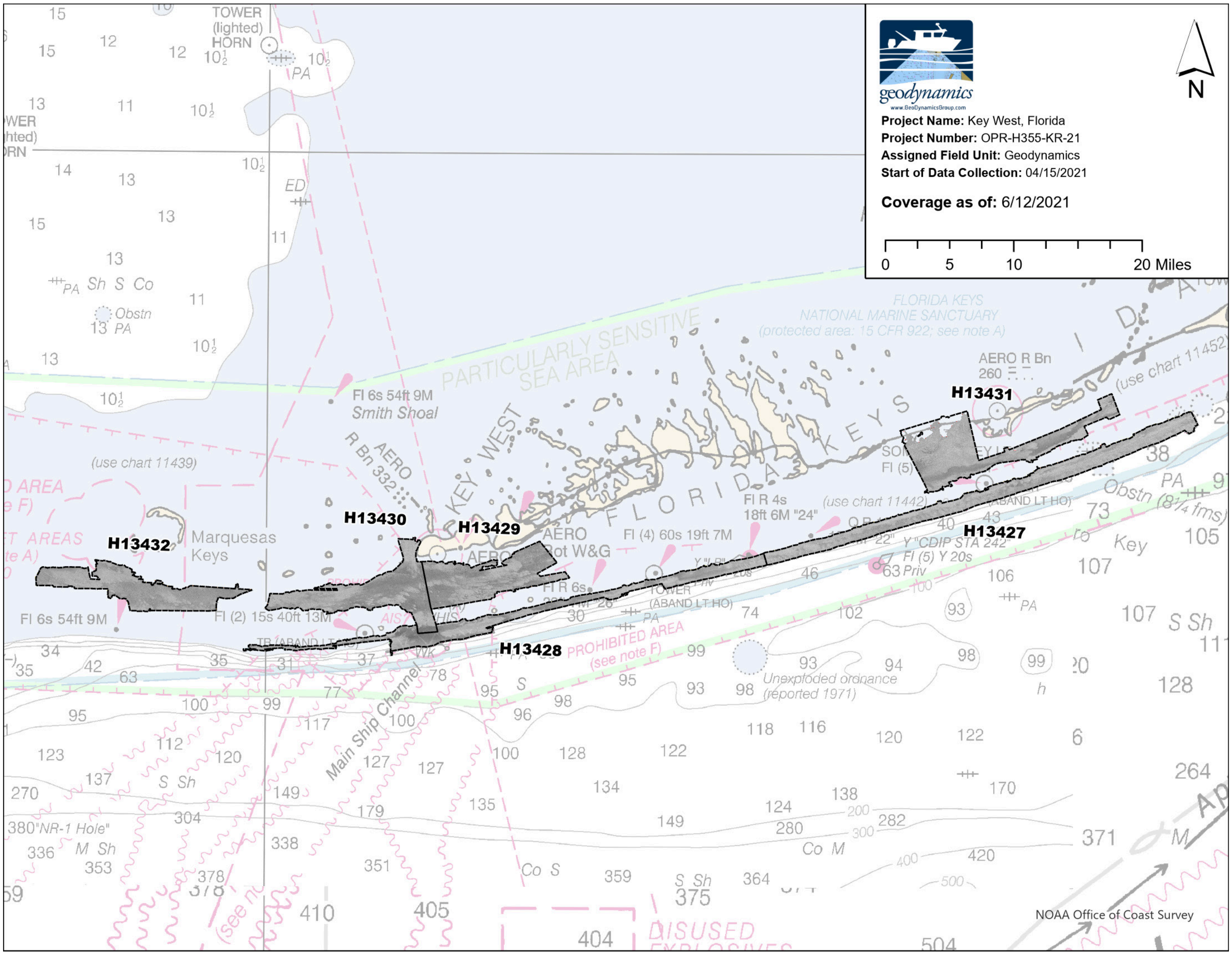

Figure 17: Example map of the backscatter weekly deliverable mosaic created with QPS FMGT and reviewed in the Processing Manager Application / ArcGIS Pro

C.2.2 Side Scan Sonar

Side scan sonar imagery was not acquired.

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

DGPS data was not acquired.

C.3.1.3 Other Horizontal Control Equipment

Data Acquisition Methods and Procedures

All survey vessels received G2+ GNSS satellite corrections from the Fugro Marinestar SBAS directly through the Applanix POS MV to provide real-time corrections to positioning. The Marinestar G2+ service provides corrections for GPS and GLONASS from a network of base stations around the world via geo-stationary satellites. Solution status was continuously monitored through the POSView controller software for dropouts or degraded accuracy.

Data Processing Methods and Procedures

For all hydrographic survey activities, POSPac data were collected through the POSView controller via Ethernet Logging and/or USB Logging. All position and attitude data were post-processed in POSPac MMS software using Trimble Centerpoint RTX solutions. The SBET was applied in CARIS HIPS to overwrite all position and attitude data and improve upon the real-time Marinestar G2+ accuracies, while minimizing Total Horizontal Uncertainty (THU). The application of the SBET in CARIS HIPS also transforms the data into the required horizontal datum. For all processed positions and data products (other than S-57 Final Feature File), the horizontal datum is North American Datum of 1983 (NAD83) (2011) Universal Transverse Mercator (UTM) Zone 17N, as required by the HSSD. Reference the corresponding Horizontal and Vertical Control Report (OPR-H355-KR-21_HVCR.pdf) for more information.

C.3.2 Vertical Control

C.3.2.1 Water Level Data

Data Acquisition Methods and Procedures

All surveys utilized an ERS workflow to reduce ellipsoid derived depths to chart datum.

All survey vessels received G2+ GNSS satellite corrections from the Fugro Marinestar SBAS directly through the Applanix POS MV to provide real-time corrections to ellipsoid heights. Solution status was continuously monitored through the POSView controller software for dropouts or degraded accuracy.

As dictated in the PI, water levels were determined from ellipsoid measurements throughout this ERS and soundings were reduced to Mean Lower Low Water (MLLW) by way of a provided VDatum Separation (SEP) model. Following pre-survey calibrations, a “float test” was performed with the R/V Benthos to ensure the quality of the GNSS corrections, SEP model, and survey systems integrations. The vessel remained stationary while nearby National Ocean Service (NOS) Water Level Station 8724580 – Key West, FL and recorded the MLLW elevation of the water surface. This information was compared to the near real-time water level data collected at Station 8724580 for the same time period and showed good agreement. Reference the corresponding Horizontal and Vertical Control Report (OPR-H355-KR-21_HVCR.pdf) for more information.

Data Processing Methods and Procedures

NOAA’s HSD OPS provided a VDatum SEP model package with the PI, the NAD83-MLLW SEP model within this package was utilized. Geodynamics requested an additional SEP model, ITRF14-MLLW, for real-time acquisition use only (not utilized for any delivered, processed data). All ellipsoid data were post-processed using the Applanix POSPac MMS software. Post-processed corrections were implemented with Trimble’s CenterPoint RTX service. The SBET was applied in CARIS HIPS to overwrite all position and attitude data, improve upon the real-time Marinestar G2+ accuracies to minimize Total Vertical Uncertainty (TVU), and transform the data to the desired vertical datum before SEP model application. The NAD83-MLLW SEP model was then utilized in CARIS HIPS to reduce the sonar data to MLLW.

C.3.2.2 Optical Level Data

Optical level data was not acquired.

C.4 Vessel Positioning

Data Acquisition Methods and Procedures

Vessel position, attitude, and trajectory data were acquired and logged with an Applanix POS MV v5. All vessels had the offsets between the Primary GNSS antenna and IMU Reference Point precisely measured and entered into the POSView controller software prior to data acquisition (see DAPR Appendix III). Additionally, vessel offsets to the tangent point of the sonar heads were entered into POSView as the Sensor 1 offset location. Prior to the start of surveys, GAMS calibrations were performed to align the Secondary GNSS antenna with the Primary GNSS antenna and IMU alignment with respect to the vessel reference frame. See DAPR Appendix IV for additional information on vessel offsets, configuration, and calibration. For the duration of the project, all survey vessels maintained subscriptions with Fugro’s Marinestar Global

Correction System and received G2+ corrections. Position, attitude, and trajectory data were logged via Ethernet Logging and/or USB Logging whenever survey activities occurred. This included five minutes before and after acquisition for adequate post-processing of kalman filtered data.

Data Processing Methods and Procedures

All position and attitude data were post-processed using Applanix POSPac MMS software and Trimble CenterPoint RTX corrections to produce an SBET file with centimeter level positioning accuracy. Post-processed solutions were reviewed for position and elevation RMS accuracies and altitude consistencies prior to exporting the SBET at the MBES systems' reference point. The SBET position and attitude data were applied to the sounding data in CARIS HIPS and further reviewed for error or inconsistencies in the post-processed data. All integrated SBETs were accompanied with a SMRMSG file for post-processed position and attitude error contributions to TPU estimates.

C.5 Sound Speed

C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

All sound speed instruments utilized AML Oceanographic Xchange sensors, which were calibrated within one year of survey operations. Calibration certificates can be viewed in DAPR Appendix II.

On the R/V Benthos and R/V Chinook, sound speed profiles were collected using Base•X and Base•X2 instruments equipped with pressure and time-of-flight sound speed sensors. Casts were routinely conducted approximately every two hours or less, and no greater than four hours, depending on conditions. Profilers were deployed and recovered by hand using a Cannon Lake-Troll Manual downrigger spooled with 300lb braided ultra-high-molecular-weight polyethylene line, recording samples at 1 Hz. Once retrieved, profile data were automatically sent to SeaCast via WLAN connection. SeaCast was setup to calculate sound velocity for saltwater, use UTC time, record in meters, split the up/down cast, and delete out of range or invalid points. Casts were reviewed and the down casts were then exported as .vel files to a folder monitored by Qinsy. The .vel files were applied automatically in Qinsy and imported into the SSM database, attributed a position from a SSM/SIS communication link, and then transmitted to SIS as an extended .ASVP file. Each vessel's daily casts were exported as an .SVP file from SSM for post-processing.

The R/V Substantial was equipped with an AML MVP mounted on the stern. The MVP integrated position and real-time depth via serial data communication from Qinsy. The free fall fish was deployed approximately every 30 - 120 minutes, depending on location, bathymetry, and water properties. The free fall fish was equipped with temperature, pressure, and time-of-flight sound speed Xchange sensors. The system recorded samples on deployment at 1 Hz and was programmed to automatically retrieve when it was ~2 m from the seafloor. Casts were transferred via TCP connection to the acquisition station for QC and application to sonar data. The casts were then imported into the SSM database, transmitted to SIS as an extended .ASVP file, and then exported as a .vel file to a folder monitored by Qinsy. Daily casts were exported as a single .SVP file from SSM for post-processing. From 05/27/2021-05/29/2021, damage to the MVP data cable led to the use of a secondary sound speed profiler, AML Minos•X. The workflow for the AML Minos•X followed the same the workflow described for the R/V Benthos and R/V Chinook, other than the initial data transfer from the instrument came from a serial connection instead of a WLAN connection.

Data Processing Methods and Procedures

Sound speed profiles collected during acquisition were thoroughly reviewed for date, time, location, depth of cast, and erroneous data. Profiles were then stored in each vessel's Raw and Processed SVP folders and also a master cast file, which stored all SVPs collected within a particular survey area (multi-vessel). In CARIS HIPS, sound speed profiles contained in the master SVP file were applied using the “Nearest in Distance within Time” approach, either utilizing 2 or 4 hours.

C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

For real-time beam forming and sound speed depiction of the upper water column, vessels used a Micro•X sound speed instrument mounted at the sonar heads. The Micro•X transmitted sound speed data (m/s) through a serial RS232 connection at 1 Hz. The systems received the surface sound speed data on the operator station through SIS.

Data Processing Methods and Procedures

In both Qinsy and SIS, an alarm was set to warn the hydrographer when real-time surface sound speed and the most recent profile differed by more than 2 m/s. Real-time surface sound speed was plotted geographically in SSM on each vessel and in the PMA for additional QC and guidance of operations. In CARIS HIPS, the "Use Surface Sound Speed" option was checked in the georeference bathymetry process.

C.6 Uncertainty

C.6.1 Total Propagated Uncertainty Computation Methods

TPU was calculated to provide an assessment of quality for the position and depth of individual soundings. Many aspects of the TPU model are based on manufacturer RMS values, while others can be more accurately modeled and minimized throughout the mobilization, acquisition, and processing phases.

The HVF contains all of the 1-sigma RMS values for the survey equipment used throughout the project for each vessel. Values for the position and attitude uncertainties are provided by Applanix, while uncertainty values with respect to sonars and frequencies are built-in to the HIPS device library. To more accurately model position and attitude uncertainties, inputs for position/navigation, gyro, pitch, roll, and GPS height were overwritten with 1-sigma RMS values stored in the SMRMSG file associated with each SBET file. Other values stored within the HVF include lever arm distances, measurement error, and patch test uncertainties. Potential uncertainties with lever arms were minimized by performing static vessel surveys using laser tracking methods to locate sensors with respect to each other and the vessel reference frame to within millimeters. Uncertainties for the alignment of sensors were minimized by integrating SBET solutions to more accurately determine biases from the patch tests. Patch tests were evaluated by multiple hydrographers to calculate standard deviation values for Motion Reference Unit (MRU) alignment for gyro and roll/pitch biases, which were placed in the HVFs accordingly.

During acquisition, careful consideration was made to minimize artifacts and their contribution to uncertainty. Hydrographers made considerable efforts to reduce the impact of sound speed issues during acquisition. These efforts included increasing the frequency of casts, closely monitoring real-time swath “smiling” or “frowning”, utilizing alerts for surface-to-profile sound speed deviation, observing the real-time standard deviation map display, and utilizing SSM to track spatial changes in surface sound speed along with profile location. When sound velocity had drastic spatial variation, the survey approach would be constrained to areas of similar water properties to avoid large refraction issues.

TPU calculations are performed using the CARIS HIPS Compute TPU process. The Compute TPU process utilizes the a-priori uncertainty estimates, the “real-time” estimates from the SMRMSG data, information from the CARIS sonar device library, and static values set for water level and sound speed uncertainty to calculate the estimated horizontal and vertical TPU for each sounding.

Uncertainty of the SEP model used to reduce soundings from NAD83 (2011) to MLLW was provided in the PI (0.089m at 2 sigma) and entered into the “Tide Measure” field of the Compute TPU process. Please refer to DR Appendix II for specific correspondence and clarification regarding the uncertainty associated with the provided SEP model. Uncertainty input to “Sound Speed - Measured” was derived from the field tolerance of 2 m/s deviance between surface and profile sound speed and the temporal distribution of casts (~2 hours). The "Sound Speed - Surface" value of 0.05 m/s reflects manufacturer accuracy at 2-sigma.

C.6.2 Uncertainty Components

C.6.2.1 A Priori Uncertainty

Vessel		R/V Benthos	R/V Chinook	R/V Substantial
Motion Sensor	*Gyro*	0.02 degrees	0.02 degrees	0.02 degrees
	Heave	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters
	Roll	0.01 degrees	0.01 degrees	0.01 degrees
	Pitch	0.01 degrees	0.01 degrees	0.01 degrees
Navigation Sensor		0.10 meters	0.10 meters	0.10 meters

C.6.2.2 Real-Time Uncertainty

Real-time uncertainty was not applied.

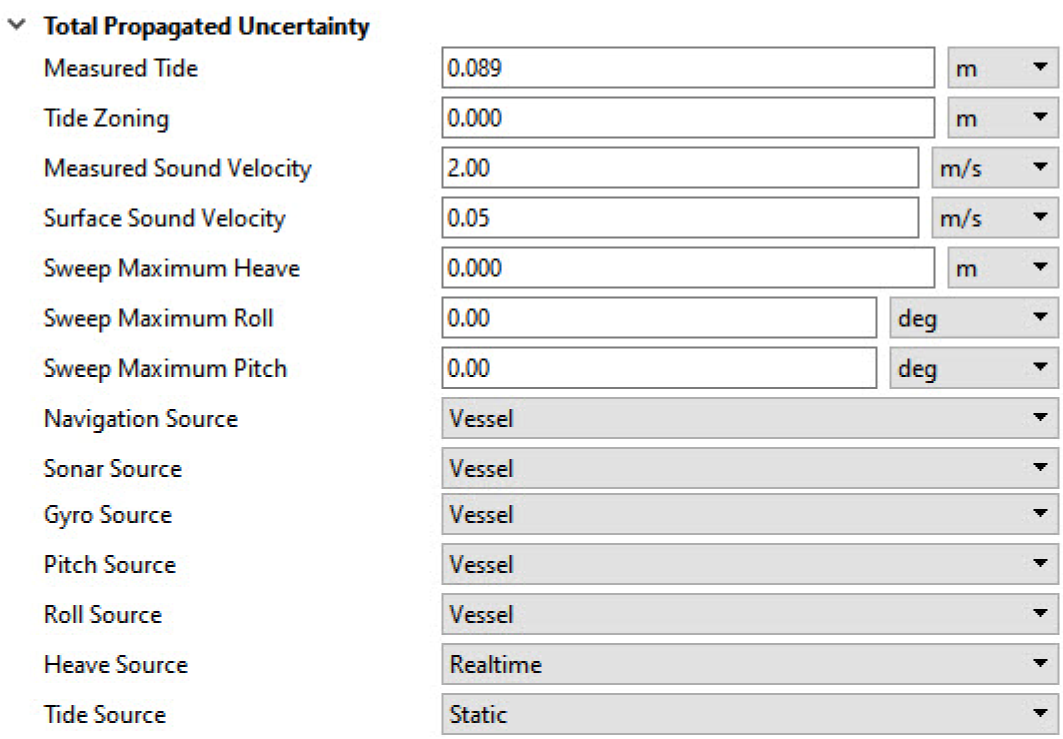

Figure 18: Uncertainty estimates parameters in the CARIS HIPS TPU Dialog within the georeference bathymetry process

C.7 Shoreline and Feature Data

Data Acquisition Methods and Procedures

No shoreline investigations or shoreline data collection were required for OPR-H355-KR-21.

Assigned features and new features identified during multibeam data acquisition were investigated and developed in accordance with the HSSD and guidance from the HSD Project Manager. Additional MBES coverage was acquired when necessary to adequately determine the least depth of features.

Above water features that were not developed with multibeam bathymetry were documented through an internally developed and customized ArcGIS Survey 123 mobile data collection application. The application reduced error, streamlined the workflow, and quality controlled feature development from collection to delivery in the Final Feature File (FFF). Hydrographers recorded feature attributes through a series of guided questions using predefined selections that eliminated erroneous descriptions and guaranteed completeness and accuracy required to attribute the FFF. GPS-tagged photos for each feature were acquired and associated with the corresponding feature when stored in the PMA, where the Lead Hydrographer and Data Processing Manager reviewed each feature in near real-time.

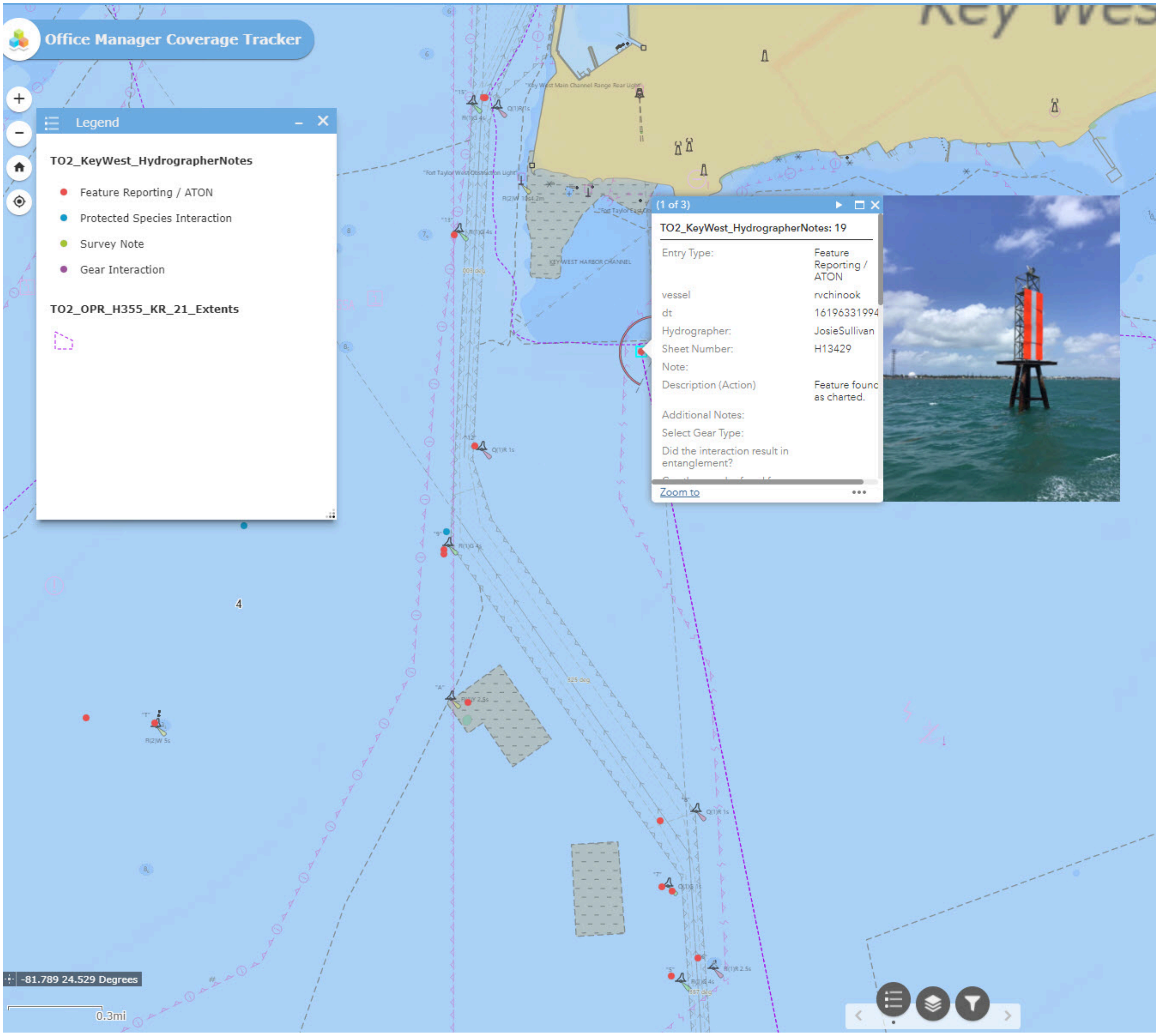

Figure 19: Processing Manager Application showing assigned and documented features

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

Feature data processing consisted of addressing all assigned features in the Composite Source File (CSF) provided with the PI package and adding all new features to a single .000 S-57 file for each survey. All multibeam data were reviewed for features, and least depths over navigationally and/or potentially significant features were flagged as “designated soundings” in CARIS HIPS. Development of each feature was completed in accordance with the HSSD including S-57 attribution and hydrographer remarks/ recommendations. Each feature included in the FFF was supplied a unique identifier, attributed in the Unique

ID field of the FFF. Associated images in the FFF utilized the unique identifier as a filename, followed by letters if there were more than one associated image.

C.8 Bottom Sample Data

Bottom sample data was not acquired.

D. Data Quality Management

D.1 Bathymetric Data Integrity and Quality Management

D.1.1 Directed Editing

Direct editing of soundings were performed to clean spurious and erroneous data that adversely affected the final surface and depth determination of features. In addition to visual assessment and cleaning from the bathymetric surface, many derivative layers computed from the bathymetric surface and sounding data were used to guide data cleaning, assess quality, and illustrate adherence to the HSSD. Node standard deviation, standard deviation, uncertainty, and TVU-ness were surface layers commonly used in data cleaning and quality assessments. In addition to a visual inspection, all CUBE surfaces were analyzed using HydrOffice QC Tools Flier Finder tool to assure data does not contain fliers (anomalous data as defined by QC Tools flier finding algorithms #2-5). The tool was run with the standard presets and results were used to guide data editing.

D.1.2 Designated Sounding Selection

Designated sounding selection followed specifications in the HSSD. The CARIS HIPS Subset Editor was utilized to view soundings and the CUBE surface in 2D and 3D. Erroneous sounding data were cleaned, and a least depth was designated when necessary. Routinely and before surface finalization, the critical soundings layer in CARIS HIPS, which contains designated soundings, was regenerated for QA/QC purposes.

D.1.3 Holiday Identification

All CUBE surfaces were analyzed using HydrOffice QC Tools Holiday Finder to determine if the surface contained holidays, as described in section 5.2.2 of the HSSD. The tool scanned the CUBE surfaces to identify any holidays and generated an S-57 file to represent the locations of holidays. Another method of holiday evaluation was to visually pan the CUBE surfaces to identify holidays. The hydrographer would often alter the surface display (color ranges, symbology, shading) to help aid in identifying coverage gaps.

During survey operations, holidays were compiled into a shapefile line plan and loaded into Qinsy on each vessel for recovery.

D.1.4 Uncertainty Assessment

All CUBE surfaces were analyzed using the HydrOffice QC Tools Grid QA tool to assure at least 95% of the surface grid nodes meet TVU specifications. Results of the Grid QA tool are illustrated in a graphical representation of the surface uncertainty statistics.

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

Crosslines were evaluated in CARIS HIPS with a detailed visual inspection followed by a thorough statistical analysis. To conduct the statistical analysis, a CUBE surface was generated with strictly mainscheme data and another, separate CUBE surface was generated with only crossline data. The mainscheme and crossline surfaces were analyzed using the Compare Grids tool in Pydro Explorer, which generated a difference surface and associated statistics. In addition to the direct statistics from the surface differencing, the tool assessed the difference surface statistics and computed the proportion of TVU consumed by the mainscheme-to-crossline differences per surface node.

D.1.5.2 Junctions

As required in the PI, junction analyses were conducted between overlapping data from OPR-H355-KR-21 surveys and with adjacent 2019 NOAA National Geodetic Survey (NGS) lidar data, registry number FL-1806-TB-C. All junction analyses were performed using the Pydro Compare Grids tool. The inputs for this tool were the CUBE surfaces for each individual survey at matching resolutions. The tool outputs a difference surface and the statistical results are illustrated in a graphical representation of the surface difference statistics. Additional inspection of junctions were performed using the 2D and 3D views in Subset Editor.

D.1.5.3 Platform to Platform

Vessel to vessel confidence checks were acquired prior to survey operations to assess confidence between each survey vessel and their respective survey systems. Confidence checks were assessed in CARIS HIPS by evaluating the agreement of sounding data as well as assessing statistics derived from vessel to vessel surface differences. Results of confidence tests can be found in DAPR Appendix V.

D.2 Imagery data Integrity and Quality Management

Imagery data integrity and quality management were not conducted for this survey.

E. Approval Sheet

This report and the accompanying data deliverable are respectfully submitted.

As Chief of Party, field operations contributing to the accomplishment of Surveys H13427, H13428, H13429, H13430, H13431, and H13432 were conducted under my direct supervision, with frequent personal checks of progress and adequacy. This report and accompanying data deliverable have been closely reviewed and are considered complete and adequate as per the Statement of Work (February 16, 2021).

The survey data meets or exceeds requirements as set forth in the Hydrographic Surveys Specifications and Deliverables 2021, Project Instructions (February 17, 2021), and Statement of Work (February 16, 2021). These data are adequate to supersede charted data in their common areas.

Approver Name	Approver Title	Date	Signature
David J. Bernstein, CH, PLS, GISP	Chief of Party	09/30/2021	David J. Bernstein Digitally signed by David J. Bernstein Date: 2021.09.30 12:56:10 -04'00'

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	I_Vessel_Wiring_Diagrams.pdf
Sound Speed Sensor Calibration	II_Sound_Speed_Sensor_Calibration_Reports.pdf
Vessel Offset	III_Vessel_Offset_Reports.pdf
Position and Attitude Sensor Calibration	IV_Position_Attitude_Sensor_Calibration_Reports.pdf
Echosounder Confidence Check	V_Echo_Sounder_Confidence_Check_Reports.pdf
Echosounder Acceptance Trial Results	N/A