DSSV Pressure Drop: Data Acquisition & Processing Report

Puerto Rico Trench Mission

December 2018

Report developed for Five Deeps Expedition by Cassie Bongiovanni

Internal Use Only

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A. Equipment

A.1 Vessel

A.1.1 DSSV Pressure Drop

Figure 1: DSSV Pressure Drop at sea (image: Atlantic Productions).

The DSSV Pressure Drop (Figure 1) is a privately-owned ~225-foot vessel built in the 1980s. This vessel is propeller powered with a hull-mounted gondola where the Kongsberg EM 124 system is mounted. The vessel reference frame is: +x bow forward, +y to starboard, and +z down (towards the seafloor). All points are referenced to the reference point (0,0,0) which is located at the MRU on the 1st deck of the ship.

A.1.2 Vessel Data Flow

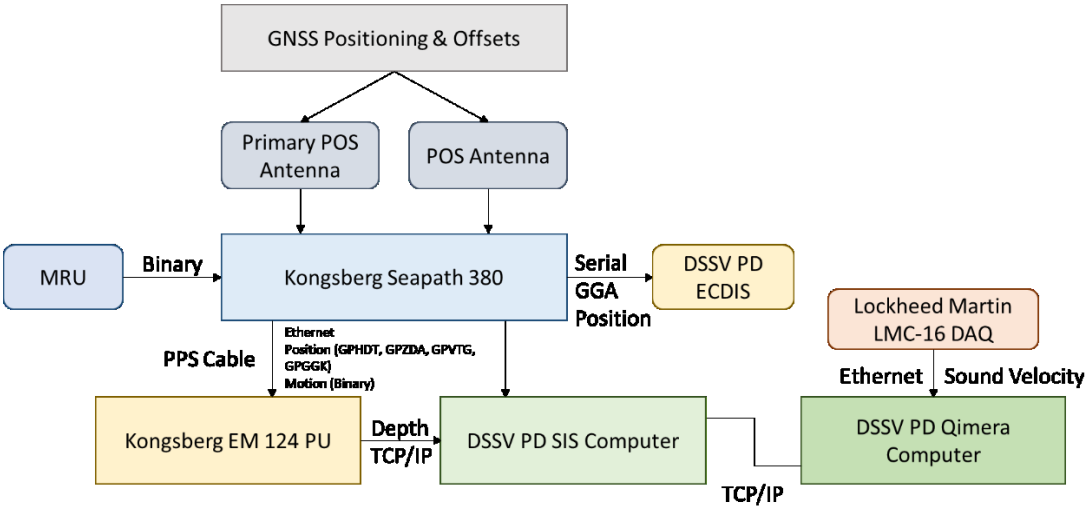

Figure 2: DSSV Pressure Drop data flow diagram.

A.2 Depth Measurement Equipment

A.2.1 Kongsberg EM 124 Multibeam Echosounder

Figure 3: Kongsberg EM 124 gondola attached to the hull of the DSSV Pressure Drop (image: Tony Dahlheim).

The EM 124 was installed on a steel gondola attached to the center of the DSSV Pressure Drop hull. The EM124 sits ~1 m below the hull and ~9m below the vessel reference point. The EM 124 is a dual-swath system with sixteen-sector angular coverage capabilities and the ability to map the deepest parts of the ocean. Data from this sonar come with a new datagram and file format .KMall, currently only accepted by Qimera (discussed in section A.6.1).

Instrument	Kongsberg EM 124 (1^o x 2^o)		
Manufacturer	Kongsberg Underwater Technology, INC.		
Installation Technician	Tony Dahlheim	**Contact:**	Tony.dahlheim@km.kongsberg-us.com
Installation Contractor	Brian Gamet	**Contact:**	brian@geosight3d.com; 01722 442302
Reference Frame Sub-Contractor	Robert Howard	**Contact:**	rob@trueposition.net; 262-689-9744
Runtime Specifications	Mounted		DSSV PD hull-mounted gondola
	Frequency		12kHz
	Ping Rate		Every ~20-29 seconds in deep water
	Swath Width		2km-20km
	Yaw Stabilized		Yes
	Pitch Stabilized		Yes
	Dual Swath		Yes, in shallow, No in deep
	Sector Mode		Yes
	Beam Spacing		Equidistant
	Max Coverage		~20km

	Backscatter	Yes
	Sonar Active Mode	No
	Water Column	Yes

Table 1: Kongsberg EM 124 description and specifications.

A.3 Positioning Equipment

A.3.1 Seapath 380+ Processing Unit and GNSS antennas

Figure 4: Kongsberg Seapath 380 in the systems rack of the electronics lab on the DSSV Pressure Drop.

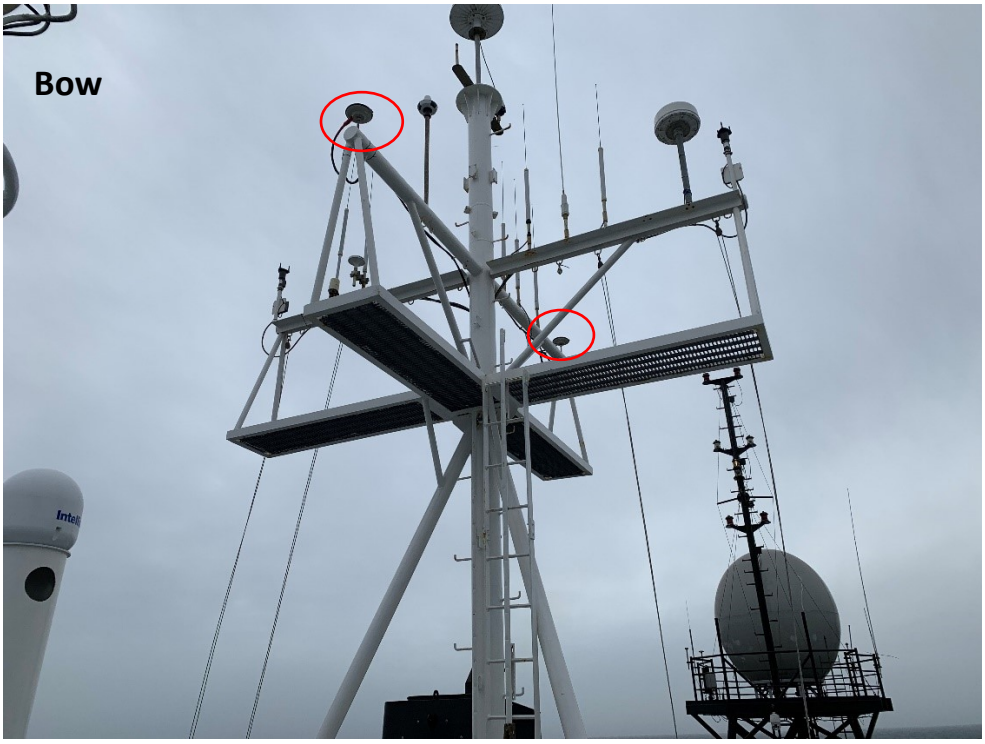

Figure 5: GPS antennas mounted at the top of the ship near the bow.

Instrument	Seapath 380	
Manufacturer	Kongsberg Maritime	
Description	The Seapath 380 provides accurate position and motion data. These data are utilized by the EM 124 for sonar beam steering corrections.	
Serial Number		
Specifications	Roll & Pitch Accuracy for ±5° amplitude	0.02° RMS
	Heading accuracy w/ 2.4 m antenna baseline	0.075° RMS
	Heading accuracy w/ 4 m antenna baseline	0.05° RMS
	Scale factor error in Roll, Pitch, Heading	0.08% RMS
	Heave accuracy	5 cm or 5% (highest)
	Heave motion periods (real-time output)	0-20 seconds
	Heave motion periods (delayed signal)	0-50 seconds
	Position accuracy w/ DGPS/GLONASS	0.5m RMS or 1m 95% CEP
	Position accuracy w/ SBAS	0.5m RMS or 1m 95% CEP
	Position accuracy w/ RTK (floating ambiguity)	0.15m RMS or 0.35m 95% CEP
	Velocity accuracy	0.03m/s RMS or 0.07m/s 95% CEP

Table 2: Kongsberg Seapath 380 system description and specifications.

A.4 Sound Speed Equipment

A.4.1 Reson SVP70 Fixed Mount at Transducer

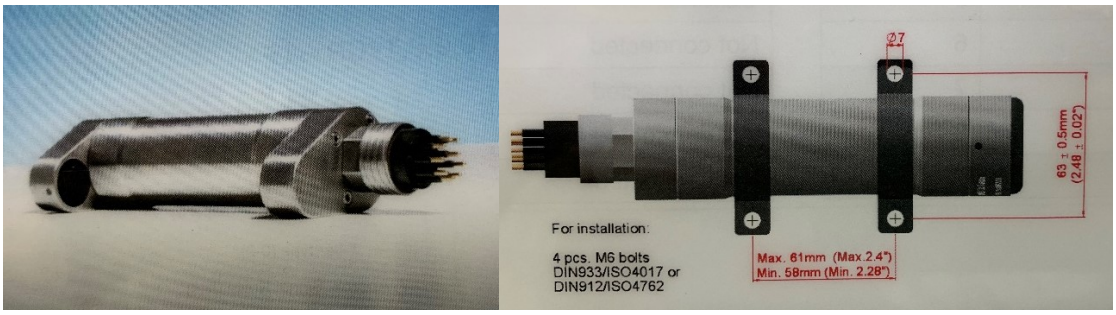

Figure 6: Reson SVP70 used for sound speed at the transducer.

The Reson SVP70 sound speed profiler was secured at the EM 124 transducer to ensure accurate sound speed measurements at the transducer head. These measurements are used by the EM 124 PU for beam corrections.

Instrument	**SVP 70**	
Manufacturer	Reson	
Description	Transducer-mounted sound velocity probe to allow for accurate bathymetry data in deep water.	
Serial Number		
Specifications	Sound Speed Accuracy	± 0.05 m/s

	Baud Rate	115200 baud
	Supply	9V to 55V <1.5W
	Depth Rating	6000 m
	Sampling Time	50 ms to 10 s
	Weight	1.0 kg

Table 3: Reson SVP70 specifications

A.4.2 AML Oceanographic Sound Velocity Profiler: Minos -X CTDSV (6000m)

Figure 7: AML Minos-X SVP in box (left) and attached to the lander (right).

The AML Minos-X CTDSV sound speed profiler was hand-deployed at the beginning of the SAT and lander-deployed at the end of the SAT. This instrument collects conductivity, depth, temperature, and sound velocity as it is lowered through the water column and is certified to a maximum depth of 6000m.

Instrument	**Minos-X CTDSV**	
Manufacturer	AML Oceanographic	
Serial Number	30930	
Description	This was attached to a science-party lander when a full-ocean depth was required and deployed individually when an upper-water column profile was desired.	
Specifications	Sampling Speed	*User defined*
	Depths	6000m (max)
	Depth Accuracy	± 3 dbar
	Sound Velocity Accuracy	0.5 m/s
	Conductivity Range	0-42 psu
	Conductivity Accuracy	± 0.010psu
	Density Range	990-1230 kg/m^3
	Density Accuracy	± 0.027 kg/m^3

Table 4: AML Minos-X SVP system description and specifications.

A.4.3 Lockheed Martin (Sippican) XBTs

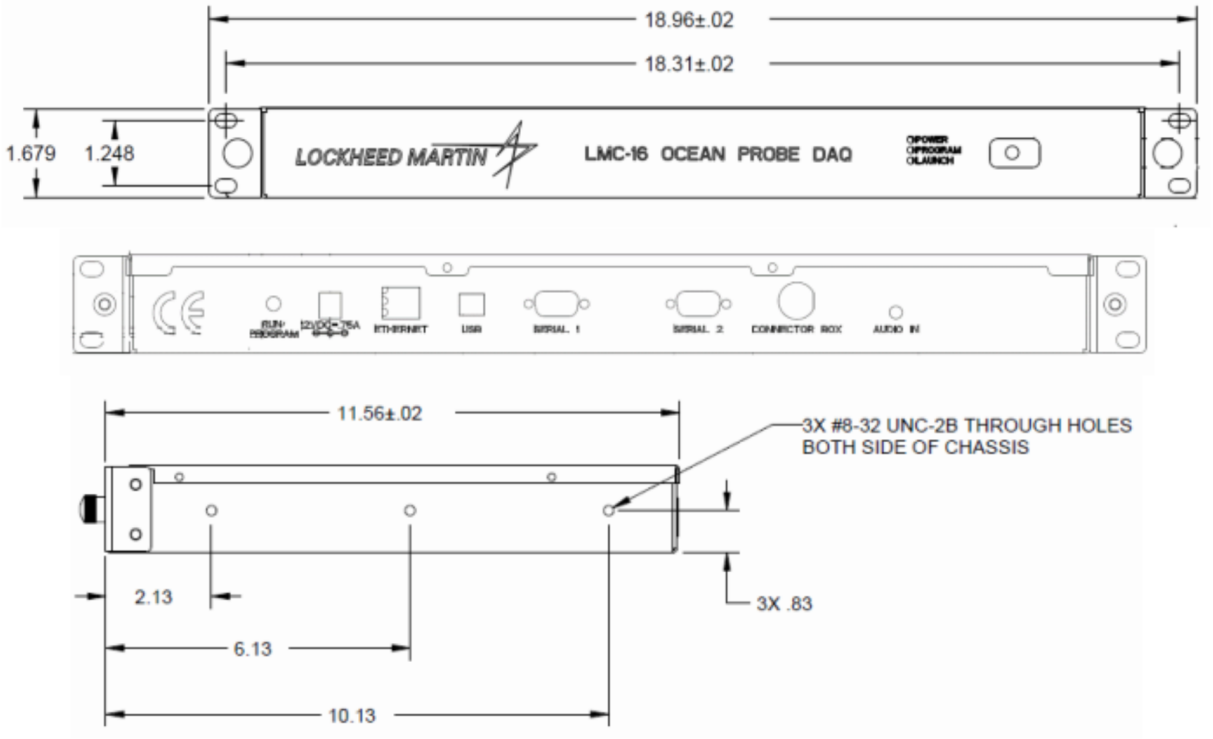

Figure 8: Lockheed Martin (Sippican) DAQ dimensions.

XBTs (or expendable bathymetric temperature gauge) measure temperature in the upper water column which are used to update sound speed profiles. Coupling XBTs and Sound Speed Manager (A.5.4), surveying can continue without the need to completely stop to take a full-depth profile. Profiles collected in this manner will be integrated into the Kongsberg acquisition software (SIS) upon collection. XBTs were launched using a hand-held launcher off the stern. The DAQ was connected via ethernet connection to the processing computer at the mapping workstation.

Probe Type	Sippican P/N	Max Depth	Max Vessel Speed
T-5	211105-1	1830m	6 knots

Table 5: Lockheed Martin (Sippican) XBT T-5 information.

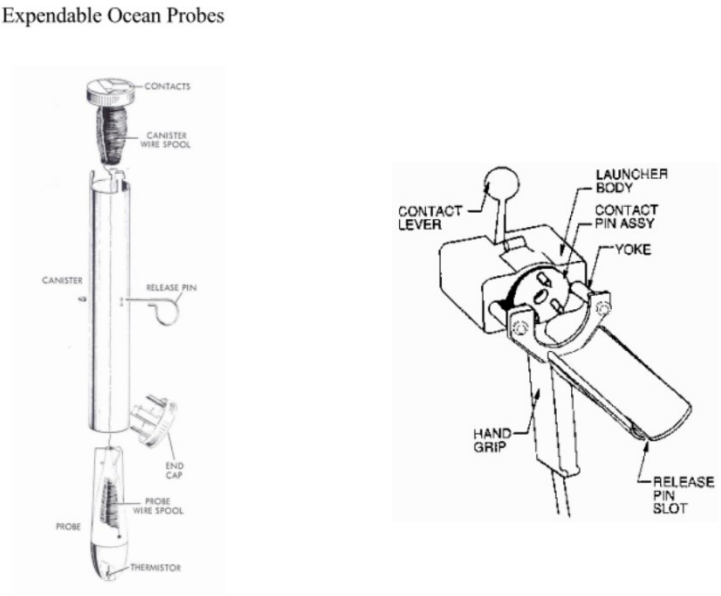

Figure 9: Lockheed Martin (Sippican) XBT T-5 and hand-held launcher dimensions and outlines.

A.4.4 Seabird SBE49 CTD

Figure 10: Seabird SBE49 FastCAT CTD

Instrument	**Seabird SBE49 FastCAT CTD**	
Manufacturer	Seabird Oceanorgaphic	
Serial Number	49-0456	
Description	This was attached to the Limiting Factor submersible as full-ocean depth sound velocity probe. Data was taken from this probe for post-processing sound velocity corrections in the trench.	
Specifications	Sampling Speed	16 Hz (16 samp/sec)
	Depths	10,500m (max)
	Conductivity Accuracy	± 0.0003 S/m
	Temperature Accuracy	± 0.002 °C
	Pressure Accuracy	± 0.1% of full-scale range
	Conductivity Resolution	0.00005 S/m
	Temperature Resolution	0.0001°C
	Pressure Resolution	0.002% of full scale range

Table 6: Seabird SBE 49 Fast CAT CTD sensor specifications.

A.5 Data Acquisition Software

The following software was used to collect accurate bathymetric (mapping) data.

Name	Manufacturer	Version	Installation Date
ArcMap/ArcGIS	ESRI	10.6.1	09/18/2018
SeaCast	AML	4.4.0	12/13/2018
SIS- Seafloor Information System	Kongsberg	5.1.1.153	12/03/2018
Seapath 380	Kongsberg SeaTex	1.11.0	12/03/2018
Sound Speed Manager	CCOM	2018.1.50	12/08/2018
Sippican WinMK21	Lockheed Martin	7.4.0.5	01/24/2019

Table 7: Data acquisition software information.

A.5.1 ESRI ArcGIS *(personal license)*

ESRI (Environmental Systems Research Institute) ArcGIS was used with a personal license to help with line planning, data visualization, and big-picture project organization.

A.5.2 AML SeaCast

SeaCast was used to collect, manage, download, and export the sound velocity data from the AML Minos-X.

A.5.2.1 Set-up Parameters

After downloading the AML SeaCast software, the following settings were designated before each drop when the profiler was connected to the computer.

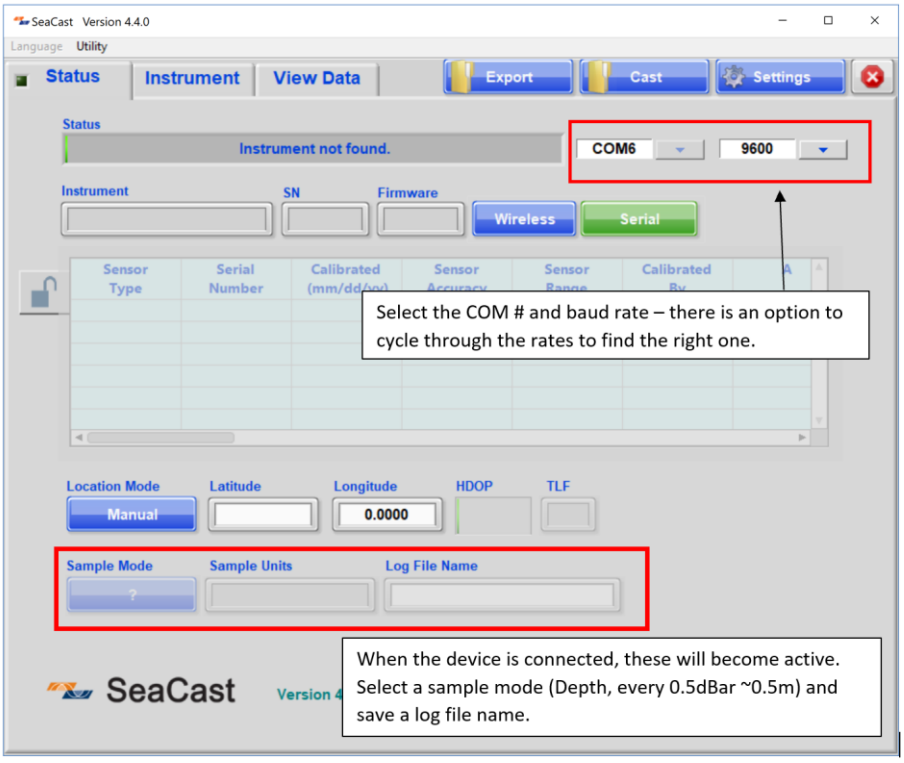

Figure 11: AML SeaCast instructional figure 1.

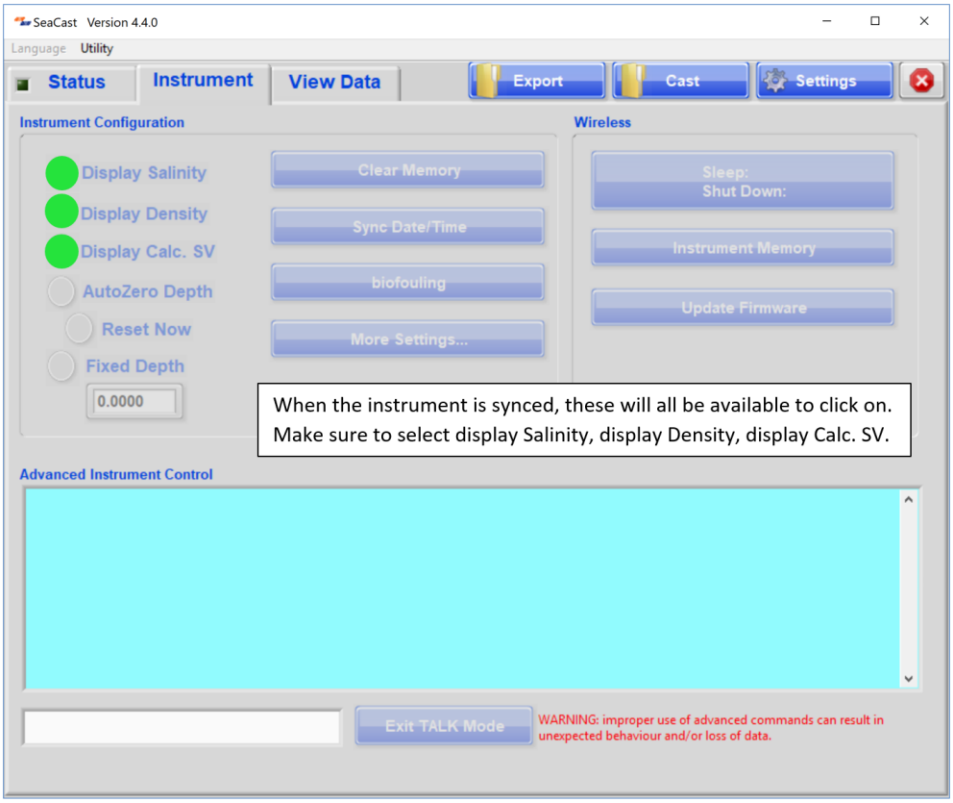

Figure 12: AML SeaCast instructional figure 2.

After the settings were determined, the profiler was removed from the system and the red plug was attached for deployment. Post-deployment, the profiler is reconnected to the computer, the data is viewed, and exported for use in SIS as an .asvp file. In SIS, the Sound Velocity Editor was used to extend these profiles to 12000m (required by SIS for each profile used).

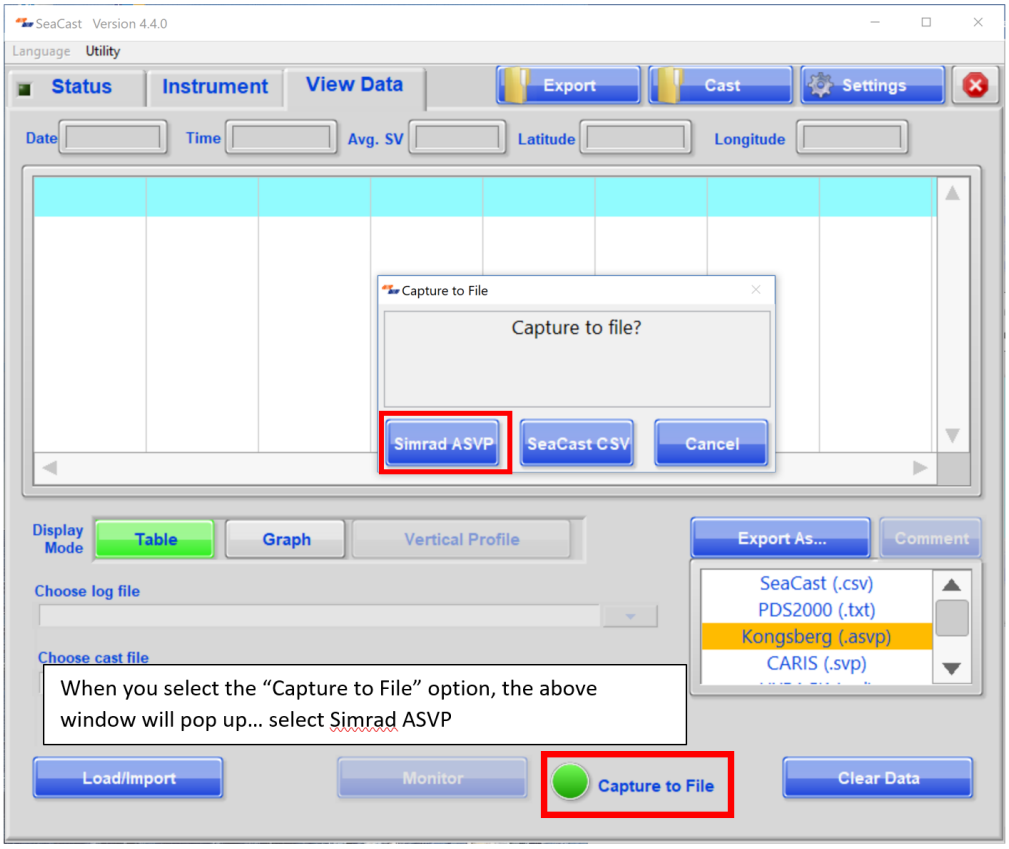

Figure 13: AML SeaCast instructional figure 3.

A.5.3 Kongsberg SIS – Seafloor Information System

SIS was used to collect EM 124 MBES data, apply lever-arms and water lines, patch test offsets, motion corrections, and real-time sound speed corrections.

A.5.3.1 Installation Parameters

The angular and location offsets for the EM 124 were entered in SIS as shown in Figure 14. The waterline was visually inspected and determined before leaving the dock in San Juan, Puerto Rico.

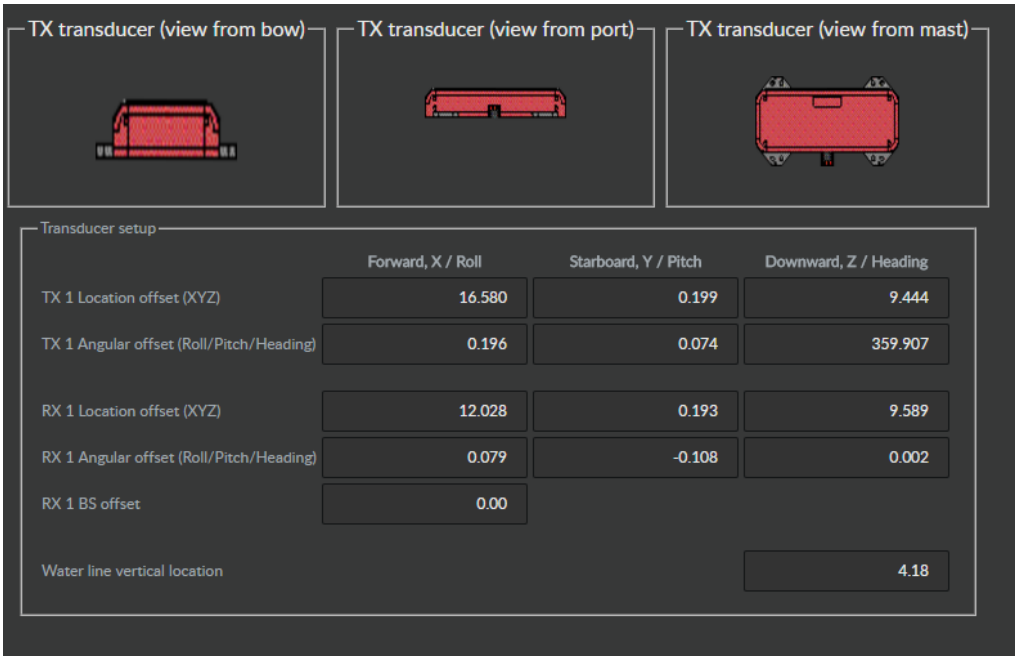

Figure 14: Kongsberg SIS 5 transducer offsets.

The input settings for each of the systems necessary to run the multibeam are shown in Figure 15.

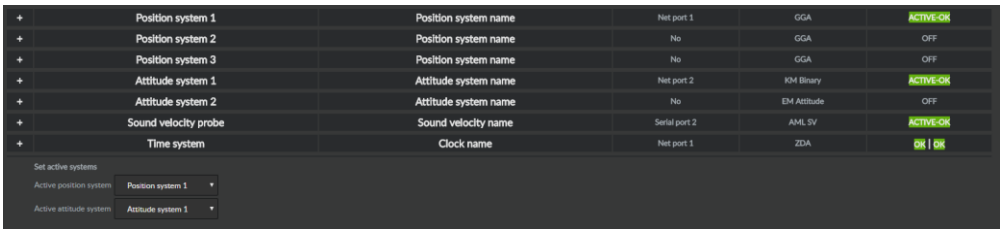

Figure 15: Kongsberg SIS 5 input parameters.

Position settings in SIS 5 are described in Figure 16 and are pulled from the Seapath 380. These were not changed for the duration of the mission.

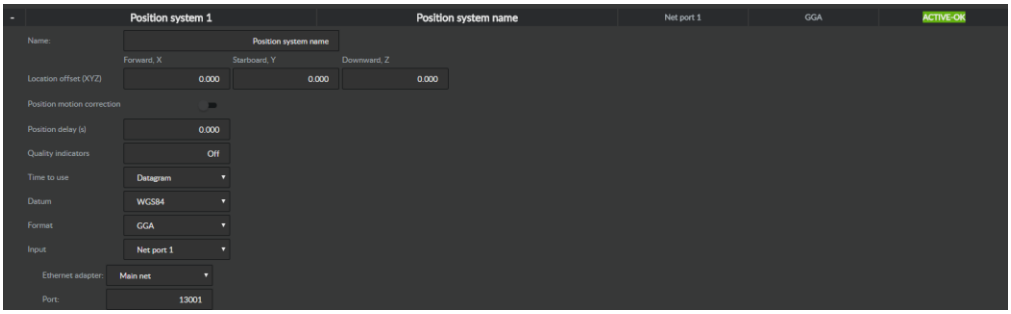

Figure 16: Kongsberg SIS 5 Position System input settings.

Attitude settings entered in SIS 5 described in Figure 17 and are pulled from the Seapath 380 which obtains this from the MRU. These settings were not changed for the duration of the mission.

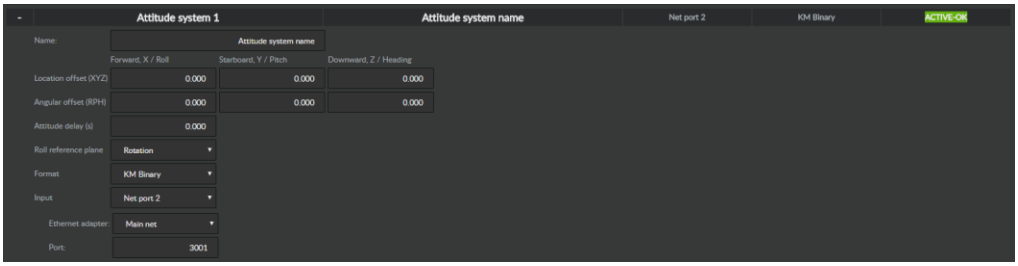

Figure 17: Kongsberg SIS 5 Attitude System input settings.

The sound velocity probe settings are outlined in Figure 18 and were not changed for the duration of the mission.

Figure 18: Kongsberg SIS 5 sound velocity probe input settings.

The time system input settings are outlined in Figure 19 and show that time was being pulled from the position datagram. *Note, it's possible this was alternatively set to be pulling the time from the "time datagram" at some point during the mission, which we believe may have contributed to the latency issues described in the attached DR.

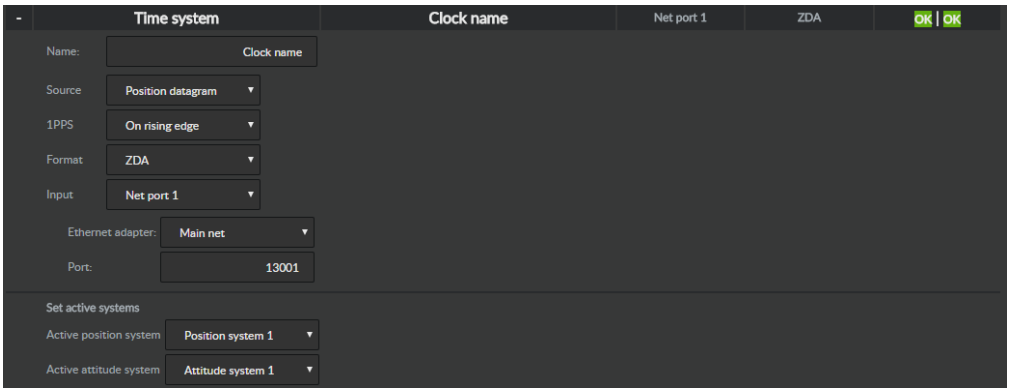

Figure 19: Kongsberg SIS 5 Time System input settings.

A.5.3.2 Output Settings

SIS output settings are outlined in Figure 20 and were not changed for the duration of the mission.

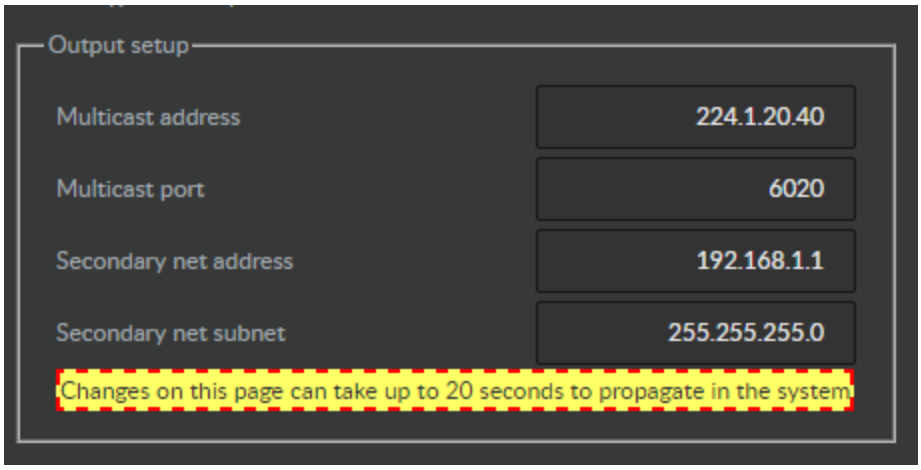

Figure 20: Kongsberg SIS 5 output settings.

A.5.3.3 Runtime Parameters

Runtime parameters changed frequently depending on what water depth we were operating in. For example, depths less than 500m needed to have a depth setting of 'Shallow Mode' and depths greater than 5000m needed to be in 'Very Deep Mode', but depths between could be in 'Auto'. Similarly, port and starboard angles were changed depending on weather and coverage – but were generally between 60-70 degrees on each side of nadir. Beam spacing was set to 'Equidistance' continuously with a maximum distance on either side of nadir set to 20 km. Dual Swath was set to 'Dynamic' (though was automatically turned off when 'Very Deep' depth mode was on) and pitch stabilization was always enabled. The pulse was set CW/FM mixed and not changed throughout the mission. To produce more accurate selections of the seafloor when noise was observed in the port side of the water column view, the transmit angle was set to 2° and sometimes changed to 3° when necessary.

A.5.4 Seapath Software

Kongsberg Seapath software was used to provide real-time GPS location and DGPS corrections via SBAS corrections (coverage permitting) to SIS, the bridge, and Triton sub navigation.

A.5.4.1 GNSS Geometry

The following image shows the lever arms entered in the Seapath and shows the vessel reference frame information. These values were measured and determined by a third-party contractor listed in Table 1 and explained in further detail in the attached supplemental report.

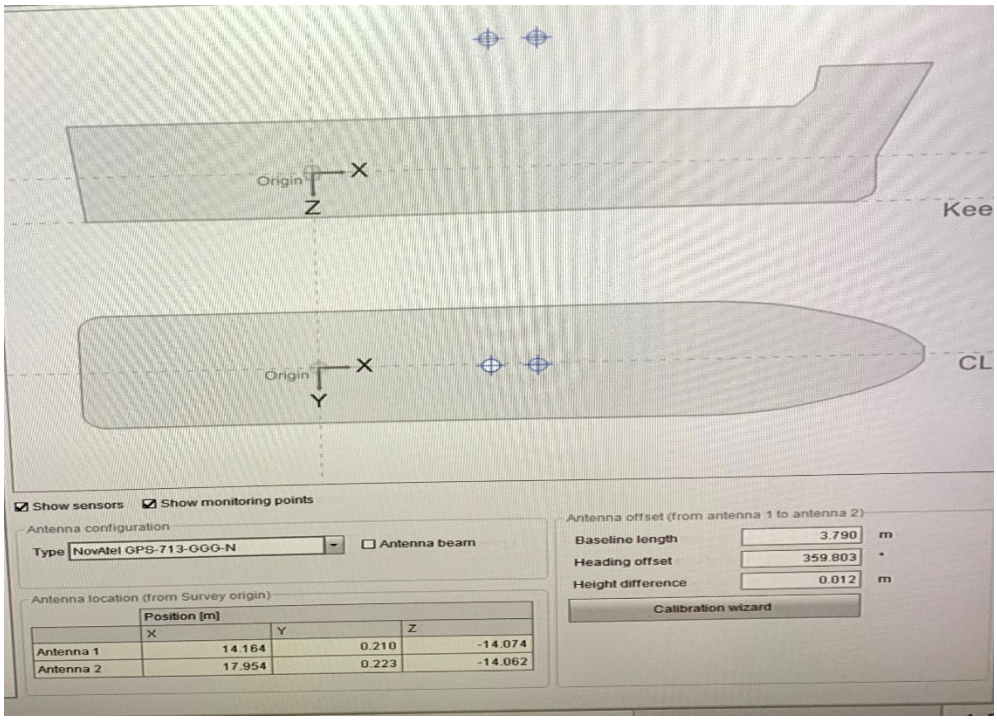

Figure 21:Seapath input geometry and offsets.

A.5.4.2 GNSS Processing

GNSS processing parameters entered in the Seapath configuration are shown in Figure 22. These parameters were not altered for the duration of the mission.

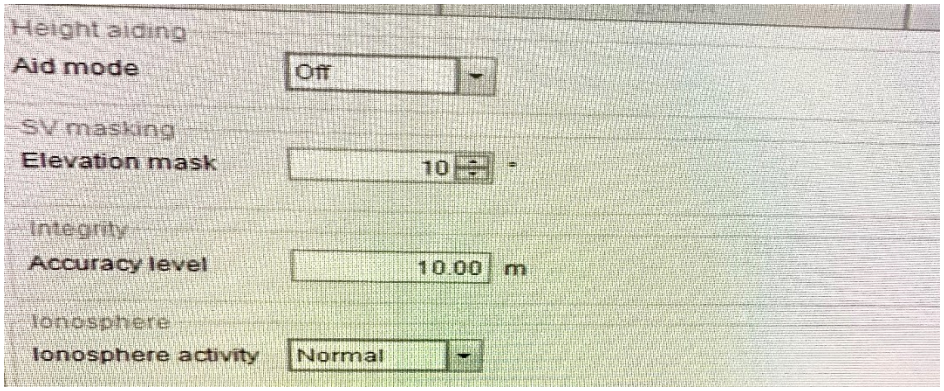

Figure 22: Seapath GNSS processing parameters.

A.5.4.3 GNSS Attitude Processing

GNSS attitude processing settings as set in the Seapath are shown in Figure 23 and were not altered for the duration of the mission.

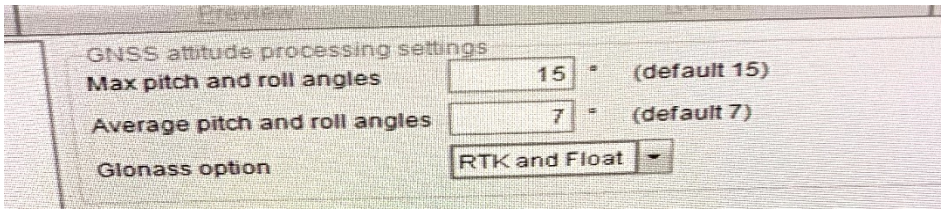

Figure 23: Seapath GNSS attitude processing parameters.

A.5.4.4 MRU Geometry

The MRU geometry angle offsets are recorded in the Seapath configuration settings as shown in Figure 24. These angles were measured by a third-party contractor as outlined in Table 1 and detailed further in the supplemental report included in this submission.

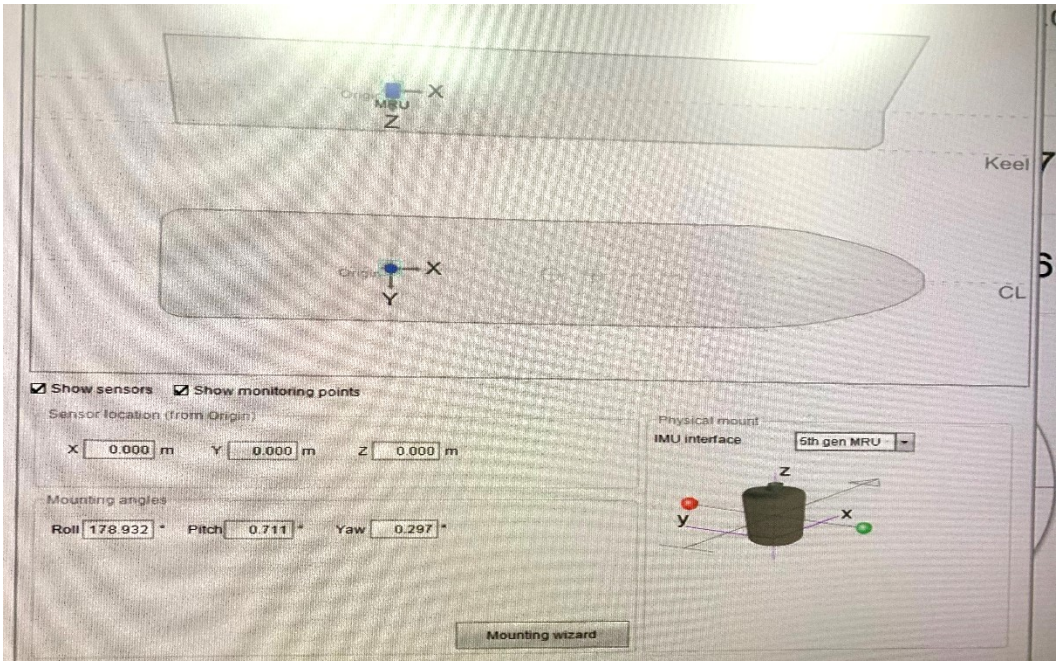

Figure 24: Seapath MRU input geometry - angles and offsets.

A.5.4.5 MRU Heave Configuration

The MRU heave information was set to 'Hydrographic survey' with a ten-second period as shown in Figure 25. These parameters were not changed for the duration of the mission.

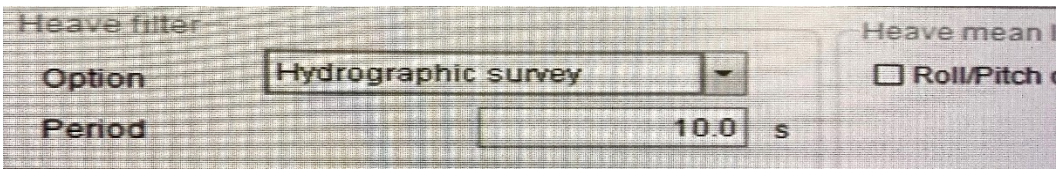

Figure 25: Seapath MRU heave configuration.

A.5.4.6 Input/Output

As shown in Figure 26, the GNSS antennas and MRU are connected via serial connections whereas positioning and attitude are relayed via ethernet connections to the EM 124 and the SIS computer. Similarly, a serial connection allows for the positioning and attitude information to be used by the DSSV Pressure Drop ECDIS for navigation. These were not changed for the duration of the mission.

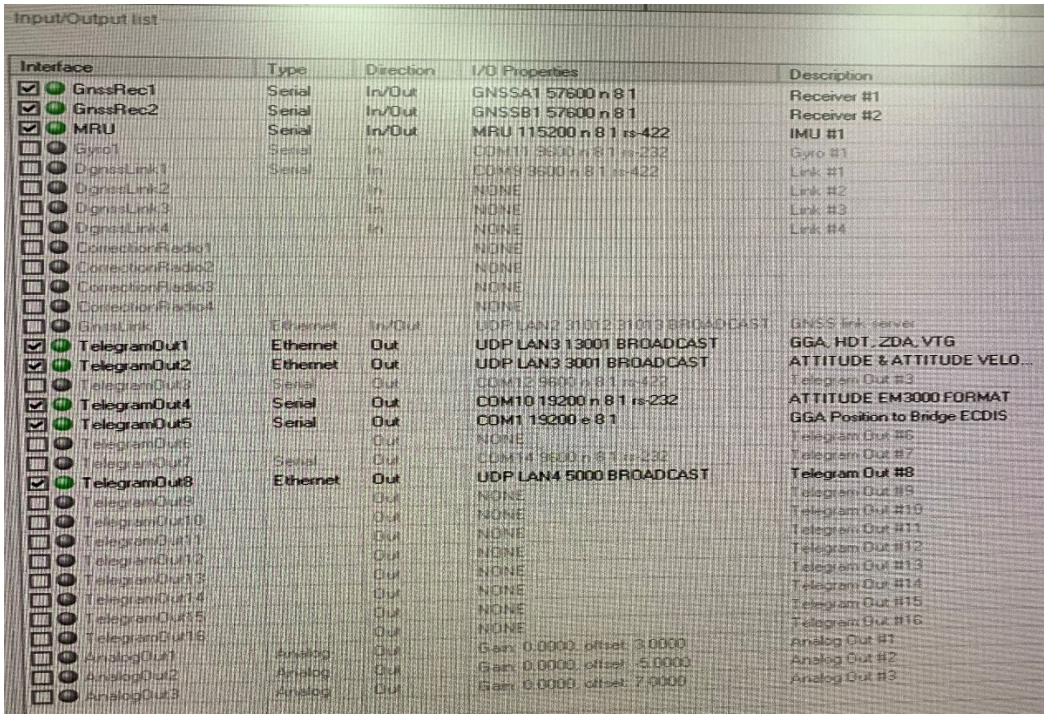

Figure 26: Seapath input and output information.

A.5.4.7 Serial Port Extender

The Seapath serial port extender parameters are shown in Figure 27 and were not altered for the duration of the mission.

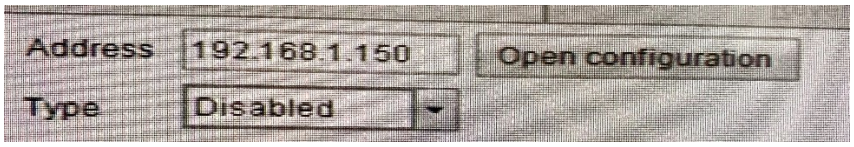

Figure 27: Seapath serial port extender input parameters.

A.5.4.8 Data Pool

The Seapath data pool parameters are shown in Figure 28 and were not altered for the duration of the mission.

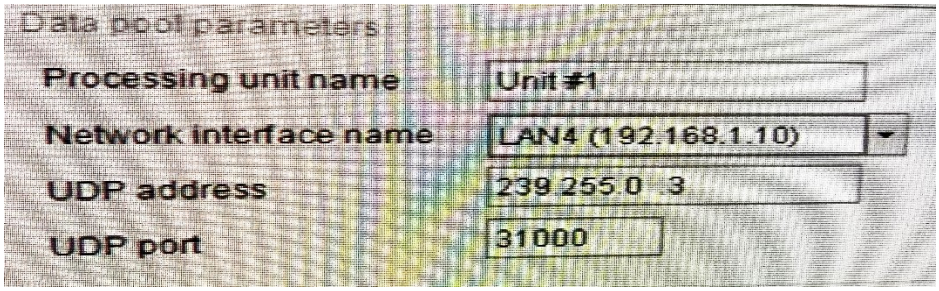

Figure 28: Seapath data pool input parameters.

A.5.5 Sound Speed Manager

Sound Speed Manager was used to create synthetic sound speed profiles during the mission when real casts were not able to be acquired. Additionally, this program was used to extend shorter profiles using archive data from the 2009 World Ocean Database. Data were able to be compared to previous casts and exported to the appropriate file format for SIS and Qimera processing.

A.5.6 Sippican WinMK21

Sippican WinMK21 is the software used to collect XBT (expendable bathythermograph) data. The XBT is fired off the back deck of the ship and the data is recorded through the LMC-16 Ocean Probe DAQ and visible in real-time in the WinMK21 software. Profiles were exported through the messaging window and brought into sound speed manager to be extended using World Ocean Atlas 2009.

A.6 Data Processing Software

Name	Manufacturer	Version	Installation Date
Qimera	QPS	1.7.5	12/04/2018
Hydro Office Sound Speed Manager	UNH CCOM/ Hydro Office	2018.1.50	12/06/2018
Matlab*	Matlab	R2018a	09/18/2018
Fledermaus & FMGT	QPS	7.8	12/04/2018
ArcMap/ArcGIS*	ESRI	10.6.1	09/18/2018

*Table 8: Data processing software and versions. *personal license*

A.6.1 QPS Qimera 1.7.5

Qimera is used for all MBES data processing including the Sonar Acceptance Test (SAT), line cleaning, and CUBE surface creation. Additionally, some of these end-product maps will be shared with Kongsberg (per user agreement) via the cloud. A connection was created by Kongsberg on the processing computer for this purpose.

A.6.2 Hydro Office Sound Speed Manager

Sound Speed Manager (SSM) was used for synthetic sound velocity profile generation during transits and extending AML Minos-X and Sippican XBT profiles. These profiles were exported as .asvp files for a direct input into Kongsberg SIS.

A.6.3 Matlab R2018a

Matlab *(personal license)* was used to parse the sub-collected CTD data to a manageable size and determine the deepest recorded depth by converting pressure (dbar) to depth (m). The parsed sound speed profile was saved and uploaded into Qimera.

A.6.4 QPS Fledermaus and FMGT

Fledermaus was used to create fly-throughs of the data and FMGT was used to create backscatter products.

A.6.5 ESRI ArcGIS 10.6.1

ESRI ArcGIS *(personal license)* was used to calculate statistics on final bathymetric surfaces, compare these data to previous estimates, and create final figures for reports.

A.7 Survey Methodology

A.7.1 Mobilization

Mobilization, including sensor installation and calibration of the EM 124 aboard the DSSV Pressure Drop occurred both at DAMEN Shipyard in Curacao (11/29/18-12/10/18) and at Mona Canyon offshore Puerto Rico (12/13/18-12/15/18) respectively. Vessel offsets and associated measurement uncertainties were calculated by a third-party contractor Robert Howard at True Position (report included as supplemental attachment). Resulting offsets and uncertainties were used in the QPS Qimera Vessel Configuration File.

A.7.2 Sonar Acceptance Test

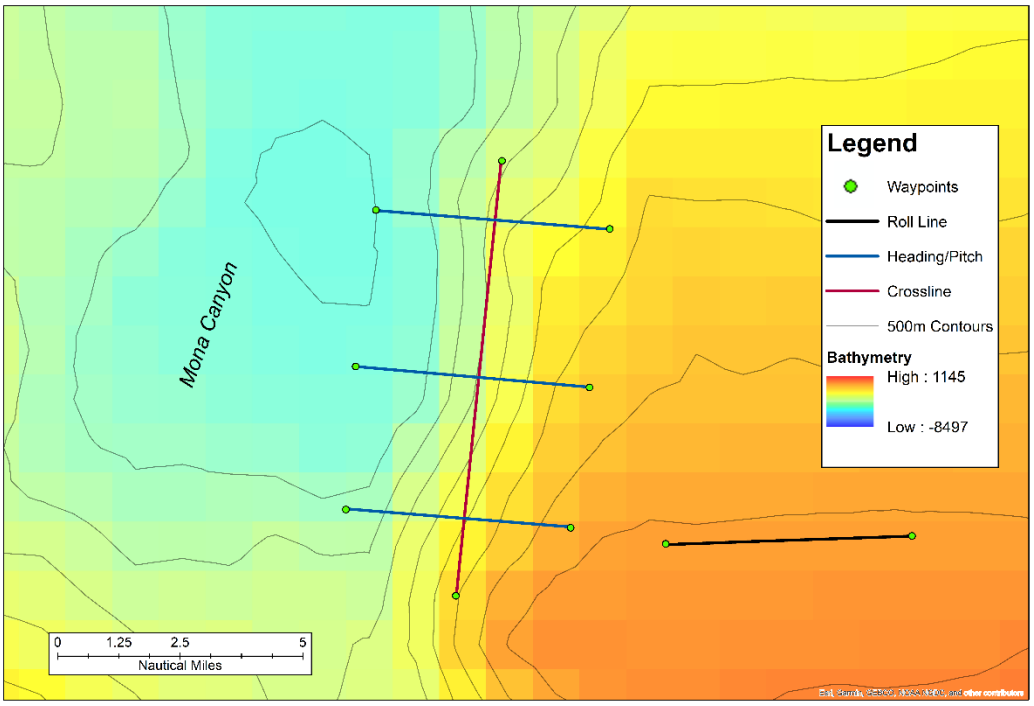

Figure 29: Sonar Acceptance Test (SAT) plan in the Mona Canyon offshore Puerto Rico and near the Puerto Rico Trench.

Shortly after the sonar was installed, a Sonar Acceptance Test (SAT) was performed by Kongsberg technicians, Kongsberg engineers, and Cassie Bongiovanni. The test calibrates the sonar for pitch, heading, and roll as time is already established by the Seapath. The SAT was performed on the eastern half of the Mona Canyon where the slope is > 20°. A full sound speed profile (>5000m depth) was collected using the CTD sensors on the science lander, XBTs were used as needed to update the upper water column.

Correction	Value	Input Value
Pitch 1	0	0
Pitch 2	0	
Heading 1	0	0
Heading 2	0	
Roll 1	0	0
Roll 2	0	

Table 9: SAT offset results.

More details on the SAT collection are included in the SAT Document (attached).

A.7.3 Survey Coverage

Survey coverage for each mapping area are discussed in more details in the location-appropriate report.

Location Name	North Western Corner	South Eastern Corner	Area (km²)
Transit to San Juan	18°16'38.922"N	12°6'54.865"N	5,923
	68°43'19.567"W	67°22'56.158"W	
SAT	18º48’26.072” N	18°37'7.329"N	219.92
	67º26’51.384” W	67°11'58.287"W	
Transit to PRT	19°5'3.786"N	18°31'11.171"N	1,411
	67°45'12.931"W	66°12'35.075"W	
Mona Channel	18°48'20.709"N	18°19'36.642"N	1,337.3
	67°43'51.048"W	67°12'49.305"W	
Puerto Rico Trench	19°46'26.034"N	19°19'47.405"N	4,115
	68°24'15.755"W	67°1'24.361"W	

Table 10: Survey locations and areas.

A.7.4 Depth Measurement Operations

All transit mapping was collected during 24-hour operations. The primary mission was broken into three parts: the calibration – comprised of a Sonar Acceptance Test (SAT) and a backscatter calibration, the Mona Channel, and the Trench. During the calibrations and the Trench projects, mapping was collected continuously for 40 and 32 hours respectively. The Mona Channel data were collected only during night operations to allow for submarine day operations. The DSSV Pressure Drop single beam was turned off for all mapping operations.

Processing was completed immediately in Qimera after each line was collected to minimize the time for feature identification and the time required for post-processing. The vessel configuration files and projection information were populated based on the information stored in the SIS raw datagram. The SVPs applied during acquisition were stored and are visible in Qimera for editing. CUBE surfaces for each project were created. Data were cleaned and edited to their final stages and exported as: BAG, ascii, .xyz, and geotiffs.

More information on data results and processes are outlined in the DSSVPD PRT DR.

B. Quality Control

B.1 Multibeam Echosounder Data

B.1.1 Acquisition Operations

Line plans were created in ESRI ArcGIS 10.6.1 to maximize survey coverage in the time allotted. Way points were given to the bridge and a new survey project is created in SIS for each mission. More information is included in the descriptive report.

B.1.2 MBES Processing Workflow

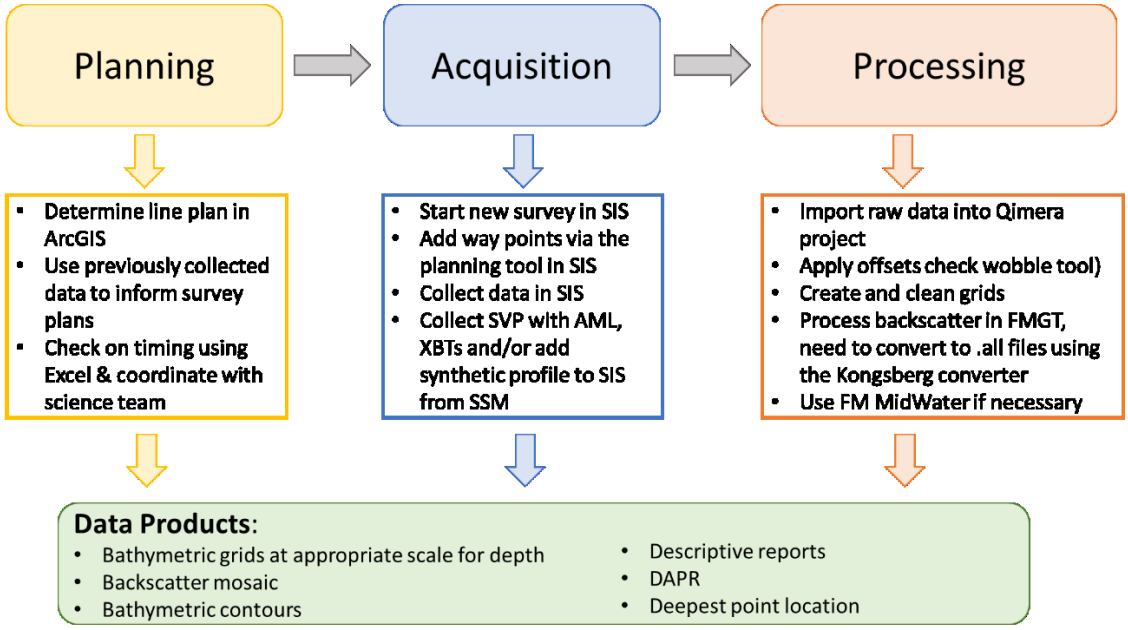

Figure 30: Multibeam processing workflow.

B.2 Backscatter Workflow

B.2.1 Backscatter Processing Workflow

Currently, QPS FMGT does not support the newest SIS output files (.kmall). As such, a Kongsberg KMALLtoALL converter is used to help with this process. Data were then brought into FMGT as source files. Due to the new file format, backscatter is saved differently, causing errors upon import that were typically resolved by adjusting the processing parameters for the backscatter acceptable dB range and applying the backscatter beam pattern correction. Backscatter mosaics were then created and exported as geotiffs.

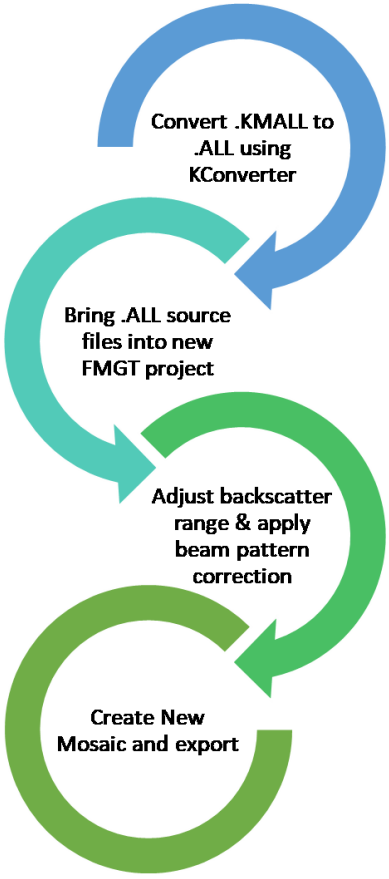

Figure 31: Backscatter mosaic workflow.

B.3 Feature Data

B.3.1 Hydrographic Features

More information detailed in the descriptive report.

C. Corrections to Data

C.1 Vessel Corrections

C.1.1 Static Offsets

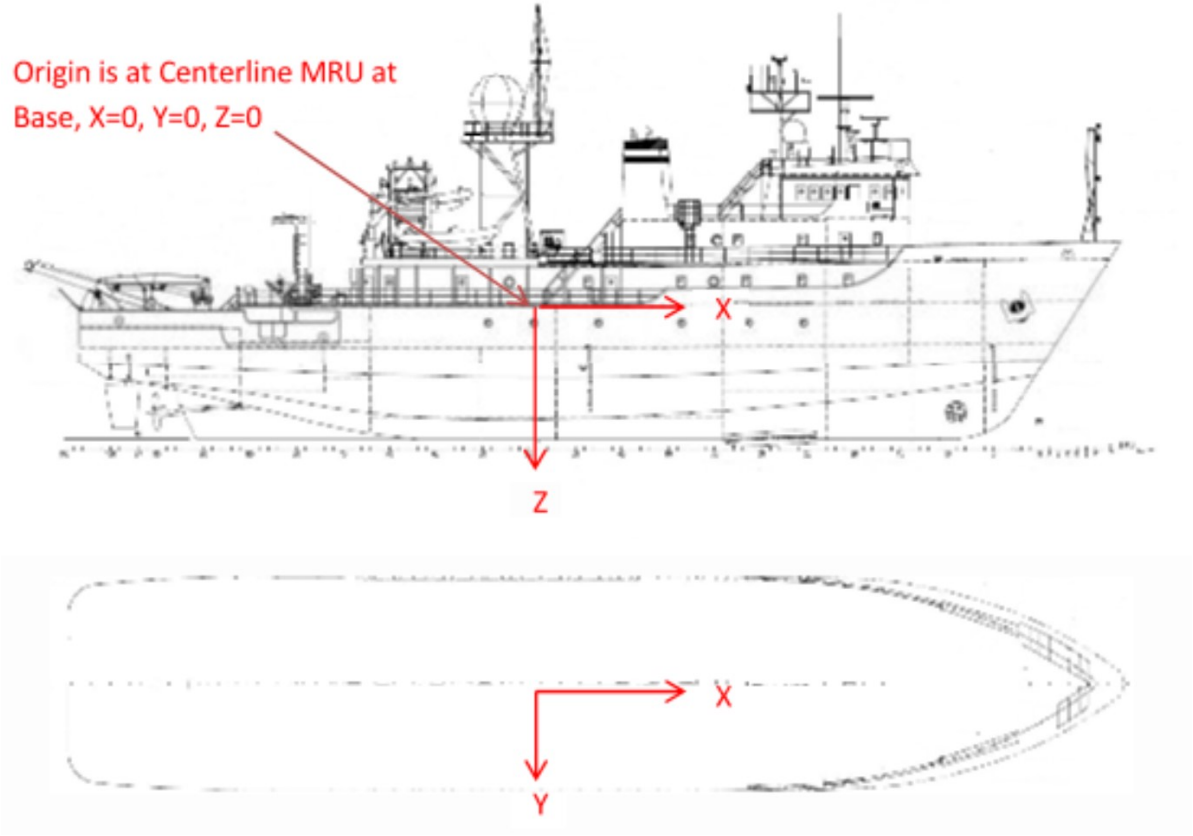

Figure 32: Vessel reference frame from DSSV Pressure Drop Report (attached).

The DSSV Pressure Drop vessel reference frame is: + x bow forward, + y to starboard, and +z down. The offsets outlined in the following table were calculated by a third-party contractor (IMTEC – Industrial Measurement Technology Engineering Consultants) and are described in more detail in the supplemental report.

	Forward (X) m	Starboard (Y) m	Downward (Z) m
EM 124 Tx	16.580	0.199	9.444
Tx angles	0.196	0.074	359.907
EM 124 Rx	12.028	0.193	9.589
Rx angles	0.079	-0.108	0.002
FWD GPS	17.954	0.223	-14.062
AFT GPS	14.164	0.210	-14.074

Table 11: DSSV Pressure Drop EM 124 (grey) and GPS antenna (white) locations within the vessel reference frame with respect to the reference point.

C.1.2 Dynamic Offsets

The data are referenced to the geoid, dynamic offsets were not applied.

C.1.3 Patch Test Biases

SAT biases were identified as 0,0,0 for pitch, heading, and roll. These were calculated twice using two different calibration software – SIS and Qimera, both were quite close. It became apparent after processing that a potential timing/latency error is present and was accounted for in Qimera by using the Wobble Tool and updating the vessel configuration accordingly. This problem became much more evident in deep water in the outer beams but is discussed further in the DSSVPD PRT DR.

C.2 Sound Speed

Synthetic profiles were used on all transit legs and most mapping days. Full-ocean profiles were acquired once via the AML SVP attached to the Clive scientific lander and once using the CTD (a Seabird SBE49 Fast Cat CTD rated to 11,000 m) attached to the Limiting Factor Submersible. The Seabird CTD collected over 70,000 data points over an eight-hour dive, resulting in multiple points per meter. These were then brought into MATLAB where a code was written (and run) to average the values for each meter of the dive. This resulted in a condensed profile with only ~8,400 points and ultimately allowed for more accurate trench depths than occurred with the synthetic (world ocean atlas 2009) profile.

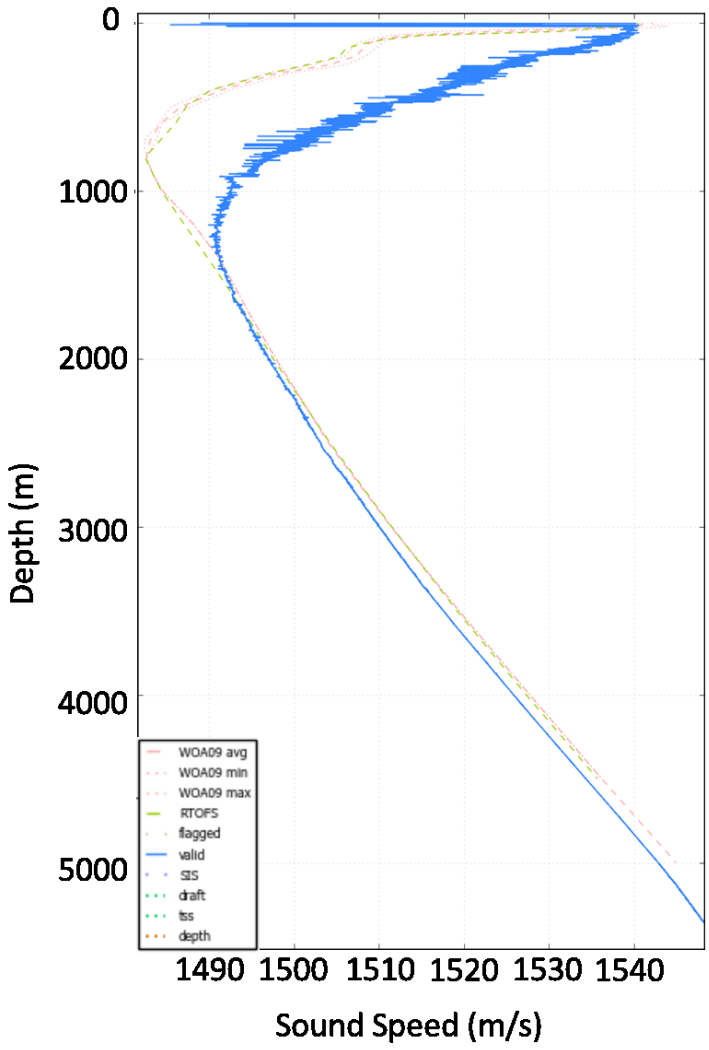

Figure 33: Difference between synthetic sound speed profile (pink) and the actual sound speed collected by the Seabird SBE49 (blue).

C.3 Horizontal and Vertical Control and Corrections

Horizontal Reference:	World Geodetic System 1984
Realization:	WGS84
Geoid:	EGM96

Table 12: Horizontal reference information.

No horizontal and vertical corrections were applied. Data are referenced to the Geoid as the undulation (or difference) between the ellipsoid and the geoid at this location is -65 m, with the ellipsoid being lower (Figure 34).

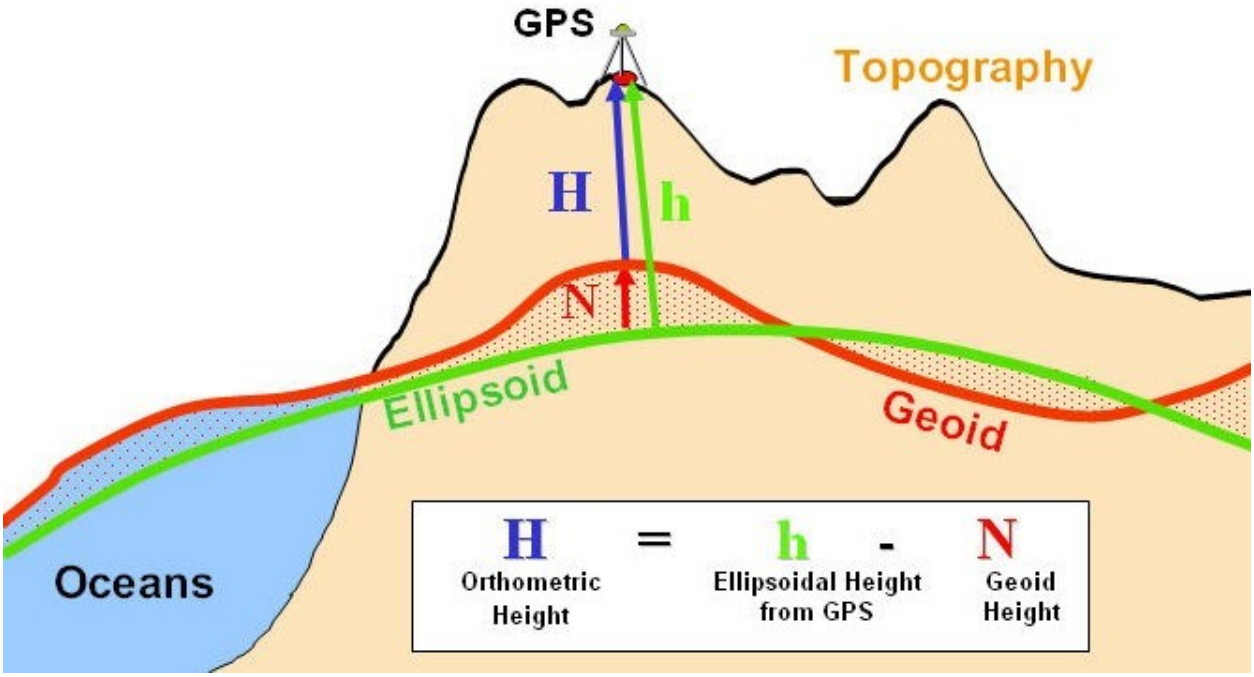

Figure 34: Geodetic vertical reference systems over land and sea to see how they change – image from google.