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Alaska Fisheries Science Center
Resource Assessment & Conservation Engineering Division
Groundfish Assessment Program

Data Acquisition and Processing Report For Fishpac16 Towed Sonar Operations

MAY 2020

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ABSTRACT

In August 2016, an acoustic seafloor survey using three different sonar systems was conducted along strong gradients of groundfish abundance, as determined from many years of Alaska Fisheries Science Center's (AFSC) Resource Assessment and Conservation Engineering (RACE) Division bottom-trawl survey catches at fixed stations. The survey corresponded to a portion of the Bering Sea trawl stations utilized by RACE Division. The goal was to use quantitative analysis of the resulting acoustic backscatter to develop a relationship between habitat characteristics and fish abundance. The survey was conducted aboard the National Oceanic and Atmospheric Administration (NOAA) ship *Fairweather*. This report details the data acquisition and processing routines of the Klein 7180 side scan sonar, one of the three sonars utilized during the survey effort.

CONTENTS

A. Equipment 2
A.1. Operational Systems 2
A.2. Ship Platform 2
A.2.1 Ship Equipment Performance Overview 3
A.3. Towfish 3
A.3.1 Towfish Equipment Performance Overview 5
A.4. USBL 5
A.5. Tow Winch 8
A.6. Speed of Sound 8
A.7. GPS Positioning Systems 10
A.8. Attitude Sensors 10
A.9. Data Collection 10
A.9.1 Overview 10
A.9.2 Coverage 10
A.9.3 Line Planning 11
A.9.4 Ping Rates 11
A.10. Software and Hardware General Comments 11
A.10.1 Vessel Software 12
A.10.2. Office Software 12
B. Quality Control 13
B.1. Overview 13
B.2. Equipment Calibration 13
B.3. Survey System Confidence Checks 14
B.4. Data Collection 14
B.5. Initial File Handling 14
B.6. Field Data Processing 15
B.7. Office Data Processing 15
B7.2 Navigation Filtering 15
B7.3 Beamforming 16
B7.4 MBSS Mosaicing and Statistics Generation 17
B7.5 38-kHz Vertical Beam Echosounder 17
B7.5.1 Effect of Gain Control on 38-kHz Bottom Detection 22
C. System Offsets 26
C.2. Sonardyne Casius USBL Alignment Offsets 26
C.3. Towfish 27
D. Instrument Interfacing and Wiring Diagram 27

OVERVIEW

The primary objective of the FISHPAC16 project was to collect acoustic data for essential fish habitat (EFH) characterization and improved stock assessments. Three different sonars were used to collect acoustic backscatter and bathymetry along tracklines defined by National Marine Fisheries Service (NMFS) bottom-trawl-survey stations on the eastern Bering Sea (EBS shelf (https://apps-afsc.fisheries.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-266.pdf). The three systems used were a hull-mounted hydrographic-quality multibeam echosounder (Kongsberg EM710) and a prototype towed long-range side-scan sonar system (Klein 7180; LRSS) which included an independent 38 kHz single-beam echosounder (Elac). This report describes the operations and processing related to the LRSS. Separate reports describe multibeam bathymetry processing of EM710 data (OPR-P335-FA-16_DAPR produced by Office of Coast Survey), and multibeam backscatter generation (AFSC HRG document in preparation). Groundtruthing efforts through the ffCPT and Seaboss are likewise not described herein.

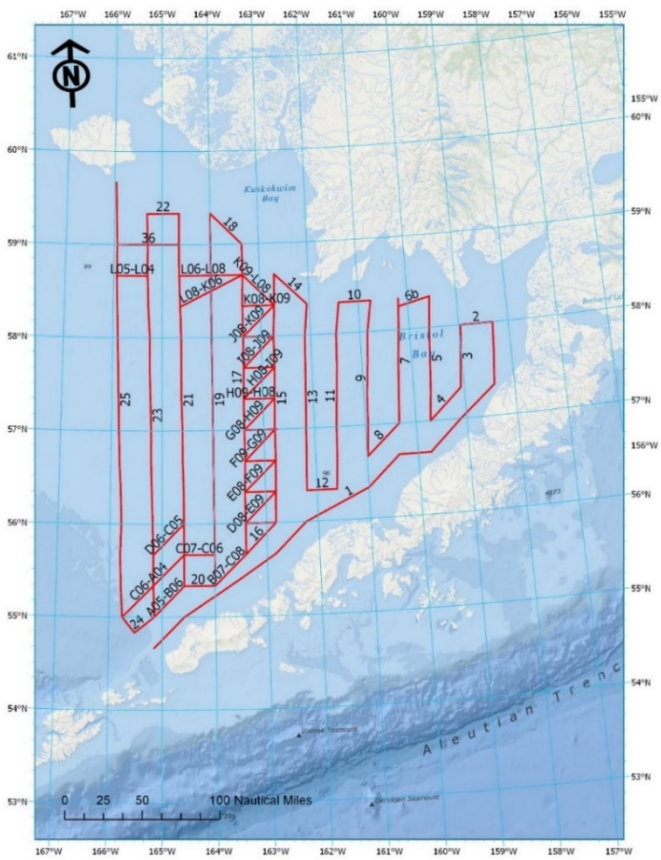

Figure 1. -- Completed Klein7180 (LRSS) tracklines for Fishpac16 Survey. Labels refer to logged line plan segments as defined in QINSy.

A. Equipment

A.1. Operational Systems

A listing of the main devices mobilized for the project are provided in Table 1.

Table 1. -- Survey equipment related to towed sonar operations used on the NOAA ship *Fairweather* in August 2016.

Description	Manufacturer	Model / Part
Sonar Acquisition	Klein	7180 (System 1)
Positioning System	Trimble	SPS855
USBL System	Sonardyne	TCVR 8021 (sn 1565) Omni WSM 8071 (address 4507)
Motion Sensors	Ship: Applanix 7180: Octans	POS MV 320V4 OEM
Gyro	Teledyne	Meridian TSS
Antennas	Trimble	Zephyr L1/L2
GPS Timing	Symmetricom	TymeServer 2100GPS
Tow Winch	DWS	DWSII-EH50
Compatt	Sonardyne	Mk4 (address 0309)
SV Devices	Applied Microsystems Rolls Royce	Micro SV (sn 7232) MVP 200 Smart SV&P (sn 5464)

A.2. Ship Platform

Towed survey operations for the Fishpac16 project in the Bering Sea were conducted using the NOAA ship *Fairweather* S220. The *Fairweather*, shown in Figure 2, is an approximately 70-m welded steel/ice strengthened hydrographic survey vessel with 13-m beam and approximately-4.5 m draft. Detailed vessel offset drawings showing the location of all primary survey equipment are included in Section C of this report.

Figure 2. -- NOAA ship *Fairweather* S220, in Dutch Harbor, Alaska.

A.2.1 Ship Equipment Performance Overview

Equipment on board the *Fairweather* performed within required specifications to produce bathymetry data for the survey. It is merely noted here that it was subsequently discovered the backscatter correction file (.bscorr) of the Kongsberg SIS acquisition system contained invalid offset entries for the starboard side beams, thus rendering unacceptable corrections to that sector of the ship's multibeam echosounder backscatter data. As such, only data from the port side beams were used for backscatter analysis from that particular sonar for this survey effort. Those details are not further discussed here, nor are they relevant to the towed sonar processing described herein but are mentioned nonetheless for reference.

A.3. Towfish

A Klein 7180 long-range side-scan sonar (LRSS) was the underwater platform used for towed survey operations (Fig. 3). The towfish contains multiple acoustic, environmental and navigational sensors which, combined with topside processing electronics, efficiently collects, processes and archives quantitative data for use in characterizing the seabed. The subsurface components generate data into multiple acoustic pipelines from two independent processing engines (Table 2). A dynamically focused interferometric multibeam side-scan sonar produces imagery and bathymetry while three separate integrated nadir-filling Elac multibeam echosounders produce additional bathymetry data. Secondary acoustic systems, including a 38 kHz single-beam echosounder, a Mills-Cross configured downward and upward-looking sonars, and a pair of scatterometers also provide bathymetric data for ancillary interpretation. Other auxiliary sensors provide full attitude instrumentation (Octans) and continuously monitor

towfish altitude, depth and speed over ground (DVL), water temperature, sound speed, and the concentrations of dissolved organics, chlorophyll-a, and total particulates in the tow path through use of an EcoTriplet sensor. The topside processing units coordinate the manipulation, storage, and display of raw and processed data, while also supporting operator control of towfish pitch, roll, and angle of attack while underway. Specialized processing software geo-locates and merges the backscatter and bathymetric data, normalizes backscatter data from the various acoustic subsystems covering the swath by adjusting for radiometric and geometric effects.

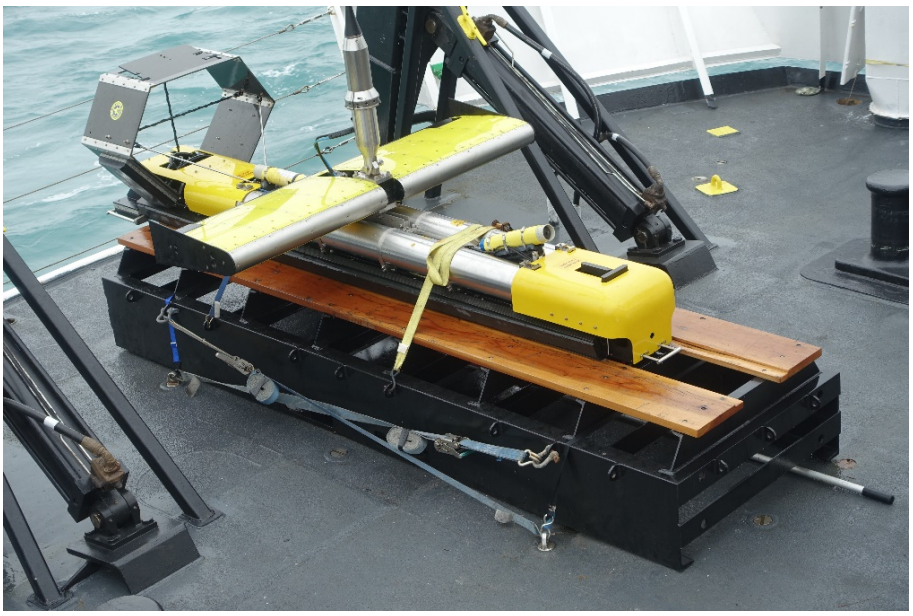

Figure 3. -- Klein 7180 (LRSS) shown with controllable angle of attack wing.

Table 1. -- Select Klein 7180 multibeam side-scan sonar technical specifications.

Source	**File type**	**Max time samples**	**Max coverage from Nadir[1]**	**Along track beam width**
MBSS	MBSS,BA0[2],BA1[2]	8000	25-85	n/a
C/ENAS	BA2_SDF	3360	0-45	2.5
PS/ENAS	BA3_SDF	6720[3]	0-55	2.5

[1]Angles are both positive and negative to nadir, [2]No backscatter from these files, [3]Combined P/S.

A.3.1 Towfish Equipment Performance Overview

Several problematic issues were encountered directly related to towed sonar operations during the project. The Octans motion sensor, mounted in the forward end of towfish electronics bottle number one, began generating randomly inaccurate heading and attitude values during the second day of operations on Line 1. Without accurate heading and attitude data, all bathymetry data produced by the towfish were deemed unusable and switched off thereafter. Side-scan sonar imagery, however, was deemed salvageable and recorded as such. The actuator driving the main angle of attack depressor wing malfunctioned and could not complete a calibration sequence. The pitch actuator suffered blunt force trauma as the towpath passed through a dense school of fish requiring repair to a bent spar arm and also needed reattachment to the motor drive. The short 4- to 8-pin subconn pigtail providing the main power source connection just downstream of the fiber optic termination became chaffed, exposing bare wire which led to intermittent ground faults. The pigtail was replaced allowing towing to resume. The internal battery on the sheave mounted T-Count cable out transmitter was found to be dead at the outset thereby rendering secondary layback calculations impossible. The omni-directional USBL transponder mounted to the towfish nose failed due to undetermined reasons on the last day and a half of survey operations leaving ship position as the only alternative for georeferencing imagery for the final day of the project since cable layback could not be calculated due to the aforementioned T-Count issue.

A.4. USBL

A Sonardyne ultra-short baseline (USBL) system was used to determine the subsurface position of the LRSS by combining acoustic range and bearing data from a vessel-mounted transceiver with vessel position obtained from the an independent WAAS enabled Trimble 855 GPS receiver and attitude and heading produced by *Fairweather's* POS/MV.

The towfish was equipped with an omni-directional acoustic transponder operated in external trigger mode (Fig. 4), interrogated by a transceiver permanently mounted in the ship's skeg. As a backup spare, another USBL transceiver was mounted on an over-the-side pole, that when deployed, would extend to approximately 1.5 m below the ship's keel. For this survey, however, the skeg-mounted transceiver was used to complete the entire survey and the pole configuration was not used.

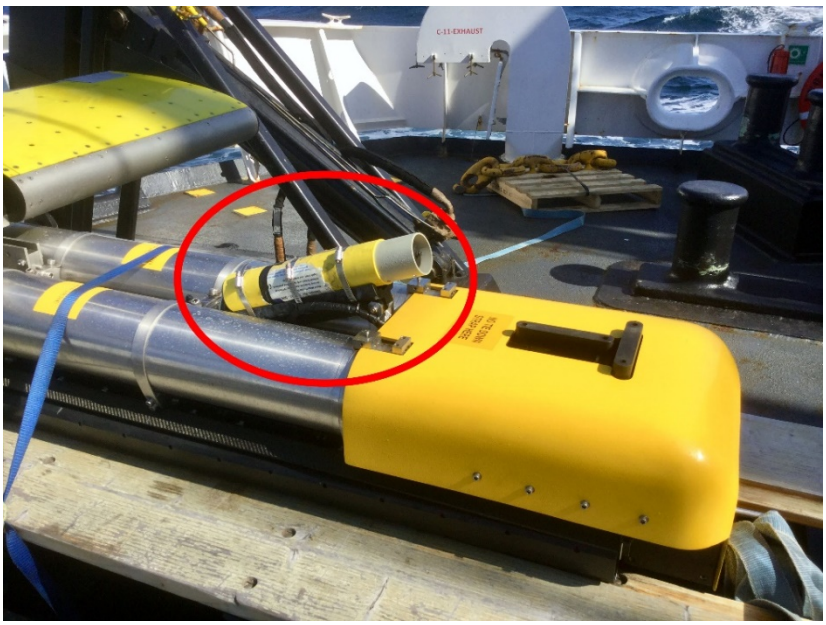

Figure 4. -- Sonardyne wideband submini WSM Type 8071 (shown within red circle) mounted in acquisition position on the LRSS.

Prior to survey operations, a Compatt Mk4 transponder (Fig. 5) was fixed to the seabed as a reference point for a dynamic calibration box-in procedure to quantify total system errors and offset bias' introduced through ordinary installation misalignment between the USBL, GPS, and ship's POSMV motion sensor reference frames. The calibration procedure was conducted just outside Dutch Harbor where a Compatt was anchored at a fixed location by an expendable heavy weight in 130-m water to approximate expected project depths. The entire procedure took approximately 5 hours for *Fairweather* to navigate twelve short lines using reciprocal headings for each pass on lines spaced roughly 60 m apart (Fig. 6). Eight lines were transited from each cardinal directional path and an additional two tracked directly over the top of the beacon. All lines were targeted to maintain constant 3-knot speed.

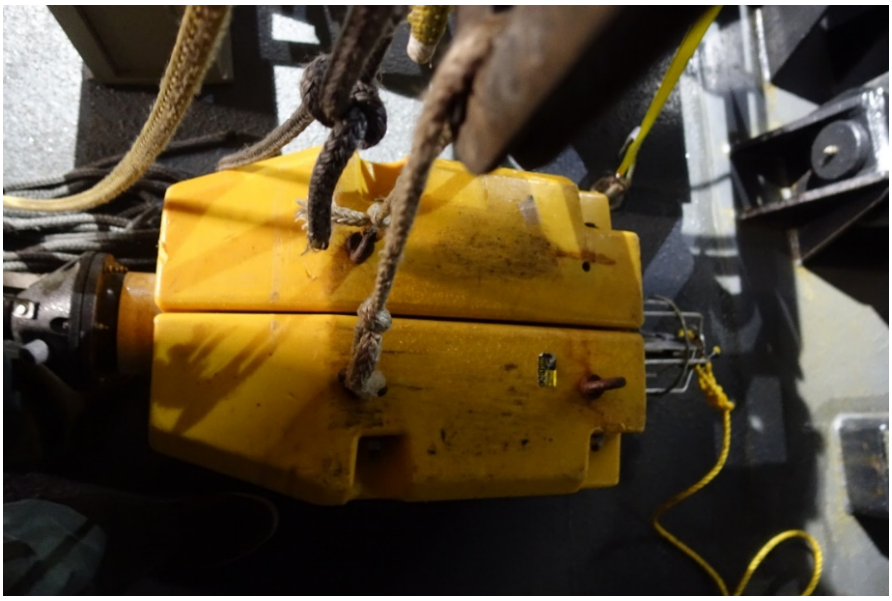

Figure 5. -- Compatt Mk4 mounted in buoyant collar. Transponder visible on left end, acoustic release on right with yellow line attached to clump weight.

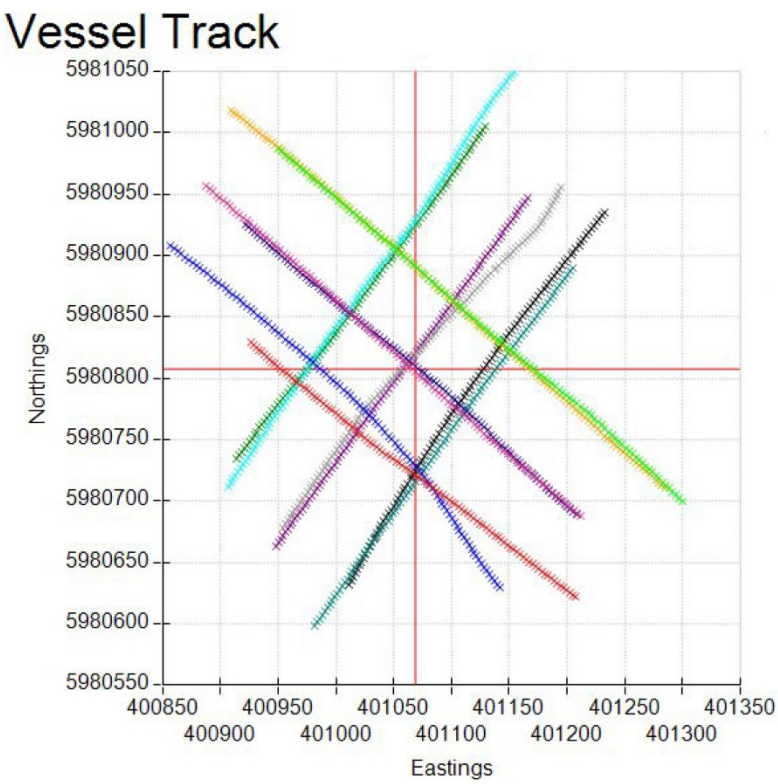

Figure 6. -- Trackline pattern navigated by *Fairweather* during the box-in procedure. Cross-hair center marks position of Compatt on the seabed.

It should be noted that each of these lines were extended by an appropriate distance to ensure the vessel had ample time to stabilize heading for at least 60 seconds prior to beginning data collection along each pass in the area shown by Figure 6. At the end of the procedure an acoustic release was triggered allowing the Compatt to float to the surface where it was recovered.

A.5. Tow Winch

A DWS-II 5050EHI cantilever hydrostatic drive tow winch was used to deploy and retrieve the LRSS (Fig. 7). The winch is customized with a closed-circuit camera system, hydro-active level wind, remotely activated control box with 45 m deck cable, and 1,300 m of 0.45-inch steel-armored cable housing with four internal multi-mode fiber optic data transmission channels.

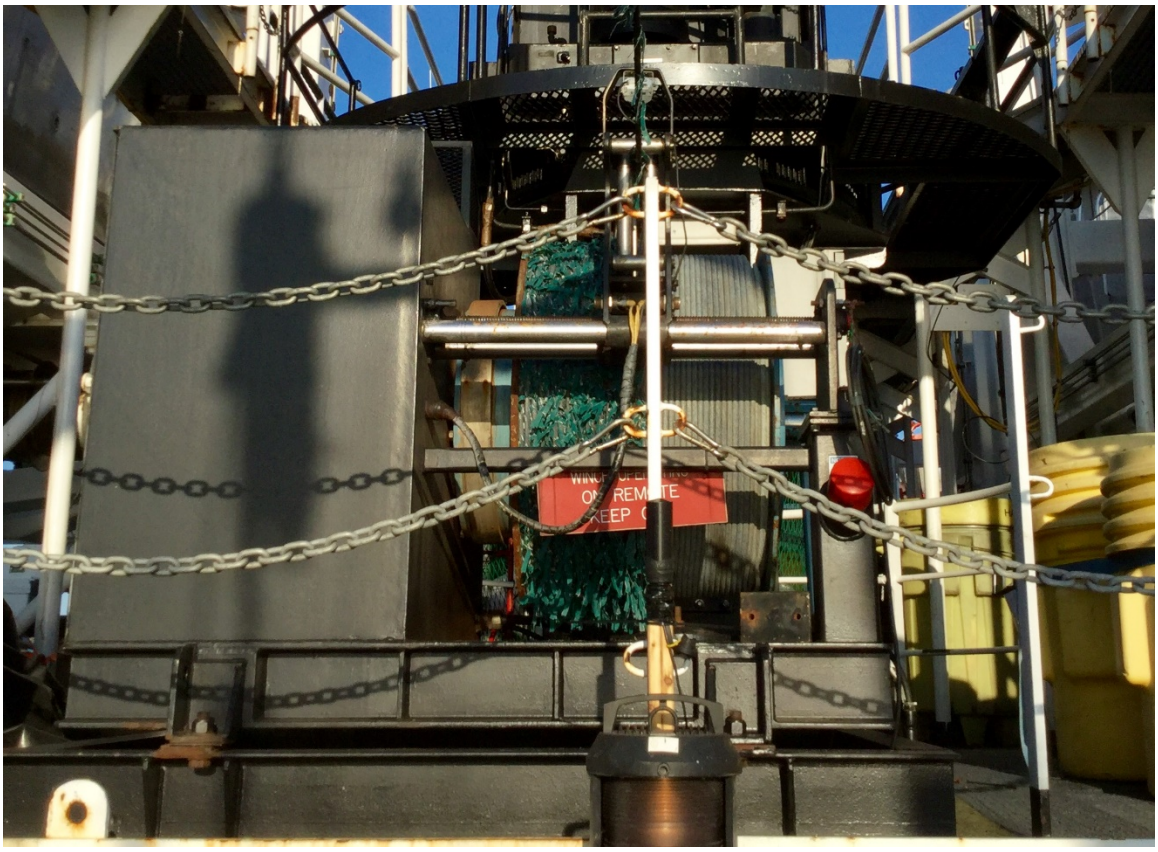

Figure 7. -- DWS-II 5050EHI tow winch.

A.6. Speed of Sound

Speed of sound data were collected using the ship's MVP 200 self-contained profiling system. For this project, an Applied Microsystems Micro SV was installed within the FFCPt probe. The profiling system has an integrated winch and hydraulic power unit, and towing boom (Fig. 8).

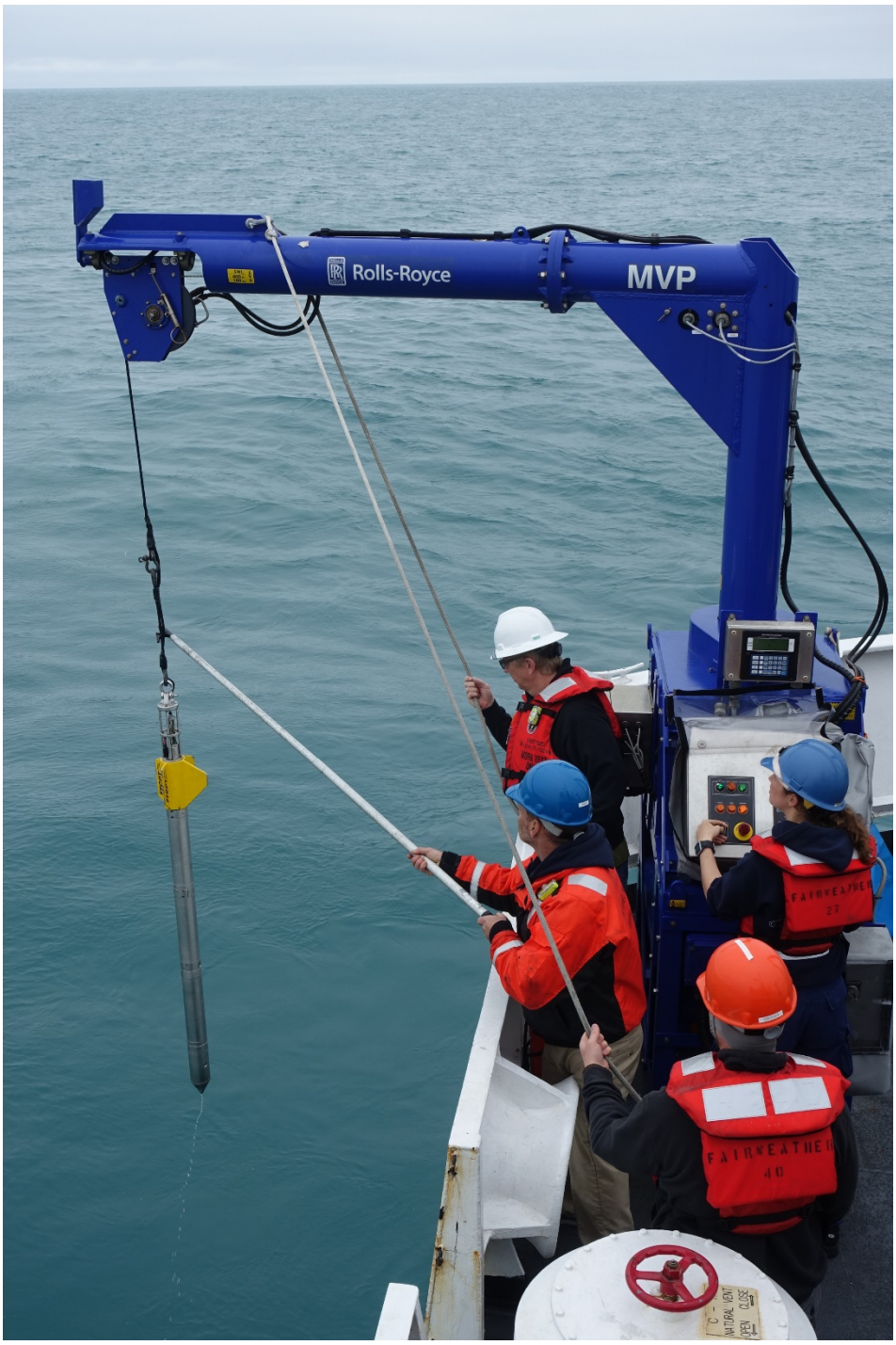

Figure 8. -- Self-contained moving vessel profiler system (MVP200) instrumented with FFCPt (Micro SV is located on the top (tail of the probe).

A Seabird SBE19 plus sound velocity profiler was also employed as a QA/QC comparison unit. An Applied Microsystems (AML) Smart SV&P sensor was additionally mounted on the bottom of the Klein 7180 to aid with beam steering at the sonar heads. Sound speed profiles were geographically distributed within the survey area and taken approximately every few hours via MVP. All profiles extended to 100% of the anticipated water depth. No data quality issues

related to speed of sound measurements were encountered during the survey or in post-processing.

The following instruments were used to collect data for sound speed profiling on the NOAA ship *Fairweather.*

Table 3. -- Listing of the sound speed measuring equipment used during the Fishpac2016 Bering Sea Survey.

SVP Sensor	Manufacturer	Serial number	Calibration
SBE19plus	Seabird - Bellevue, WA	19P36026-458	2/1/2016
Micro SV[1]	AML – Sidney, BC	7232	10/14/2005
Smart SV&P	AML – Sidney, BC	5464	7/14/2012

[1]SVP sensor on the Klein 7180 towfish.

A.7. GPS Positioning Systems

Position control for the *Fairweather* was provided by an Applanix POS M/V 320 v4 position and attitude system while a Trimble SPS855 receiver using WAAS corrections served as the primary GPS source for towfish navigation. GPS data were fed into both the USBL and QINSy navigation topsides at 1Hz intervals using the National Marine Electronics Association (NMEA) message $GPGGA. The USBL was used to calculate a subsurface range and bearing from the hull-mounted transceiver to the towfish, and was ultimately telemetered to the towfish as a TLL message.

A.8. Attitude Sensors

Inertial measurements from the POSMV IMU were sent to QINSy and the USBL system as a TSS1 binary message and heading information was provided by a Teledyne Meridian gyro compass via GPHDT message format. As previously mentioned, the internal towfish motion sensor was inoperable.

A.9. Data Collection

A.9.1 Overview

The towed operations were conducted using side-scan sonar collection techniques. Data from an independent 38-kHz vertical beam echosounder were also captured simultaneously. No multibeam data were acquired. In general, data were gathered on an approximate 24-hour basis, by a crew of five surveyors operating in 12-hour shifts. There was a brief daily stoppage to inspect the towfish and swap hard drives in the RAID.

A.9.2 Coverage

The line plan provided no adjacent overlap.

A.9.3 Line Planning

Line planning consisted of a single pass as shown in Figure 1 with no adjacent overlap.

A.9.4 Ping Rates

The ping rate of the LRSS is 1.1 pings per second.

A.10. Software and Hardware General Comments

Sonar data were collected on a pair of Intel core i7 PCs built by Superlogics operating in the Windows XP environment and using a custom version of SonarPro designed specifically for the LRSS in a master/slave configuration. TPU1 mastered all towfish controls for the entire subsea system. In practice, TPU2 would operate in a slave state receiving all towfish commands from TPU1, including duplicate copies of DVL, Octans, and transmissometer data in a time synched fashion from TPU1, along with the port and starboard multibeam echosounder data. For this survey, however, even though TPU2 was powered the data were not captured due to the Octans failure. Sonar data were logged onto a 16-bay StorCase RAID. Only three drives were used each day and were built as a 1.5 TB RAID5 array connected by SCSI to SU1. All other computers in the workgroup had connection through a network switch using TCPIP protocol.

A Symmetricom Tymeserver 2100 was used to provide timing to both TPUs via the IRIG Tcode out connector with use of a BNC splitter. The Tymeserver also doubled as an NTP stratum 1 time server for all computers in the workgroup using Symmetricom Symmtime program installed on each computer connected by Ethernet.

All GPS, attitude, USBL and timing data streams ultimately passed into QINSy through a Moxa 16 port RS232 NPORT serial device. QINSy, operating on a Windows 7 32-bit architecture, then provided ship and towfish telemetry to the towfish where it was logged by SonarPro inside the sonar datagrams in Klein .sdf2 format.

A replicate helmsman display was also provided to the bridge from QINSy via a Blackbox VGA to CAT5 splitter set, effectively allowing their watchmen to steer the acoustically tracked towfish along the planned line instead of the ship itself.

A type 8021 hemispherical USBL transceiver was mounted to the skeg of the ship and communicated with a Type 8071 omni-directional beacon affixed to the towfish. Data transmissions were linked to a rack-mounted navigation control unit (NCU) which was serially interfaced with Sonardyne's Fusion software package operating in a Windows XP environment.

Table 4 provides a listing of the software used on the *Fairweather* during the at-sea survey. Table 5 details various tools used in the office for pre-survey planning and post-survey processing.

A.10.1 Vessel Software

Table 4. -- Software used aboard the *Fairweather* during survey.

Program name	Version	Primary function
Klein Sonarpro	12.1	LRSS controller and acquisition
QPS QINSy	8.10	Navigation acquisition and serving
Applanix POSView	5.1.0.2	POS M/V setup and monitoring
Sonardyne Fusion	1.09.03	USBL acquisition
Pydro/VelociPy	15.10	Sound Velocity Processing
Symmtime	4.93	Time synching

A.10.2.Office Software

Table 5. -- Software used in the office during post-processing.

Program name	Version	Primary function
Klein MBSS Beamformer	V3.Build14	Side scan beamforming
Klein Bathy Beamformer*	V3.Build16	BA0 and BA1 bathy beamforming
ENAS Python Script*	10	BA2 and BA3 bathy beamforming
Export SDF Python Script	1.2	Exporting datagram sections to .CSV
Import SDF Python Script	1.2	Importing datagram sections to .sdf2
FMGT	7.7.7	Side scan mosaicking
QINSy	8.10	USBL and GPS filtering
Matlab	R2007	Navigation filtering
MWS Impulse	15.0	38 kHz processing
ESRI ArcMap	10.5	GIS management software

*Neither the bathy beamformer or the ENAS script were required or implemented in processing the 2016 data, since no bathymetry were acquired or processed due to the Octans failure. Under normal circumstances, these tools would be employed into the processing pipeline.

B. Quality Control

B.1. Overview

Every effort was made to ensure the integrity and traceability of side-scan sonar, attitude, and navigational data as they were moved from the acquisition phase through processing. Consistency in file and object naming combined with the use of standardized data processing sequences and methods formed an integral part of this process.

As previously mentioned and presented in Table 5, QINSy was integral for the navigation acquisition and filtering, while SonarPro provided side-scan sonar logging and FMGT ultimately produced georeferenced greyscale mosaics.

B.2. Equipment Calibration

If possible, each item of survey equipment was calibrated prior to the survey to assess the accuracy, precision, and alignment of sensors. The USBL calibration procedure accounted for spatial alignment mismatches between the GPS, POSMV and transceiver reference frames. The sound velocity probes were factory calibrated before deployment. The individual overlapping LRSS sonar systems were calibrated using a unique cascade calibration procedure which, in essence, involved using of a known reference sphere being placed under the downlookers, then using the inherent swath overlap to pass offsets to other sonar sectors. A patch test was completed during a previous outing, to adjust roll bias' in the Octans installation orientation by examining processed bathymetry of two reciprocal line surfaces acquired over the same area of flat seafloor and tweaking the offset values until they converged. The EcoTriplet transmissometer was initially calibrated at the factory and additionally adjusted to local conditions through use of a dark/count offset procedure which involved placing a piece of black electrical tape over the sensor window, soaking the towfish to log a few minutes of data, then averaging the logged count values (for each of the triplet of sensors). These dark count values are then subtracted from the logged values acquired during survey and adjusted by a coefficient provided by the factory calibration sheet (Table 6).

Table 6. -- Transmissometer calibration parameters for processing Wetlabs EcoTriplet data for instrument BBFL_2L3K_275.

Sensor	Units	Formula
Chlorophyll-a	µg/l	0.0057*(CHLO value)-55)
Scattering	m^{-1} sr^{-1}	0.00000346*(SCAT value-44)
CDOM	ppb	0.098*(CDOM value-44)

First (offset) and last (dark count) formula values provided by the instrument calibration sheet. The second value is the average logged during the "black tape test period".

B.3. Survey System Confidence Checks

QA/QC checks of sound velocity measurements were accomplished by making occasional dual casts and comparing output between the MVP and SBE19plus instrument readings.

B.4. Data Collection

Side-scan sonar data collection was accomplished using a custom build of Sonarpro software. File prefixes were manually set at the beginning of each day/line break, then Sonarpro automatically split files every minute to keep file sizes manageable. This naming convention further ensured that individual survey lines had unique names based on time of collection. Sonarpro wrote two sets of time synched .sdf2 files, one for each processing engine. Engine 1 (TPU1-SU1) contained data for the side-scan sonar, Center-ENAS system, 38-kHz vertical beam echosounder, GPS, transmissometer, all scatterometers, sound velocity, DVL, and Octans sensors. Engine 2 (TPU2-SU2) contained data for the Port and Starboard ENAS systems, and duplicate copies of GPS, sound velocity, DVL, and Octans sensors. All raw data files were stored on a 16-bay RAID chassis attached to the SU1 acquisition computer. Sonarpro was also configured to send towfish depth to QINSy for logging, and to Fusion for beacon depth aiding in the USBL.

The QINSy navigation and acquisition software package was configured to capture ship navigation, GPS time, towfish USBL position, ship attitude from the POS M/V, and heading from the ship's gyrocompass. Data were stored in QINSy proprietary database files. QINSy also provided Sonapro with ship position and towfish position via GGA and TLL data strings, respectively.

Sonardyne Fusion stored the raw USBL data in Microsoft .mdb format and was configured to create a new file every 10 Mb. Fusion also sent a calculated towfish position to QINSy and received towfish depth information from Sonapro. Ship and towfish positions were also relayed to a separate helm display installed on the ship's bridge.

The POS M/V was not set up to acquire RTCM DGPS correctors since no CORS station was operable in the area. However, motion data were sent to QINSy and Fusion.

Sound velocity profiles were acquired with a Seabird SBE19plus profiler as .hex and .cnv files, while the MVP captured .m1 files. Raw sound velocity files were converted to .svp format using Pydro/Velocipy, and were input into Fusion for proper ray tracing.

Chronological logs containing information specific to each line were maintained by operators as an independent reference to aid in data integration and error tracking. Acquisition logs included the line name, start and end times and any additional comments deemed significant by the operators.

All acquired data were referenced to the UTM Zone 3N projection, using the NAD83 datum, regardless of whether the planned lines crossed into a different zone.

B.5. Initial File Handling

Shipboard data handling proceeded as follows: As side-scan sonar data collection was conducted, the Sonarpro acquisition software captured the raw .sdf2 sonar files real-time into two separate folders. One containing data produced from the TPU1-SU1 engine, and another from the TPU2-SU2 engine. At the end of each line segment, these two "child" folders were

manually moved into a higher directory folder that was organized by Line number. At the end of each survey day, the system was shut down and a new 3 HDD array was inserted into the RAID chassis where the process repeated. At the end of the project, all survey data were copied onto several external 4 TB USB drives for redundancy. The back-ups ensured data security against catastrophic equipment failure.

B.6. Field Data Processing

No field data processing was undertaken since the initial step involves navigation filtering which requires use of QINSy. Having only one licensed copy of QINSy precluded any real-time post-processing, as the software was required to be online for acquiring data.

B.7. Office Data Processing

B.7.1 sdf2 Sonar File Data Section Export

Random navigation blow outs, from both the ship GPS and the USBL, from an undetermined cause required filtering prior to sonar processing. The Python-based SDFTool set was used to export all data records from every TPU1-SU1 data file collected during the survey. The 'Export' script produces seven human readable comma-separated-value files containing data specific to various sections within the raw sdf2 files. The two section files needed for the filtering process of the 2016 data were the OCTANSDATASECTION and GPSDATASECTION. The TRANSMISSSECTION was also used for plotting and examining the EcoTriplet data in a GIS.

B7.2 Navigation Filtering

Bad navigation fixes were initially dealt with in QINSy. A 7-point mean moving box filter was applied to the data using the 'Analyze' tool to remove gross outliers from each database file. This filter was set up for Latitude GGA, Longitude GGA, and GGA height in one group and USBL X, USBL Y, and USBL Z measurements in a separate group, thereby resulting in two filter processes being applied on each file. Filter results were reviewed with remaining obvious artifacts being manually struck and filled with interpolation.

Each new "filtered" database file was then replayed in QINSy for a final review in the navigation screen. Using the Raw Data Manager, the following records were selected for export from each "filtered" database with output producing a single ASCII text file: date, time, ship latitude, ship longitude, ship easting, ship northing, speed over ground, course over ground, ship heading, fish latitude, fish longitude, fish depth, fish course over ground, fish heading, fish easting, and fish northing, and database filename.

The filtered navigation data from QINSy was then copied over the raw navigation fields contained within the GPSDATASECTION file exported by the ENAS script. To accomplish this, the GPSDATASECTION file and the filtered navigation ASCII file produced from QINSy were both imported into an ARCGIS geodatabase and joined using ping number as the joinID. After the join was complete, the filtered columns of ship latitude, ship longitude, fish latitude, and fish longitude were merely copied from the QINSy side of the join over to the GPSDATASECTION side of the join, effectively overwriting the bad raw data. The new data were examined once again in ARCGIS and another round of manual deletion was undertaken if more obvious erroneous GPS fixes were apparent.

When the Octans motion sensor malfunctioned, it began producing random values for pitch, roll, and heading which were of course recorded into the raw sonar .sdf2 files. In order to salvage the entire data set, the random pitch, roll, and heading values needed to be removed to permit producing a reasonable georeferenced mosaic. Therefore all pitch and roll values were merely replaced with all zeroes and the heading values were replaced with the ship's course over ground which was logged in QINSy. The joined and edited table was then exported from ARCGIS as a new ASCII text file.

The exported table was then opened in Excel, where all fields from the QINSy side of the join in addition to any added by ARCGIS were removed, leaving the original GPSDATASECTION field structure intact. The entire above procedure was carried out independently for each planned survey line (or day, whichever the case may be). It should be noted, if the number of records in the final exported joined table exceeded the number or records allowable in Microsoft Excel (1,048,576), then the table had to be imported into Microsoft Access to remove the above mentioned fields by simply creating a Query which contained only the columns contained in the GPSDATASECTION structure and exporting them as an ASCII file instead.

Even though the navigation data were essentially smoothed at this point, there existed holes in the consecutive ping sequence since many were removed, either by the QINSy manual strike and interpolate step or through the gross point-removal step undertaken in ARCGIS. The missing pings created from the filtering process were repopulated using a Matlab (R2007) script which essentially ordered the data, searched for gaps in the ping sequence, then interpolated the ship and fish positions, and heading data using a 100-point Hamming Window Filter. This procedure has roots in signal processing but is essentially a tapered window filter that smooths discontinuities at the beginning and end of the "signal", or in this case data set.

The GPSDATASECTION file was then reinserted into the raw .sdf2 files using the SDFTools Python Import script. The original raw sonar files now contained filtered navigation data that could be mosaicked without error.

If bathymetry would have been acquired, this entire procedure would have been replicated with the .sdf2 files contained within the TPU2-SU2 folder.

B7.3 Beamforming

All .sdf2 files from within the TPU1-SU1 engine were beamformed using the MBSSBeamformer application. Of note, execution of the program requires a simple text file named RawDataFile.idx to exist in the same folder as the raw sonar files with the contents being a listing of every .sdf2 file within the folder, or that need processing.

If the Octans attitude sensor would not have malfunctioned during the survey, all filtered .sdf2 files from within the TPU2-SU2 folder would have been beamformed as well. The BathyBeamformer application would be run twice. A first run to produce the BA0 long range bathy angles (out to about 30 degrees from nadir) and a second run to produce the BA1 long range bathy angles (out to about 20 degrees from nadir). Additionally, the 'ENAS specific files' Python script would be executed to produce the BA2 and BA3 sets of bathy and backscatter angles. The C_ENAS (BA2) would cover -45 to 45 degrees from nadir while the Port/Starboard_ENAS (BA3) would range roughly -55 to 55 degrees from nadir. Again, those data were not available for this survey.

B7.4 MBSS Mosaicing and Statistics Generation

Side-scan sonar data from the TPU1-SU1 beamformed .sdf2 files were processed in FMGT version 7.7.7 using the LRSS SDF2 to XTF plugin utility. Files were merged and sliced into 10,000 ping segments. Tiles were created for memory management and mosaics were created at 1-m resolution and statistical derivative surfaces were produced at both 50-m and 100-m bin sizes. Mosaics were exported as 8-bit grey scale geotiffs and statistical values were exported, along with bin data, into a comma-separated value file.

B7.5 38-kHz Vertical Beam Echosounder

The raw unbeamformed.sdf2 files from the TPU-SU1 data engine contain 38-kHz vertical beam echosounder packets produced from a transducer with a 26-degree beam width mounted to the underside of the towfish. These data were processed using Maritime Way Scientific's Impulse 15.0 software package. Impulse processes signals from single-beam echosounders in an unsupervised fashion using various characteristics produced by the interaction of the echo with the sea floor. The data processing routine involved importing the raw SU1 sonar files, ensuring a proper bottom detection for each file, generating full feature vector files (ffv), creating a classification catalogue, performing a cluster classification, exporting a single ASCII text file for the entire survey, and finally importing this ASCII file into an ARCGIS geodatabase for display and query as a vector point feature class.

As with the MBSS FMGT data, Impulse processing was organized and carried out by project line whereby unique projects were created in Impulse for each line number. Channel 64 (high gain) data were used for all processing. Of special note, low gain data logged in channel 63 could be used in instances where the channel 64 data were found to be clipped. This was not the case for this particular survey data.

In general, the bottom picking parameters were set according to Figure 8, however in areas where the MBSS sonar gain control was set below TvgPage(9), it was often helpful to lower the Threshold % below 10. It was also necessary to alter the blanking to a value very near the seabed for the entirety of the dataset.

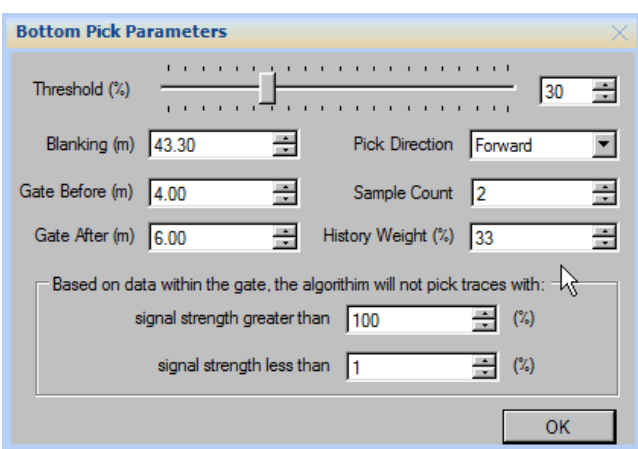

Figure 8. -- Impulse bottom pick parameters. Threshold and blanking values were altered as needed.

In many areas water column clutter, likely from dense schools of fish, had to be removed by manually adjusting the bottom pick (Fig. 9).

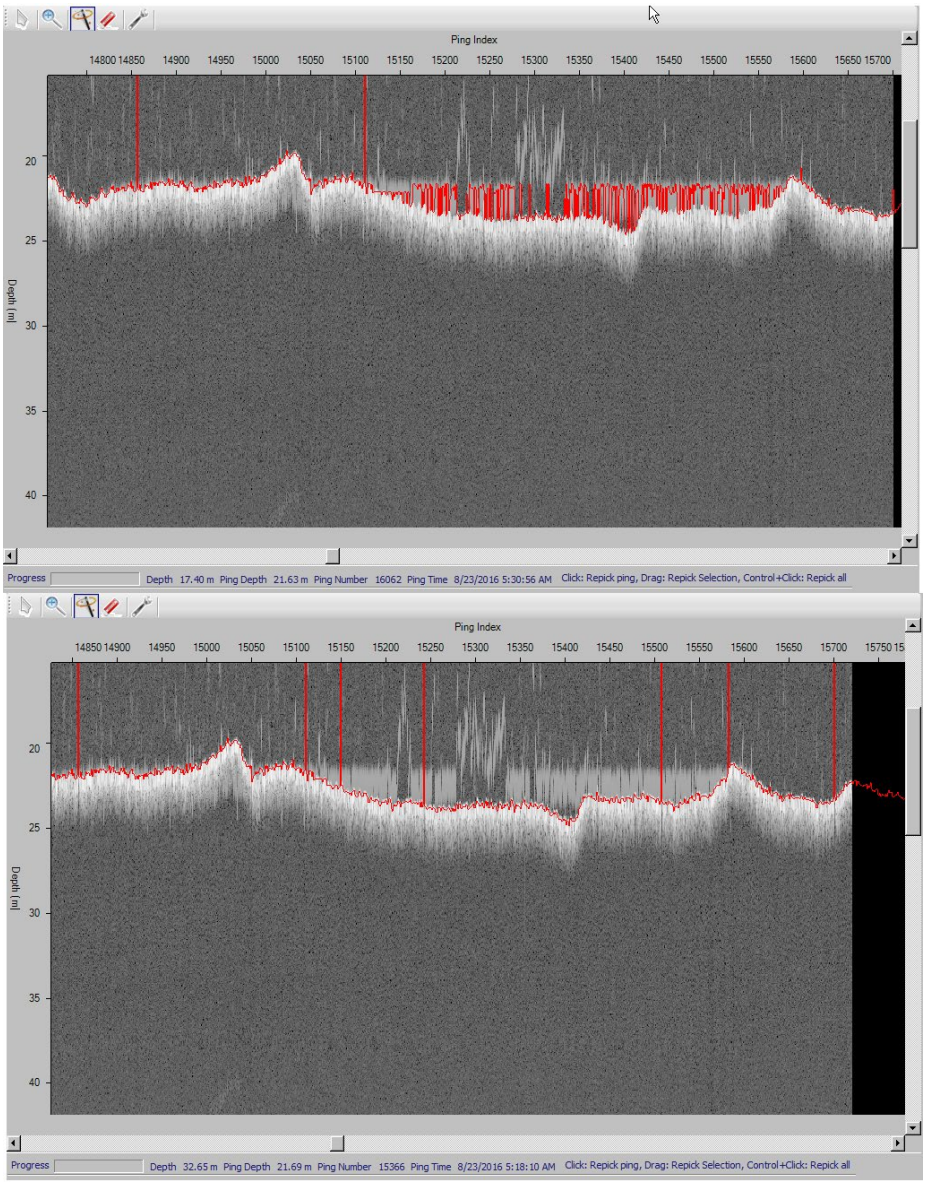

Figure 9. -- An area where fish or some other water column disturbance required manual bottom detect adjustment. The top echogram shows where the layer degraded bottom detection. The bottom echogram shows resulting adjustment after manual intervention. The remaining seven vertical red lines were pings where no bottom detect could be rectified at all, and as such were excluded from analysis.

The feature generation stage proceeded using default Impulse values (Fig. 10), with a ping stack of five for each project. Standard Echo Length (SEL) settings and depth and time filters were also kept at default, as well as the number and selection of statistical input features.

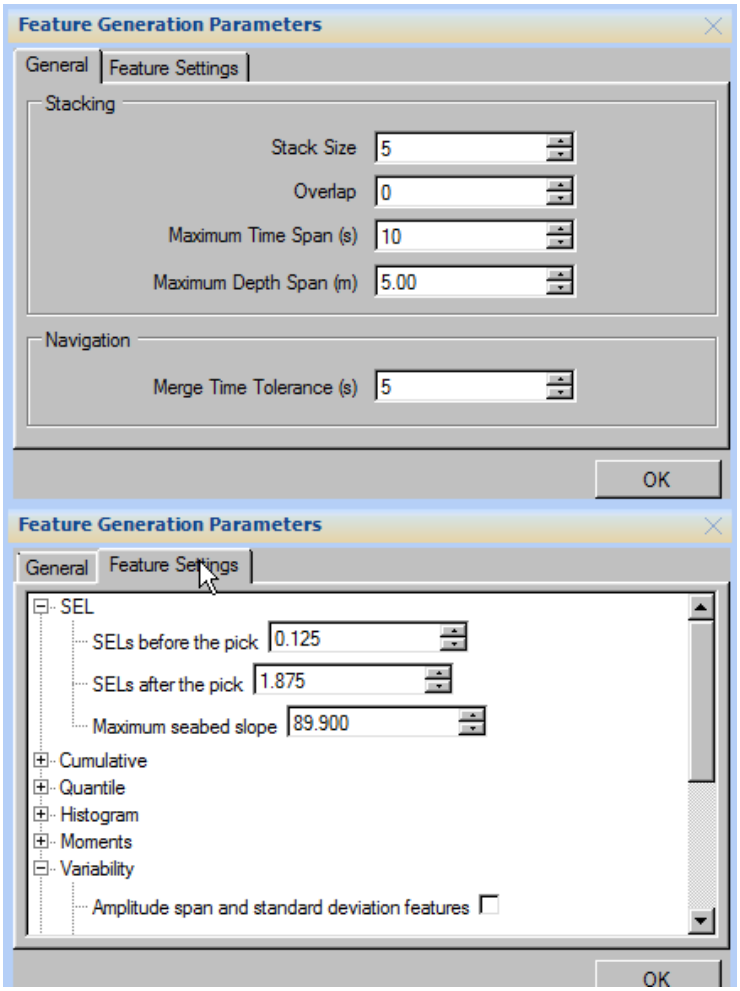

Figure 10. -- Impulse feature generation parameters used for processing 2016 data.

Due to the extreme file size of the raw .sdf2 files, it was not possible to create a single Impulse project to import all the survey data and then initiate the bottom detection and feature generation due to hardware and software limitations. Instead, all lines were imported, bottom detected, and the FFVs generated as individual projects by survey line using the five stack ping settings stated above. After this was complete, an all inclusive final Impulse project was created whereby a feature catalogue was built by changing the FFV import path to a folder that contained all of the 16,499 FFVs generated from each of the individual line projects.

The catalogue builder created a .seabed file and applied principal component analysis (PCA) to the selection of FFV files and generated a reduction matrix. The reduction matrix was then used to reduce the 56 acoustic features down to just three Q-values, which in theory captured the majority of the statistical acoustic diversity of the data set.

Once the catalogue was built, the Automatic Clustering Engine (ACE) was used to create classified clusters of the acoustic data. ACE can be described as an automated clustering process that uses a Simulated Annealing K-Means algorithm on the input .seabed classification file with the goal of finding an optimal number of classes and the corresponding assignment of records to

classes in an objective manner. For this analysis, the ACE parameters were altered several times, output reviewed, then the range of classes was ultimately changed from the default of 15 down to 8 since in either case the optimal number of classes produced by the algorithm turned out to be 3 (Fig. 11). It should be noted the scores of several other class groupings were quite similar to the three-class result, so in reality there is a chance that additional groundtruthing might have indicated the need for choosing a higher number of classes to represent the data set more accurately.

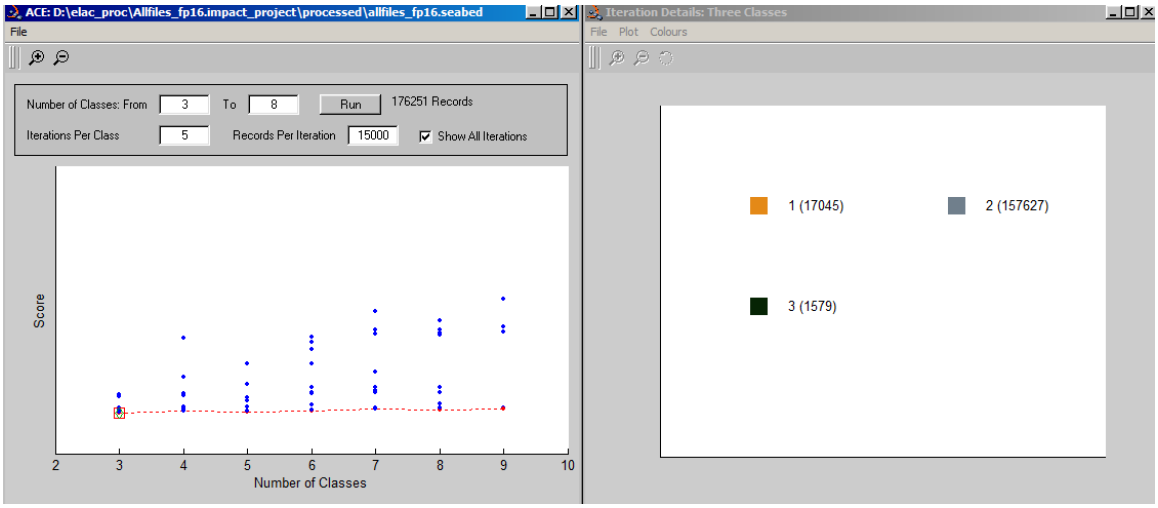

Figure 11. -- ACE output indicating three classes (shown on the right through similarity colors) that optimally represent the acoustic characteristics of the dataset (indicated by the red square around the lowest score in the left plot.

Graphical representations of the three classes in Q-space (Q1 vs. Q2 vs. Q3) are shown in Figure 12, while Figure 13 shows the same classes plotted in the geographic latitude and longitude trackline space as conducted in the Bering Sea.

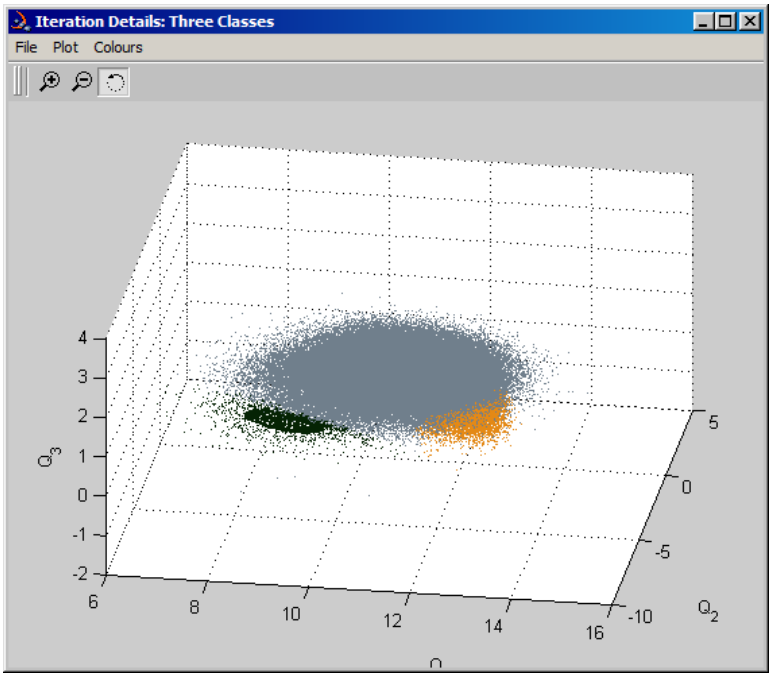

Figure 12. -- Acoustic data shown in Q-space, where Q1 is the dominant component that describes most of the acoustic characteristics of the dataset. Interestingly, nearly all of the data were classified as class 1.

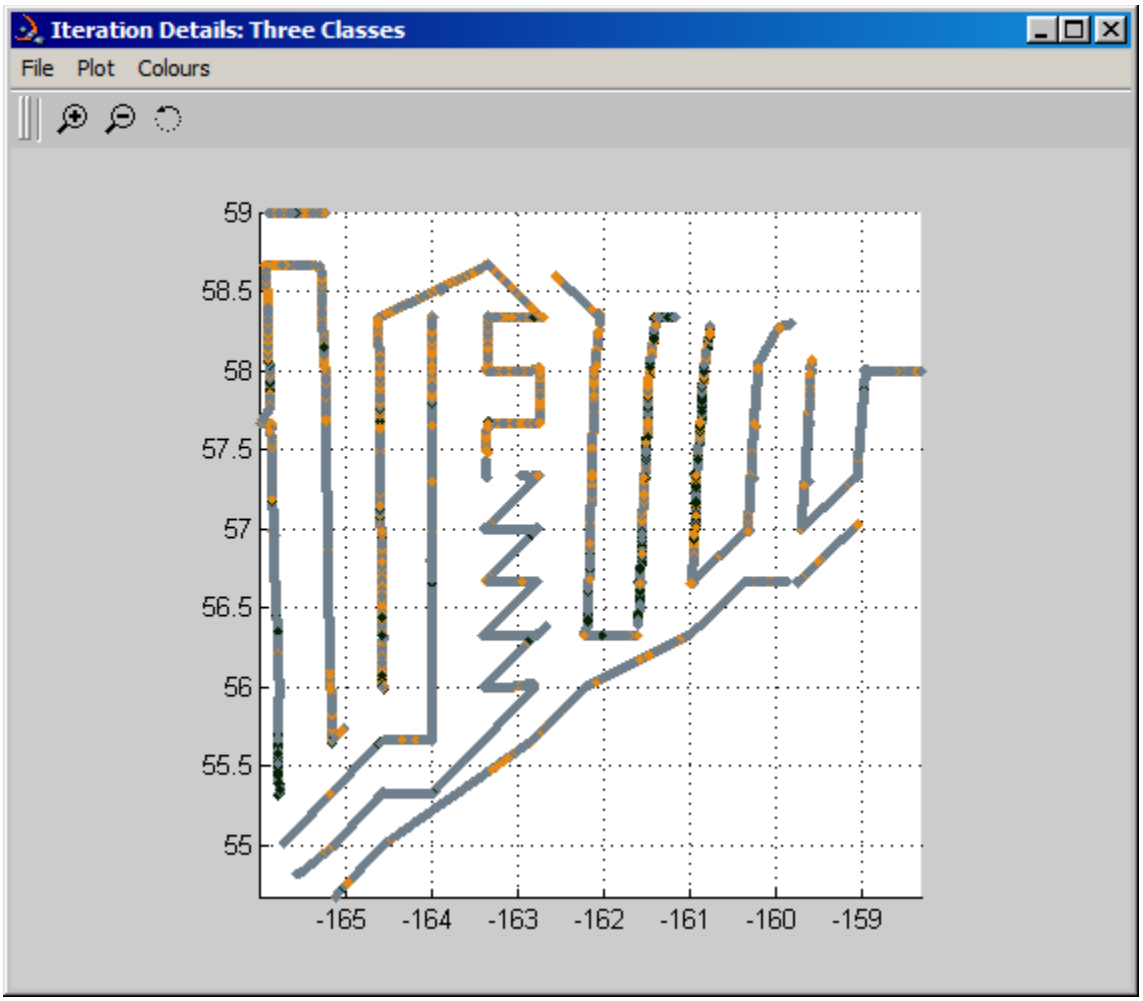

Figure 13. -- Trackline plot of the three acoustic classes. X-axis is longitude in degrees and Y-axis is latitude in degrees.

A 3-class sediment representation of the entire survey area is likely underrepresentive and probably in part due to a noisy acoustic system associated with the 38-kHz component of the Klein 7180. As mentioned at the beginning of this section, it was determined that changing the sidescan sonar gain during acquisition had an effect on the bottom detection of the 38 kHz data in post-processing. Further details on this subject are described in the next section.

B7.5.1 Effect of Gain Control on 38-kHz Bottom Detection

Overall, the bottom detection process was extremely laborious, due to what turns out be an inherently noisy system. However, after intensive scrutiny of the dataset, it also appeared the performance of the 38-kHz bottom detection depended greatly on sonar gain setting (Fig. 14), whereby the bottom detection was poor at certain gain settings and quite reasonable at others. This was determined by noting the ping number of the bottom detection failure points and subsequently examining the gain settings (logged as hex strings) at this ping location using a raw sonar file data reader. A primer on the Klein 7180 system design and its associated gain

implementation might help to better understand the underlying issues with the problematic bottom tracking and are paraphrased in this section from direct personal communications with Peter Runciman at Klein Sonar Systems.

By design, the sonar is built with two electronics bottles with gains being grouped into a set of subsystems. The MBSS, scatterometer and 38-kHz systems are all captured in bottle 1 and controlled by gain group 1. The C-ENAS and down/uplookers are also captured in bottle 1 but are controlled by gain group 2. The MBES channels are then captured in bottle 2 and are controlled by gain group 3. Each electronics bottle (or SU) has 128 (127 actual) channels of acquisition which is gathered on four subsystems – each of 32 channels. This description is important when trying to unravel the hex gain message and the way it is logged within each SU file.

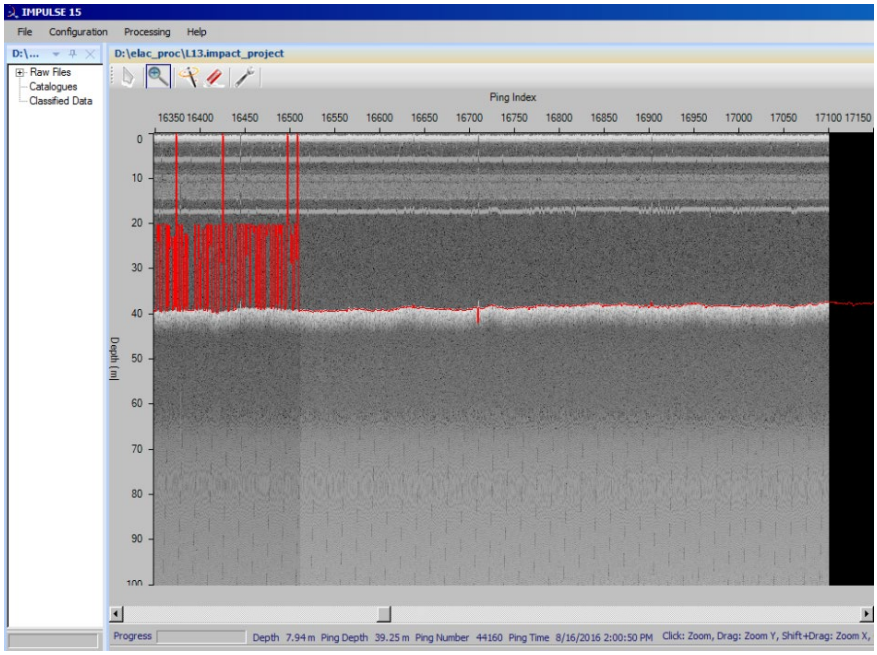

Figure 14. -- Note poor bottom detection until approximately ping 16000. It can easily be seen where the MBSS/scat/38-kHz gain setting changed from tvgPage(8) to tvgPage(10) in this example, and corresponds to the change from bad to good bottom detection.

Each subsystem has an independent TVG generator and the TVG (a voltage controlled gain amp) is based on an EPROM with 15 files. Each file is a tvgPage and each page is a one second DAC waveform. Further, the EPROM pages all have the range-gain shape of

tvg(time,tvgPageNum) = 20*log10(time*c/2) + 0.1*(time*c/2) – 40 + 2*tvgPageNum [dB],

where tvg is limited to [12dB,60dB] .

The 15 pages are merely 2 dB gain increments from the previous page with the same overall shape. Additionally, there is one page that is reserved as a flat gain of 40 dB. All 32 channels of an SU (i.e., bottle 1 or bottle 2) have a single selected gain-time profile applied. Under this design, if the sonar operator changes the gain setting (Fig. 15), for example, to enhance MBSS reflectivity, the 38-kHz data will also be affected at the same time, as seen above in Figure 14.

In looking deeper at the Sonarpro .sdf2 files, we see there is a hex number for each tvgPage that indicates the 1-of-15 pages. This is reflected in the ping header as a byte, hence the 0×07 or 0×0A, etc. that are logged. The ping header entry includes 4 bytes (a 32-bit number) which indicates the 4 hex gain pages selected for the 4 subsystems of an SU. Again, the tvgPage selection for each subsystem (4 in each SU) are controlled separately. SonarPro sends multiple hex messages to the towfish for groups that extend over multiple 32-channel subsystems. That said, an operator changing the MBSS gain in SonarPro will automatically result in two messages going down; for a total of 64 channels. For bottle 1, this would be 30-port-sidescan channels, 30-starboard-sidescan channels, two channels for the scatterometer, and one for the 38-kHz.

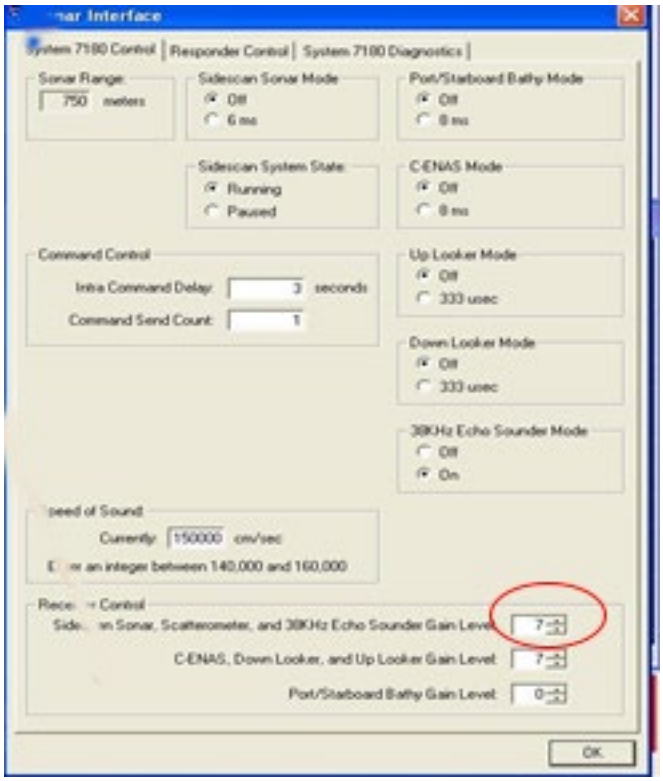

Figure 15. -- Sonar Acquisition Interface showing the three gain group controls at the bottom. The first group affects the 38-kHz data.

If reviewing the ping header for an SU1 file using the Klein SDF2viewer, a tvgPage value of 0x07070808 would mean that the MBSS/scatter/38 would have the 8th TVG-page applied in the towfish acquisition. When that changes to 0x07070A0A then the MBSS/scatter/38 will now have the 10th TVG-page, which is 4 dB hotter over the entire range scale. The CNAS/up/downlookers are another two subsystem (of 32 bits each) and are reflected in the first 4 bytes of tvgPage … that is, the 7th TVG-page in this example.

So with all that in mind, it appears that the bottom tracking on the 38-kHz falls apart at a gain page less than hex(09), the 3rd and 4th byte shown in the TVG message. For future surveys it might be beneficial to keep the MBSS gain page at 9 or higher to make the bottom tracking component of the 38 kHz analysis much less time consuming. If the data become clipped, perhaps one could instead use channel 63 (the low gain data) to process the 38-kHz.

B7.6 Transmissometer

The TRANSMISSOMETERDATASECTION comma-separated values file, produced from the Python SDFTools script, was imported into ARCGIS as a table and converted to a feature layer after plotting the easting and northing positions. Count values for the chlorophyll-a, scattering, and CDOM sensors were converted to meaningful units using the formulas provided in Table 6.

B7.7 ARCGIS Archiving

Side-scan sonar mosaics were imported into multiple geodatabases, all of which were created and organized around planned line number. Greyscale images were imported into a raster catalogue within each geodatabase. Imported raster images for each line were then added to a mosaic dataset.

As with the mosaics, descriptive statistical products were imported into multiple geodatabases assigned by line number. Within each geodatabase four raster catalogues were created. One as a container for integer-based rasters, and another for floating point formatted data. The two types of gridded data were archived at both 50-m and 100-m cell sizes. Table 7 lists the statistical products associated with each type of raster format.

Transmissometer and navigation data for both the ship and towfish were imported into feature point layers.

FGDC metadata was created and archived with all data layers using ArcCatalog.

Table 7. -- Statistical derivative layers by gridded raster format type.

Floating point-based grids	Integer-based grids
Kurtosis, Maximum, Mean	Grazing Angle
Median, Minimum, Mode	Number of Independent Samples
10th, 25th, 75th, and 90th Percentiles	
Quartile Range, Skewness	
Standard Deviation	

C. System Offsets

All ship-based sensor installation offsets were referenced to the granite block.

C.1. Fairweather

Sensor offsets for all ship-based instruments, except for the Trimble SPS855 GPS, were established through a precise spatial relationship survey of the vessel during the 2014 winter dry dock period by use of a Total Station (Table 8). The Trimble GPS was tied in during the Fishpac 2016 mobilization effort with a simple tape measure, and using the G-Deck centerline benchmark as the closest reference point.

Table 8. -- Select *Fairweather* sensor offset values important for the Fishpac 2016 survey.

Offset from CRP (m) using Caris Conventions				
Equipment	**Manufacturer / Model**	**X**	**Y**	**Z**
Granite Block	CRP	0.0000	0.0000	0.0000
IMU	Applanix POS M/V	0.0003	-0.4830	-0.0997
G-Deck Benchmark	Benchmark Punch	-11.7440	1.3695	-9.5527
GPS1 (Primary)	Applanix POS M/V	-11.8037	2.4058	-13.2788
GPS2 (Secondary)	Applanix POS M/V	-11.8098	0.4080	-13.2864
GPS (QINSy antenna)	Trimble SPS855	-11.9400	0.5600	-12.9200
Gyro	Teledyne TSS	-1.0794	0.6861	-3.3263
USBL Skeg	Sonardyne TCVR	-28.3621	1.4524	4.2930

C.2. Sonardyne Casius USBL Alignment Offsets

The USBL transceiver to both the Trimble GPS and POSMV reference frames were determined by using the offsets provided in Table 8 and performing a calibration of attitude procedure with Sonardyne Casius software (v5.0.1). By maneuvering near a stationary Compatt deployed on the seabed (Fig. 6) and recording DGPS positions and acoustic positions relative to the beacon it is possible to solve for the position of the Compatt (BOXIN position), the prevailing sound velocity (through the water column), the Acoustic Transceiver offsets from the DGPS antenna, and the pitch, roll and heading corrections that should be applied within the USBL system.

In general practice the Sonardyne USBL common reference point (CRP) should be defined as the ship's center of gravity, as such, for the 2016 Fishpac survey, the CRP was defined as the Applanix IMU (Table 9).

Table 9. -- Sonardyne Fusion offsets as determined by the Casius box-in calibration procedure.

Offset from CRP (m) using Sonardyne Conventions					
Node	**X**	**Y**	**Z**	**Roll**	**Pitch**
IMU	0.0003	-0.4830	-0.0997		
GPS	-11.9402	0.5580	12.9200		
USBL Tcvr	-28.7800	0.4300	-4.2900	-0.31	2.89

C.3. Towfish

The various Klein 7180 transducer offsets, shown in Figure 16 for reference, were not necessary or used in processing the 2016 data since they are only applied during the TPU2-SU2 .sdf2 to SDF bathymetry file conversion pipeline.

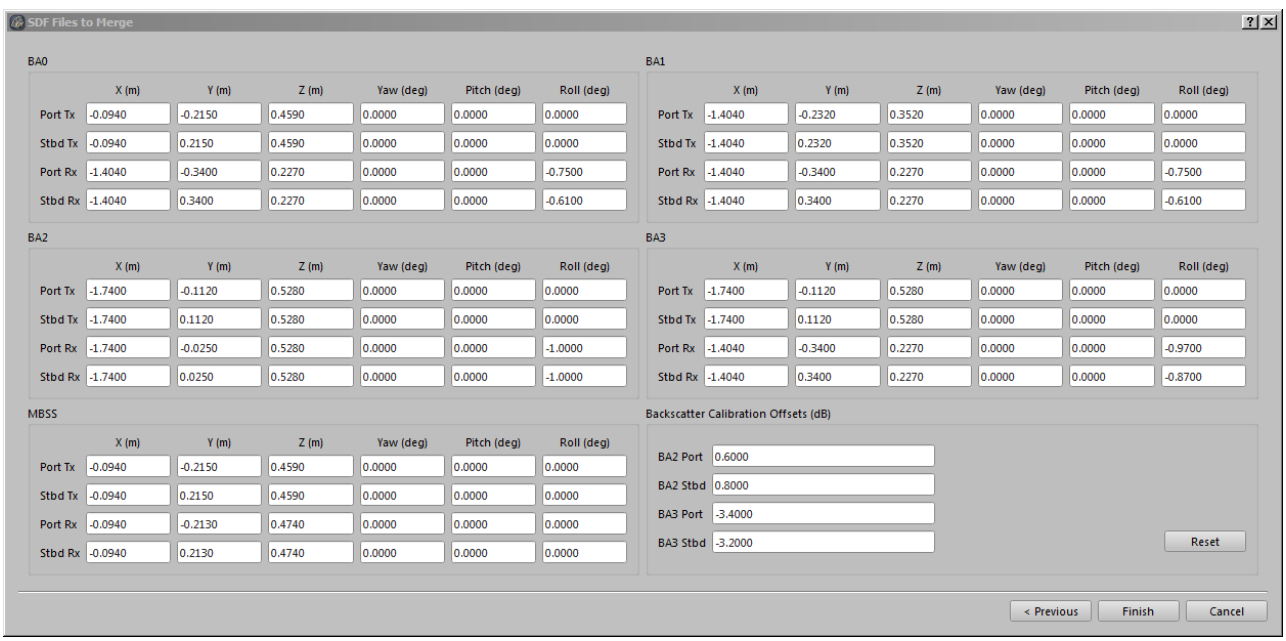

Figure 16. -- Klein 7180 offsets for converting TPU2-SU2 .sdf2 files to SDF format.

D. Instrument Interfacing and Wiring Diagram

The wiring diagrams shown in Figures 17 and 18 are provided as an interface reference for all instrument and computer connections passing through Plot1 and the D-Deck Sonar Room, respectively.

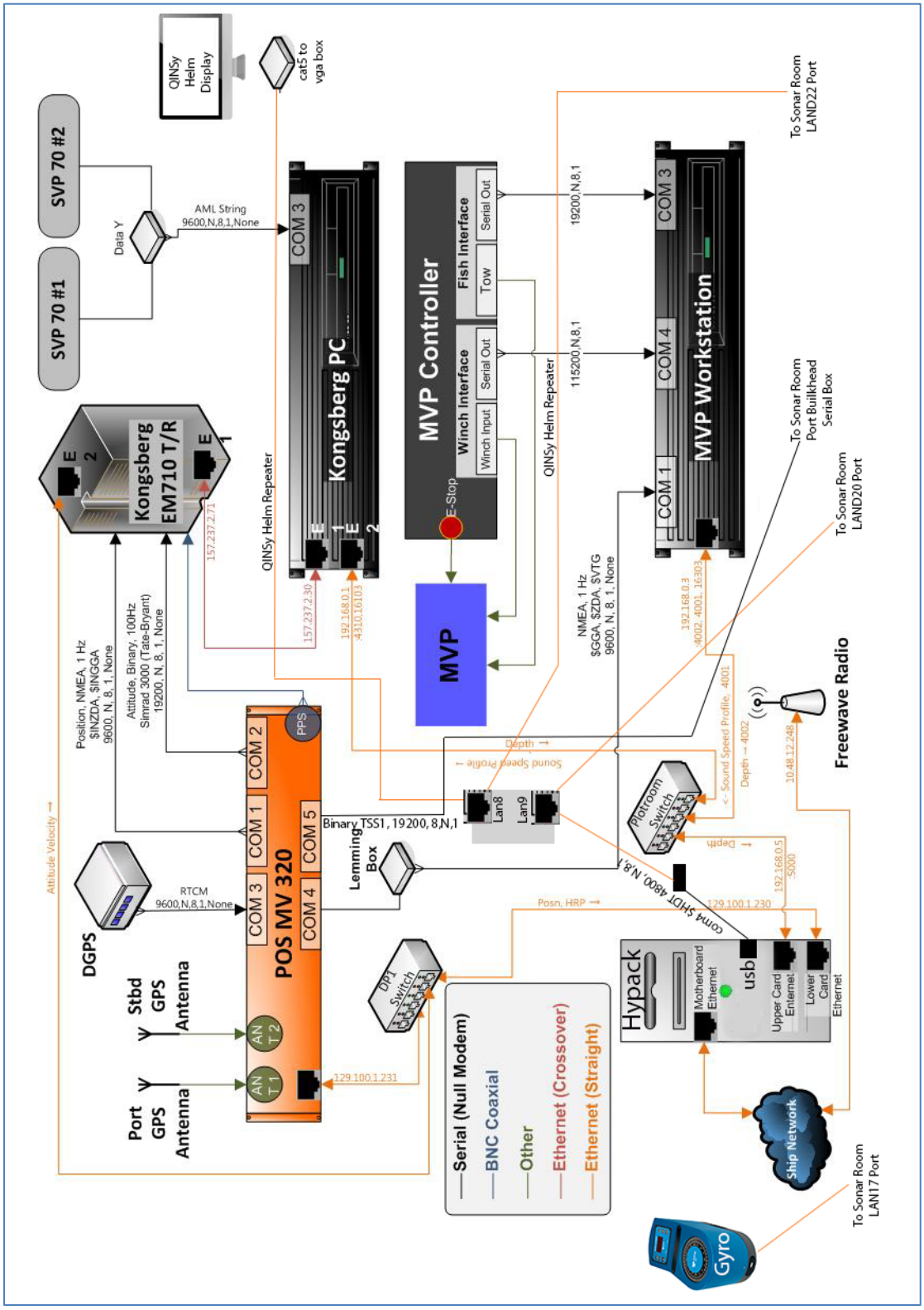

Figure 17. -- Plot1 Wiring Configuration (*Fairweather* equipment).

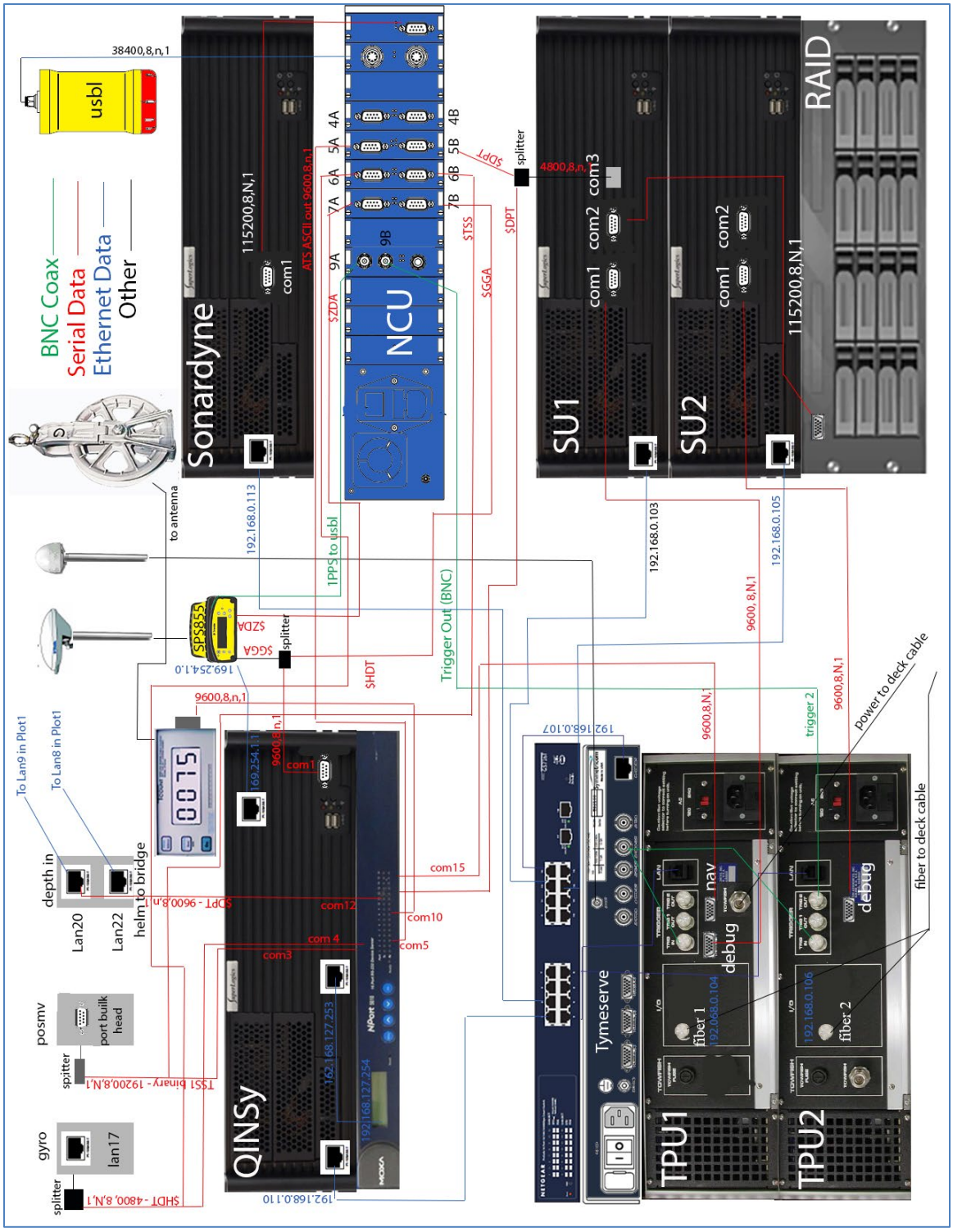

Figure 18. -- Sonar Room Wiring Configuration (AFSC HRG equipment).

U.S. Secretary of Commerce
Wilbur L. Ross, Jr.

Acting Under Secretary of Commerce
for Oceans and Atmosphere
Dr. Neil Jacobs

Assistant Administrator for Fisheries
Chris Oliver

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