DATA ACQUISITION AND PROCESSING REPORT

Type of Survey	**Hydrographic**
Project	**M-M928-KR-09**
Contract No	**DG133C08CQ0006**
Task Order No	**T003**
Time Frame	**August 2009 - September 2009**

LOCALITY

State	**Oregon**
General Locality	**Pacific Ocean - Northern Oregon**

2009

CHIEF OF PARTY

Jonathan L. Dasler, PE (OR), PLS (OR,CA)

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DATE

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

REGISTRY No

H12129

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.

FIELD No

David Evans and Associates, Inc.

State **Oregon**

General Locality **Pacific Ocean - Northern Oregon**

Sub-Locality **Cape Perpetua**

Scale **1:20,000**

Date of Survey **August 7, 2009 - September 1, 2009**

Instructions dated **June 2009**

Project No. **M-M928-KR-09**

Vessel *R/V Pacific Storm*

Chief of party **Jonathan L. Dasler, PE (OR), PLS (OR,CA)**

Surveyed by **David Evans and Associates, Inc.**

Soundings by echo sounder, hand lead, pole **RESON 8101-ER**

Graphic record scaled by **N/A**

Graphic record checked by **N/A**

Automated Plot **N/A**

Verification by

Soundings in **Meters at MLLW**

REMARKS: **All times are UTC.**

The purpose of this contract is to provide NOAA with modern, accurate hydrographic survey data with which to update the nautical charts of the assigned area. Data is also to be multi-use for Oregon Seafloor Mapping.

SUBCONSULTANTS: **Geomatics Data Solutions, LLC, 4128 Ingalls St, San Diego, CA, 92103**

OSU Marine Mammal Institute, 2030 SE Marine Science Drive, Newport, OR 97365

OSU COAS, 104 COAS Administration Building, Corvalis, OR 97331-5033

TABLE OF CONTENTS

List of Figures

List of Tables

Acronyms and Abbreviations

AML	Applied Microsystems, Ltd
BAG	Bathymetric Attributed Grid
COAS	OSU College of Oceanic and Atmospheric Sciences
CO-OPS	Center for Operational Oceanographic Products and Services
CORS	Continuously Operating Reference Station
CTD	Conductivity, Temperature and Depth
CUBE	Combined Uncertainty and Bathymetry Estimator
DEA	David Evans and Associates, Inc.
DGPS	Differential Global Positioning System
DN	Day Number
GPS	Global Positioning System
HDCS	Hydrographic Data Cleaning System
HIPS	Hydrographic Information Processing System
HSD	Hydrographic Surveys Division
HSX	Hypack Hysweep File
HVF	HIPS Vessel File
HSSD	Hydrographic Surveys Specifications and Deliverables
IAKAR	Inertially-Aided Kinematic Ambiguity Resolution
IHO	International Hydrographic Organization
IMU	Inertial Motion Unit
INFORM	S-57 attribute providing textual information about an object
M_COV	S-57 object describing the coverage and extent of an area
M_QUAL	S-57 object describing the quality of data within an area
MVP	Moving Vessel Profiler
NAD83	North American Datum of 1983
NAS	Network-Attached Storage
NATSUR	S-57 attribute used to describe the composition of the sea bed
NATQUA	S-57 attribute used to qualify NATSUR attributes
NGS	National Geodetic Survey
NAVD88	North American Vertical Datum of 1988
NMEA	National Marine Electronics Association
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
OSU	Oregon State University
PBO	Plate Boundary Observatory
PHB	Pacific Hydrographic Branch
POS/MV	Position and Orientation System for Marine Vessels
PPS	Pulse per Second
RMS	Root Mean Square

RPM	Revolutions per Minute
RTG	Real-Time GIPSY corrections to GPS
R/V	Research Vessel
SBDARE	S-57 object describing the sea bed
SBET	Smooth Best Estimate and Trajectory
smrmsg	PosPac dynamic error file
SVP	Sound Velocity Profiler
TPU	Total Propagated Uncertainty
TXTDCS	S-57 attribute providing textual information about an object
UNAVCO	University NAVSTAR Consortium
UTC	Universal Time Coordinated
WADGPS	Wide Area Differential Global Positioning System
XTF	Extended Triton Format
VDatum	NOAA Vertical Datum Transformation Tool
ZDA	Global Positioning System timing message

M-M928-KR-09 Oregon Coastal Mapping Project   *September 2009*
Data Acquisition and Processing Report   *Field Unit: David Evans and Associates, Inc.*

iv

Data Acquisition and Processing Report
Project M-M928-KR-09
Oregon Coastal Mapping Project
August 2009 – September 2009
R/V Pacific Storm
David Evans and Associates, Inc.
Lead Hydrographer, Jonathan Dasler, P.E., P.L.S.
ACSM/THSOA Certified Hydrographer

INTRODUCTION

This report applies to survey H12129 located in the Pacific Ocean along the Northern Oregon Coast off Cape Perpetua. These contract surveys were performed under M-M928-KR-09 as specified in the *Statement of Work* dated June 2009, and *Project Instructions* received on August 20, 2009. All survey methods meet or exceed requirements as defined in the National Ocean Service (NOS) *Hydrographic Surveys Specifications and Deliverables* (April 2009) (HSSD) with the exception of multibeam resolution requirements and tides and water levels requirements. Required multibeam resolution was reduced by waiver from the Chief of the Data Acquisition and Control Branch on September 1, 2009. David Evans and Associates, Inc. (DEA) received permission from the Hydrographic Surveys Division (HSD) on January 5, 2010 to use Global Positioning System (GPS) water levels acquired directly at the survey vessel in lieu of the tide zoning scheme included with the water levels requirements. A copy of the waiver and HSD correspondence is included in the *Appendix IV Supplemental Survey Records and Correspondence* of the survey's Descriptive Report. This project is in support of the Oregon Seafloor Mapping Project established under the West Coast Govenor's Agreement. The project instructions required complete multibeam coverage and in areas with greater than 8-meters water depth and delivery of a copy of the multibeam bathymetric grids and backscatter data to Oregon State University (OSU) in support of mutli-use mapping of the Oregon seafloor.

All references to equipment, software or data acquisition and processing methods were valid at the time of document preparation. All changes to data acquisition and processing methods will be specifically addressed in the Descriptive Reports of the project surveys.

A. EQUIPMENT

For this project, DEA implemented state-of-the-art data acquisition systems aboard the Research Vessel (R/V) Pacific Storm, in accordance with National Oceanic and Atmospheric Association (NOAA) standards and modern remote sensing techniques. Instrumentation and equipment used to conduct the survey and redundant systems to provide confidence checks are listed in Table 1.

Table 1. *R/V Pacific Storm* **Hardware**

Instrument	Manufacturer	Model	Serial Number	Function
Multibeam Echosounder				
	RESON	SeaBat 8101 Multibeam sonar system	8002024	240 kHz Multibeam bathymetry
Deck Unit	RESON	8101	8002024	
Wet End	RESON	8101-ER	3507003	
Navigation and Attitude				
Deck Unit	Applanix	POS MV 320 V4	3588	Primary source for navigation and attitude
IMU		POS MV V4	288	
Starboard Antenna	Trimble	Zephyr Compact	30939211	
Port Antenna	Trimble	Zephyr Compact	30942877	
WADGPS Receiver	Navcom Technology	SF 3050	11101	Positioning system used to increase real time navigation accuracy
WADGPS Antenna	Navcom Technology	ANT3001R	5072	
DGPS Receiver	Trimble	DSM-132	224093932	Secondary positioning system
DGPS Antenna	Trimble	33580-00	220360503	
Dissolved Oxygen				
Dissolved Oxygen Sensor	Applied Microsystems, Inc.	Idronaut DO2	7737	Primary DO Sensor
Sound Speed				
Moving Vessel Profiler	Brooke Ocean Technology, Ltd.	MVP30	10767	Primary SV sensor and automated profiler
		Winch	WFMQ824-40-2-56	
		Controller	7710	
		Sheave	10766	
Sound Speed Sensor	Applied Microsystems, Inc.	Micro-SV	7710	
Sound Speed Profiler	Seabird Electronics Inc.	SBE-19	4962	Secondary SV sensor

A1.   Survey Vessel

The R/V Pacific Storm, which is owned and operated by Oregon State University, Marine Mammal Institute, was chartered as the survey vessel for the project (Figure 1). The R/V Pacific Storm, IMO 7942685, is a 74-foot steel hulled vessel with a 24-foot beam. The vessel is equipped with a starboard side custom multibeam pole mount, stern mount A-frame, server station, and acquisition station. No unusual sensor setup configurations were used aboard R/V Pacific Storm.

Figure 1. *R/V Pacific Storm*

A2.   Multibeam Systems

The Reson SeaBat 8101-ER multibeam sonar with single frequency configuration was pole-mounted on the R/V Pacific Storm. The Reson 8101 operates at 240 kHz frequency producing a 150° swath of 101 uniform beams with a beam width of 1.5° x 1.5°.

Triton Isis was used to acquire multibeam depth and backscatter data in the XTF format.

A3.   Position, Heading, and Motion Reference Systems

Position and attitude data were obtained from an Applanix Position and Orientation Systems for Marine Vessels (POS/MV) 320 v4. The system was comprised of an inertial motion unit (IMU), two Global Positioning System (GPS) dual frequency (L1/L2) antennas, and a data processor.

To enhance real-time navigation, a separate L1/L2 antenna was installed and routed to a NAVCOM receiver utilizing the STARFIRE Real-Time GIPSY (RTG) correction. The NAVCOM Wide Area Differential GPS (WADGPS) solution was sent to the POS/MV as an auxiliary input, and provided the primary source of position information in the field. The NAVCOM positions were not utilized during post-processing.

For redundancy, a Trimble DSM 132 receiver was installed onboard and acquired corrections from the U.S. Coast Guard beacon located at Fort Stevens, Oregon (287 kHz) providing tertiary differential corrections for quality control purposes. Positions from all systems were displayed in real-time using Hypack and compared while online. In addition, the POS/MV QC plot was displayed and monitored onscreen during data acquisition.

A periodic comparison between all positioning systems was observed and documented while the vessel was stationary in port. Logged position data was imported into Excel and a difference computed.

Position, timing, heading, and motion data were output to the Isis acquisition system using the real-time ethernet option at 25 Hz. Motion data were output to the Hypack backup acquisition system over a serial connection with motion data output at 25 Hz; position and heading were output at one Hertz. All POS/MV data was logged to POSPac files for subsequent post-processing.

The POS/MV provided time synchronization of sonar instruments and logging computers using a combination of outputs. The Reson 81-P processor and ISIS logging computer were provided GPS derived universal time coordinated (UTC) message from the POS/MV to achieve time synchronization. The HYPACK logging computer was provided both a pulse per second (PPS) and a National Marine Electronics Association (NMEA) GPS timing message (ZDA) to achieve synchronization with the POS/MV. All messages contained time strings and caused the clocks of the computers and sonar to synchronize to the time contained within the message. Time offsets between the instruments and computers, relative to the times contained in POS/MV network packets, were typically sub-millisecond.

Using the ethernet logging controls, the POS/MV was configured to log all of the raw observable groups needed to post-process the real-time sensor data with the file size control option set to limit file size to 128 megabytes. This setting resulted in a .000 file recorded approximately every hour. The TrueHeave™ data group was also logged to these files.

A4.   Sound Speed Measurement Systems

Sound speed sensors were calibrated prior to the start of the survey. Factory calibration results are included in the Separates II Sound Speed Data of the Descriptive Report for the survey.

A Brooke Ocean Technology Moving Vessel Profiler (MVP) 30 was mounted on the stern of the R/V Pacific Storm and was used as the primary method for deployment of the primary sound speed sensor (AML Micro SV&P) to correct multibeam data.

A Sea-Bird Electronics 19 SEACAT profiler was used to acquire sound speed profiles for weekly comparisons to the primary sound speed profiler.

A5. Acquisition and Processing System

The acquisition and processing stations were custom installed and integrated on the R/V Pacific Storm by David Evans and Associates, Inc. and consisted of a Triton Isis data acquisition system, Hypack navigation software, a 'Notes' workstation, an MVP topside processor, and a CARIS field processing workstation. During acquisition, data were logged locally on acquisition PCs and transferred to two QNAP networked-attached storage (NAS) systems. One NAS system remained on the vessel throughout survey operations as the primary field data storage unit. The other NAS was used to transfer field data to the processing servers at David Evans and Associates, Inc. office in Vancouver, Washington. Preliminary processing occurred onboard the R/V Pacific Storm alongside data acquisition to facilitate survey coverage optimization and creation of fill plans. Additional processing and creation of deliverables was performed in the Vancouver office. The software and version numbers used throughout the survey are listed in Table 2.

Table 2. Acquisition and Processing Software

Software	Manufacturer	Version	Install Date
Acquisition			
Hypack	Hypack, Inc	9.1.0.0	7/24/2009
Isis	Triton Imaging,Inc	7.1.500.123	7/24/2009
LineLog	DEA, Inc	1.0.6	7/24/2009
MV-POSView	Applanix Corporation	4.3.4.0	7/24/2009
Smart Talk	Applied Microsystems Ltd.	N/A	7/24/2009
Reson 8101	Reson		7/24/2009
ODIM MVP Control	Brooke Ocean Technology, Ltd.	2.41	7/24/2009
Seaterm	Seabird	1.59	7/24/2009
Seabird Data Processing	Seabird	5.37e	7/24/2009
Velociwin	NOAA	8.96	7/24/2009
Processing			
HIPS	CARIS	6.1 SP2 HF7	3/20/2009
Notebook	CARIS	3.0 HF2	8/10/2008
		3.0 SP1 HF1	4/8/2009
Bathy DataBASE	CARIS	2.1 HF6	8/10/2008
		2.1 HF10	4/8/2009
HYPACK	Hypack, Inc.	8.0.1.2	8/10/2008
ArcMap	ESRI	9.3 SP1	5/23/2008
POSPac MMS	Applanix Corporation	5.3.3524.25247	7/24/2009
Velociwin	NOAA	8.96	8/14/2009
Other			
Microsoft Office Suite	Microsoft	2003	

A6. Survey Methodology

A6.a Mobilizations

Mobilizations, sensor installations, vessel and sensor survey, and calibrations occurred at Toledo, OR in July, 2009. All sensors were surveyed in using a terrestrial land survey total station on July 25, 2009. Values from this survey were used to calculate sensor offsets and uncertainty estimates used in the HIPS vessel file (HVF) for project M-M928-KR-09.

The vessel and sensor survey involved use of a land survey total station to position the sonar mount, all GPS antennas, the IMU and general outline of the survey vessel. Brackets were installed on the gunwhale port and starboard of the vessel reference point. The brackets were used for subsequent measuring to the water line to obtain draft or water line readings. All survey points were positioned from a minimum of two locations such that a position uncertainty could be determined.

Once installations were completed and the hydrographer was confident that all sensors were operational, the vessel underwent system calibration tests, including settlement and squat and initial patch tests.

A6.b Multibeam Sonar Operations

Twenty four (24)- hour multibeam operations met coverage requirements via techniques stated in the M-M928-KR-09 Statement of Work and defined by the NOS Hydrographic Surveys Specifications and Deliverables (April 2009) excepting reduced resolution requirements permitted by approved waiver. Complete multibeam coverage, including backscatter data, was required in all areas with water depth greater than eight meters. The multibeam sonar was operated at different range scales throughout the survey by adjusting the depth range to obtain the best coverage in varying depths of water. Gain and power were adjusted in order to record a strong bottom return capable of supporting quality depth and backscatter data, but excessive tuning and over saturating the return, which could reduce the quality of the backscatter data, were avoided. Table 3 lists the typical sonar settings for the survey.

Table 3. Reson 8101 Sonar Settings

8101 Parameter	Value
Range	Variable, depth dependent
Gain	Variable, Default 5
Power	Variable, Default 5
Spreading	30 dB
Absorption	70 dB/km
Ping Rate	4.8 - 14.3 p/s
Pulse Width	88 µs

A6.c   Bottom Sampling

A total of 51 bottom sediment grab samples were obtained within the survey area which exceeded the requirements set in the HSSD. Samples were obtained by OSU College of Oceanic and Atmospheric Sciences (COAS) aboard a second vessel with a Shipek grab sampler. COAS graduate students logged position, depth, date, time, unique identifier, description, and photograph recorded for each sample. Each sample was described in accordance with International Hydrographic Organization (IHO) S-57 requirements for Seabed Area (SBDARE) features with attribution of color (COLOUR), Nature of Surface Qualifying terms (NATQUA), and Nature of Surface (NATSUR). IHO S-57 attributes were verified by DEA hydrographers by comparing field attribution to photographs of the samples.

A7.   GPS Reference Station Network

Prior to the start of hydrographic survey operations publicly available GPS reference stations were selected to enable GPS post-processing of the POS/MV sensor data using the SmartBase option within Applanix POSPac MMS. This option creates a virtual reference station from a network of GPS base stations. No less than nine GPS reference stations from the National Geodetic Survey (NGS) National and Cooperative Continuously Operating Reference Stations (CORS) or the UNAVCO (University NAVSTAR Consortium) Plate Boundary Observatory (PBO) were used during each post-processing session. Station P367 was selected as a control for the entire project and surrounding stations ranging approximately 32 to 188 kilometers from the survey area were used to populate the network. From this network a virtual reference station was derived for post-processing. Table 4 indicates the reference stations used in the network and their approximate distance to the survey area subdivided by data provider. Stations were selected based on distance from survey area, data availability and data quality. After overriding the control station position and ellipsoid height with published NGS NAD83 coordinates the SmartBase Quality Check utility was run to evaluate data quality of the GPS reference stations and to perform a network adjustment of the remaining stations. When results indicated a station location outside the allotted 10-centimeter accuracy for position of the constrained network, the station was disabled.

Table 4. Continuously Operating Reference Stations

NGS		UNAVCO	
Station ID	Distance (km)	Station ID	Distance (km)
CABL	163	P365	98
CHZZ	135	P373	96
CORV	76	P374	47
LFLO	32	P375	74
P367	35	P378	100
OBEC	86	P395	86
		P404	115
		P407	188

A8.   Quality Assurance

Acquisition and processing methods followed systematic and standardized workflows established by DEA. These systems include but are not limited to staff training and mentoring, a formalized project management program, an established set of standards for record and log keeping, software version management, and a multilevel review process.

MBES survey data were converted and processed in Caris HIPS v6.1 SP2 Hotfix 7. Processing methodology followed the standard Caris HIPS CUBE (Combined Uncertainty Bathymetric Estimator) workflow with integration of post-processed sensor data through the HIPS Load Attitude and Navigation Tool.

The default *CUBE Parameters.XML* was replaced with a file issued to DEA by the Pacific Hydrographic Branch (PHB) and also issued to all NOAA hydrographic field units and processing branches in Hydrographic Surveys Technical Directive 2009-2. This updated XML file used new resolution dependent maximum propagation distance values required in the HSSD 2009.

B. QUALITY CONTROL

B1.   Data Acquisition

B1.a   Multibeam
The Isis acquisition station operator monitored the multibeam sonar, selected appropriate range, gain, and power settings for quality bathymetric returns, monitored the Isis Acquisition software, monitored the POS/MV POSView software, and maintained the digital line log. The Hypack station operator controlled the Hypack acquisition station, monitored Hypack matrix coverage, and operated the MVP. The Hypack operator also monitored primary and secondary navigation systems to ensure quality position and height data were acquired at all times.

During acquisition, data were monitored in real-time using the 2-D and 3-D data display windows in ISIS and Reson SeaBat displays, including a waterfall display for the imagery from sonar backscatter. HYPACK was used to monitor vessel navigation with respect to track, navigation quality from HDOP, and survey coverage. POSView was used to monitor the type of GPS solution and the quality of attitude measurements. Raw soundings, attitude, heading and position data were recorded in ISIS XTF format and also in HYPACK Hysweep file (HSX) format as a backup. Adjustments to the sonar, including changes in range and gain were made, as necessary, during acquisition to ensure the best bathymetric data quality. Additionally, vessel speed was adjusted to ensure the required along track coverage in accordance with the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2009).

B1.b   Survey Coverage
The Oregon Coast (M-M928-KR-09) was surveyed using Hypack line plans, which were spaced and oriented for optimal multibeam coverage based on survey boundaries and charted contours. Coverage was evaluated in real time using the Hypack Hysweep matrix. Matrix settings were adjusted to account for swath width, vessel draft and tides. In places where coverage was insufficient or the vessel had to maneuver to avoid crab pots in the survey area, targets were

marked in Hypack Survey in order to subsequently fill gaps. In addition, soon after collection, coverage was evaluated in the field by computing CARIS Combined Uncertainty and Bathymetry Estimate (CUBE) surfaces. Fill lines were created over gaps in the CUBE surface or over significant features that required more coverage.

B2.   Methodology Used to Maintain Data Integrity

The acquisition systems and survey protocols were designed with some redundancy to demonstrate that the required accuracy was being achieved during the survey and provide a backup to primary systems. Data integrity was monitored throughout the survey through system comparisons. Three positioning systems were used to provide real-time monitoring of position data. A position confidence check and multibeam to leadline check were conducted when the vessel was in port to confirm required accuracy was being maintained. Weekly checks of the sound speed profiler integrated into the MVP-30 were conducted by deploying the SeaBird Conductivity, Temperature, and Depth (CTD) SBE 19 profiler in tandem with the MVP-30. Sound velocity profiles were computed for each of the sensors and compared to confirm the MVP-30 was functioning within survey tolerances.

Significant features found in the multibeam backscatter during sonar acquisition were noted in the digital line log. The line log was consulted while data cleaning.

A flow diagram of the multibeam data acquisition and processing pipeline is presented in Figure 2. This diagram graphically illustrates the data pipeline and processing workflow.
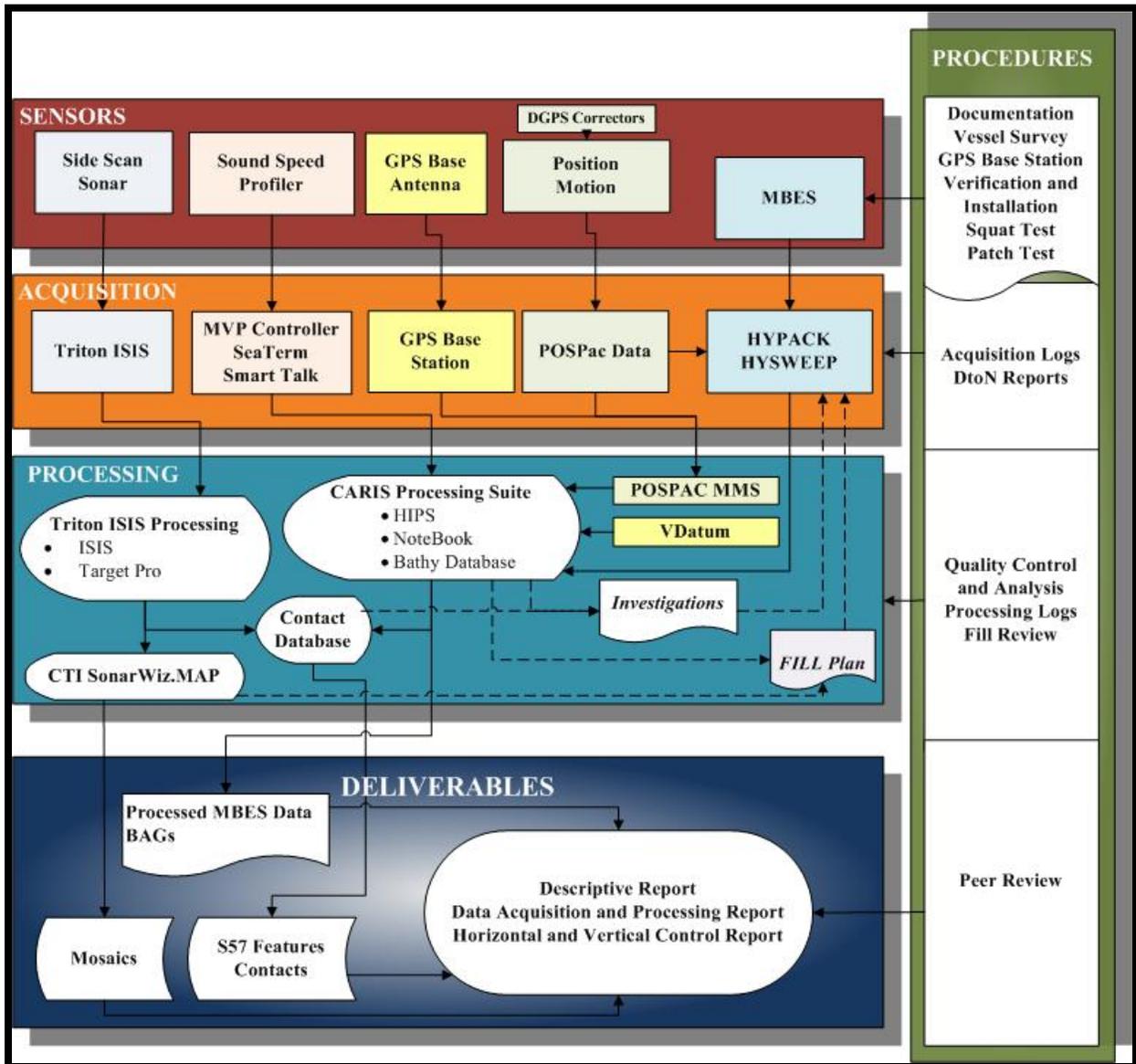
Figure 2. Flowchart of multibeam data acquisition and processing pipeline

B2.a   HIPS Conversion

Multibeam data were converted from XTF format to CARIS HDCS format using the HIPS Conversion Wizard (XTF converter 6.1.2.3) with ship navigation, attitude, and gyro from the raw navigation datagrams. Backscatter data were not converted or processed in Caris HIPS as this capability was not implemented in HIPS version 6.1.

No data were rejected based on quality flags during conversion. The CARIS output window was reviewed for failures during conversion.

B2.b   Vessel File

A HIPS Vessel File (HVF) was created to correspond to the vessel configuration used during the survey (Table 5). The vessel files contain all offsets, uncertainty and system biases for the survey vessel and its corresponding systems, as well as error estimates for latency, sensor offset measurements, attitude and navigation measurements, and draft measurements.

Table 5. HIPS Vessel File

HIPS Vessel File	HIPS Converter	Sonar Type	Comment
N928-KR-09_PS.hvf	XTF 6.1.2.3	Multibeam	MBES hvf

Sensor offset values were calculated from the vessel survey conducted prior to the start of field operations. Draft (waterline) values were measured when the vessel was in port and entered into the vessel configuration file. Dynamic draft (settlement and squat) values were calculated through the use of post-processed GPS observations. These offsets are listed in tabular format in Section C of this document. Both dynamic draft and waterline values were used to properly position the multibeam in the water column for the sound velocity correction. GPS Tides were computed using the "apply dynamic draft" and "apply waterline offset" options, which subtract the waterline height and dynamic draft values from the final signal. Therefore, the dynamic draft and waterline values are not used as correctors in the sounding reduction, other than their role in the sound velocity correction.

Best estimates for total propagated uncertainty (TPU) values were entered into the vessel file based on current knowledge of the TPU/CUBE processing model. The manufacturers' published values were entered into the static sensor accuracy fields. Other values were either calculated or estimated. Real-time error values created during POSPac post-processing sessions were loaded for position, heading, height, and attitude and used during TPU computation. Table 6 indicates the manufacturer uncertainty values for sensors aboard the vessel.

Table 6. Hydrographic Vessel File Uncertainty Values

Manufacturer Accuracy Values for Uncertainty Computation HIPS Vessel File (HVF)*				
Vessel	**R/V Pacific Storm**			
Motion Sensor	POS/MV 320 V4			
Position System 1	POS/MV 320 V4			
Position System 2	NAVCOM with STARFIRE RTG			
Position System 3	Trimble DSM 132			
Gyro - Heading		**Latency**		
Gyro (°)	0.02		Timing Trans (s)	0.005
Heave			Nav Timing (s)	0.005
Heave % Amplitude	5		Gyro Timing (s)	0.005
Heave (m)	0.05		Heave Timing (s)	0.005
Roll and Pitch			Pitch Timing (s)	0.005
Roll (°)	0.02		Roll Timing (s)	0.005
Pitch (°)	0.02	**Measurement**		
Navigation			Offset X (m)	0.005
Position Navigation (m)	1		Offset Y (m)	0.005
Draft and Loading			Offset Z (m)	0.005
Loading	0.000	**Physical Alignment Errors***		
Draft (m)	0.010	**Alignment**		
Delta Draft (m)	0.000		MRU align Stdev gyro	0.090
Speed			MRU align roll/pitch	0.059
Vessel Speed (m/s)	0.030	*All values given as 1 sigma.		

The estimated uncertainty of the ellipsoid to MLLW separation model was computed from values published on NOAA's VDatum website[1]. This estimate is the cumulative uncertainty of the source data and transformation uncertainties required to convert an ellipsoid height to MLLW in VDatum. The model uncertainty was introduced into the TPU computation by entering the 1 sigma uncertainty into the Tide Zoning field since HIPS does not currently allow for the application of a separation model uncertainty. Table 7 lists the published source and transformation uncertainties used to compute the separation model uncertainty.

[1] http://vdatum.noaa.gov/docs/est_uncertainties.html

Table 7. Estimated VDatum Model Uncertainty

Oregon - Central Oregon Region	
Transformation Uncertainty	**1-Sigma (cm)**
NAD83 to NAVD88	5.0
NAVD88 to LMSL	2.7
LMSL to MLLW	17.6
Total Transformation Uncertainty	*18.49*
Source Uncertainty	
NAD83	2.0
NAVD88	5.0
LMSL	1.2
MLLW	1.2
Total Source Uncertainty	*5.65*
MODEL Uncertainty	**19.34**

Sound speed and tide uncertainty values are listed in Table 8.

Table 8. Tide and Sound Speed Uncertainty

Total Propagation Error Computation in CARIS HIPS	
Survey Specific Parameters	
Tide Value	**H12129**
Tide Value Measured	0.00
Tide Value Zoning	0.19
Sound Speed Values	
Sound Speed Measured	1.00
Surface Sound Speed	0.50

*All values given as 1 sigma.

B2.c   Sound Speed

Sound speed profiles were applied to each line using the nearest in distance within "time (two hours)" option in the Caris SVP correct routine. Velocity casts were taken at frequent intervals through the use of the MVP-30. The frequency of casts was taken at approximately 10- to 15-minute intervals to account for upwelling and fresh water intrusion from rivers in the Oregon Coast Range. A weekly comparison of sound velocity profile measurements was made in the survey area between the SBE-19 CTD and the MVP-30.

B3.   Multibeam Data Processing

Multibeam data processing followed the standard HIPS workflow for CUBE editing except that the hypothesis surface was not edited. Instead, fliers influencing the CUBE surface were rejected and critical soundings that were not incorporated in the CUBE surface were designated. Below is an overview of the processing steps including filters applied to the bathymetric data in CARIS. The TPU was re-computed for the multibeam data as needed to reflect changes in the correctors.

1. Apply true heave
2. Load post-processed attitude, height, navigation, and heading
3. Load post-processed error estimates
4. Compute GPS tides using VDatum-derived separation model
5. Apply sheet wide concatenated sound speed profiles
   - "Nearest in distance within time 2 hours"
6. Merge vessel offsets, apply GPS tides
7. Compute TPU via values listed in Table.
8. Filters applied based on the following criteria:
   - Reject soundings with poor quality flags (0 and 1 for Reson)
   - Reject swath angles greater than 55°. In water depths of less than 20m, angles greater than 60° were rejected.
9. Data reviewed and fliers removed in Swath Editor and/or Subset Editor
10. Add data to field sheet:
    - "CUBE" weighted surface of appropriate resolution for water depth
      - IHO S-44 Order 1
      - Density & Local Disambiguation method
      - Advanced configuration using the 2009 NOAA field unit parameters of the appropriate resolution surface
11. Review data in subset using tiles with reference surface on

Navigation, attitude, height, heading, and their corresponding error estimates were applied during post-processing in HIPS. Data were post-processed using POSPac MMS software. The POSPac SmartBase routine was used to generate a virtual base station from a network of continuously operating GPS stations. In generating the virtual base station, the published NAD83 (CORS96) Epoch 2002.0 coordinates were used for the control station. The virtual base station was used to generate a tightly coupled post-processed Inertial-Aided Kinematic Ambiguity Resolution (IAKAR) navigation and attitude solution. The resulting Smooth Best Estimate and Trajectory (SBET) and POSPac smrmsg dynamic error files were applied in HIPS with the Load Attitude/Navigation data and Load Error data tools.

One field sheet was created to correspond to the survey sheet. CUBE surfaces were created over the entire sheet for each required resolution, with the exception of the 50-cm grid which was only generated over potential features requiring object detection coverage. Coverage and grid node density were evaluated on each surface within the applicable depth bands (Table 9). These grid resolution and depth thresholds were discussed and agreed upon with the Chief of the Data Acquisition and Control Branch prior to CUBE creation. A copy of this waiver and related email correspondence is included in *Appendix V Supplemental Survey Records and Correspondence* of

the *H12129 Descriptive Report*. Grids were reviewed within their applicable depth bands to ensure no data gaps (i.e. no more than three empty connected nodes) were present. CUBE parameters were configured using the CUBE Parameters .XML file issued to DEA by the Pacific Hydrographic Branch (PHB) and issued to all NOAA hydrographic field units and processing branches in Hydrographic Surveys Technical Directive 2009-2. This updated XML file uses new resolution dependent maximum propagation distance values required in the HSSD 2009.

Table 9. CUBE Surface Resolution Requirements

Depth Range (m)	CUBE Resolution (m)
0-18	1.0
15-40	2.0
35-70	4.0
65 and greater	8.0
0-18 Object Detection	0.5
15-40 Object Detection	1.0

All data were initially reviewed in HIPS swath editor and all obvious fliers and data anomalies were rejected. Following swath editing, all data were reviewed in HIPS 2D subset with the appropriate or higher resolution CUBE reference surface visible. Fliers making the CUBE surface more shoal than expected by more than the allowable IHO Order 1 error were rejected. Any legitimate sounding that was not incorporated into the CUBE surface and more shoal than the surface by more than half the allowable IHO Order 1 error was flagged as a designated sounding. Least depths were designated from subset for all navigationally significant features. Subset tiles were used to track the progress of processing activities. In addition, data processors reviewed sounding data and CUBE surfaces for excessive motion artifacts or systematic biases. All crosslines were manually reviewed to ensure high internal consistency between the datasets and comparison statistics were also computed using the HIPS QC Report tool.

B4.   GPS Post-processing

Applanix POSPac MMS software was used via the Applanix SmartBase technique to generate a virtual reference station from a network of no less than nine continuously operation reference stations (CORS) to create a post-processed Inertially-Aided Kinematic Ambiguity Resolution (IAKAR) navigation solution. Based on its proximity to the survey area, the NGS CORS Station P367 was selected as the control station for project M-M928-KR-09. The network included continuously operating reference stations from the National Geodetic Survey (NGS) and UNAVCO sites. A single CORS control station was used to minimally constrain the network of reference stations to the NAD83 (CORS 96) datum and calculate a virtual SmartBase station. The SmartBase position was used to post-process a tightly coupled PPK navigation and attitude solution. The improved attitude and navigation data and corresponding error estimates were subsequently loaded into CARIS. Detailed POSPac processing logs are included in *Separate I Acquisition and Processing Logs* of the Descriptive Report.

This post-processed solution included new position, heading and attitude measurements which used reference station observables to mitigate atmospheric and satellite biases and to resolve integer ambiguities. The software also used a forward and backward smoother to blend the inertial position and sensor data into a smoothed best estimate trajectory (SBET).

POSPac processing followed the workflow recommended by Applanix. RINEX files were loaded from the appropriate reference stations for the day being processed. The only deviation from standard procedures was the use of the NAD83 coordinate system which is required by NOS *Hydrographic Surveys Specifications and Deliverables* (April 2009). Since POSPac only works with real-time sensor navigation using the WGS-84 coordinate system the software's default settings for WGS-84 real-time input and post-processed output were used even though the real-time input navigation was relative to NAD83. NAD83 coordinates of the GPS reference stations were used even though the software assumed the coordinates were relative to WGS-84. This processing configuration resulted in a post-processed navigation solution (SBET file) relative to NAD83 without the need of a transformation. A POSPac station database file with the NAD83 project coordinates for each CORS was created and distributed to all processing computers in order to remove the need to manually enter the coordinates during each processing session.

After the post-processed solution was created it was reviewed to insure that the optimum solution was achieved. Processing review included graphical review of the vessel track while color coded by position Root Mean Square (RMS) and the creation of a NAV-DIFF graph which showed the difference between the real-time and post-processed solutions in the X, Y, and Z coordinates. POSPac processing logs were kept for each survey sheet. The logs were used to record POSPac project information, vessel and base station used, and major processing steps. These logs have been included in *Separate I Acquisition and Processing Logs* of the Descriptive Report.

B5.   Final Bathymetric Processing

Upon completion of editing multibeam data in HIPS, finalized CUBE grids were generated using the "greater of the two" option for the final uncertainty value. Depths and contours were generated from the surfaces and used for chart comparison purposes, but are not included with the deliverables. Finalized surfaces were reviewed in the HIPS 3D graphics window with sufficient vertical exaggeration to verify that all fliers have been removed from the surfaces. Bathymetric Attributed Grids (BAGs) for each CUBE surface were exported from HIPS for submittal.

Designated soundings were used as a starting point for S-57 feature creation. Designated soundings that were determined to be obstructions, rocks, wrecks, or other significant features were imported into the S-57 feature files and attributed. The feature file also includes bottom samples (SBDARE) and required meta-objects (M_COVR and M_QUAL). All feature's mandatory attributes have been populated. In addition, the INFORM and TXTDSC fields of some features have been used to supply supplemental information.

C. CORRECTIONS TO ECHO SOUNDINGS

C1.   Static Draft

Static draft marks were surveyed and painted on the R/Vs Pacific Storm multibeam pole mount. A fixed bracket was mounted to the port and starboard sides of the R/V Pacific Storm and surveyed as a point of reference for draft measurements. Port and starboard draft readings were averaged to obtain the multibeam draft in relation to the center of the vessel.

Draft was observed during in-port periods before and after any major loadout changes (fueling, taking on potable water, grey water pumping, etc.). Measurements from the installed port and starboard brackets to the water surface were take with a metric tape. The port and starboard draft was averaged to obtain the draft at the vessel reference point. Linear interpolation at daily intervals was used to determine draft from settlement for days in between the weekly draft readings. These values were entered daily into the waterline field of the Caris HVF.

As discussed in Section B2.b static draft (HIPS Waterline) was applied during computation of GPS Tides in order to properly apply sound speed corrections, but the static draft measurements were backed out of the sounding reduction computation during the HIPS merge process.

C2.   Dynamic Draft

Dynamic draft values for the *R/V Pacific Storm* were calculated through the use of inertial-aided post-processed Kinematic (PPK) GPS observations utilizing a virtual base from a network of continuously operating reference stations.

A settlement and squat test for the *R/V Pacific Storm* using post-processed GPS height observations was performed in Yaquina Bay, Newport, OR on August 6, 2009 (DN218). Data from these measurements are displayed in Figure 3 and are also included in *Appendix V Supplemental Survey Records and Correspondence* of the Descriptive Report.

The settlement and squat values were obtained by computing an average of GPS height values at different ship speeds, measured in knots and revolutions per minute (RPM). Transects were run twice at each RPM interval along opposing headings.Vessel speeds in increments of 200 RPMs were observed from 500 to 1700 RPM. With the vessel at rest, static GPS height observations were recorded between each RPM interval in order to obtain a baseline GPS height value not affected by tide changes during the test. These values were linearly interpolated to determine the baseline GPS height at the time of the dynamic draft measurement. The difference between the GPS height while the vessel was in motion and the interpolated static GPS height was used to calculate the dynamic draft for each transect. An average dynamic draft corrector was then calculated from the average of the two values for each RPM interval. The average speed for each RPM interval and the average dynamic draft corrector were entered into the HIPS vessel file. Uncertainty estimates for dynamic draft were calculated by taking the average of the standard deviation for all dynamic draft calculations per transect.
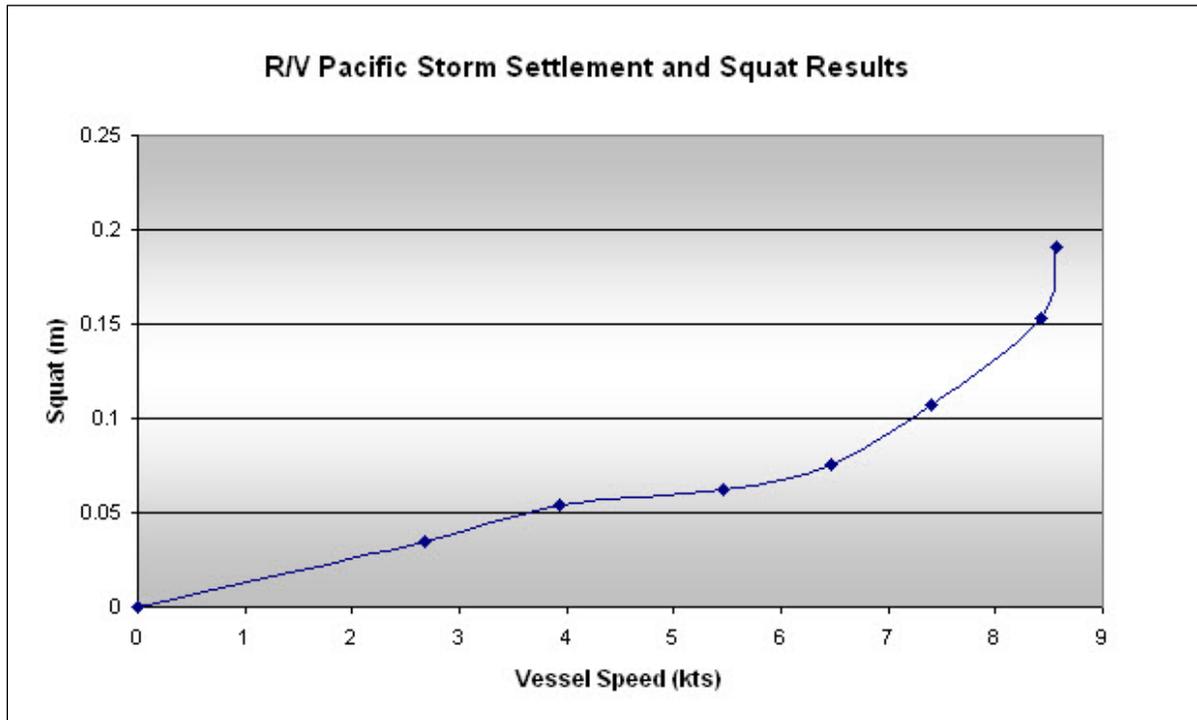
Figure 3. *R/V Pacific Storm* **settlement and squat results**

Dynamic draft values for *R/V Pacific Storm* are presented in Table 10.

Table 10. Vessel Settlement and Squat Results

R/V Pacific Storm	
Speed (kts)	**Squat (m)**
0.00	0.000
2.67	0.035
3.94	0.054
5.47	0.062
6.46	0.076
7.40	0.107
8.42	0.153
8.57	0.191

As discussed in Section B2.b, dynamic draft was applied during computation of GPS Tides in order to properly apply sound speed corrections, but the dynamic measurements were backed out of the sounding reduction computation during the HIPS merge process.

C3.   Leadline / Multibeam Comparisons

Leadline checks were performed against the multibeam echosounder when in port to confirm that the system was functioning properly. The leadline was lowered to the natural bottom adjacent to the multibeam sonar. The depth of the leadline was compared to the depth reported by the sonar and recorded in a comparison log. Table 11 below details the average difference, standard deviation and maximum deviations.

Table 11. Leadline to Multibeam Comparison Summary

	Value in Meters
Average Difference	0.004
Standard Deviation	0.013
Maximum Deviation	0.030

Tabulated leadline to multibeam comparisons may be found in the bar check logs included in *Separate I Acquisition and Processing Logs* of the Descriptive Reports.

C4.   Heave, Roll , Pitch, and Navigation Corrections

An Applanix POS/MV 320 version 4 was used for the motion sensor for this survey. The POS/MV 320 is a six-degree of freedom motion unit, with a stated accuracy of 0.05-meter or 5% for heave, 0.01° for roll, pitch, and heading. Real-time displays of the vessel motion accuracy were monitored throughout the survey with the POS/MV controller program. If any of the vessel motion accuracy degraded to greater than 0.05° RMS, survey operations would be suspended until the inertial unit was able to regain the higher degree of accuracy. Manufacturer reported accuracies as published on the Caris website (http://www.caris.com/tpe/) were entered into the HVF and used for TPU computations.

As previously discussed, attitude, height and heading were reapplied after post-processing navigation and inertial sensor data in POSPac. SBET files were applied in HIPS with the Load Attitude/Navigation data tool.

Installation bias and patch test results were computed at the start of the survey. Additionally, patch tests were performed throughout the survey to monitor known values and account for changes due to sensor replacements. All values were stored in the Caris HVF files.

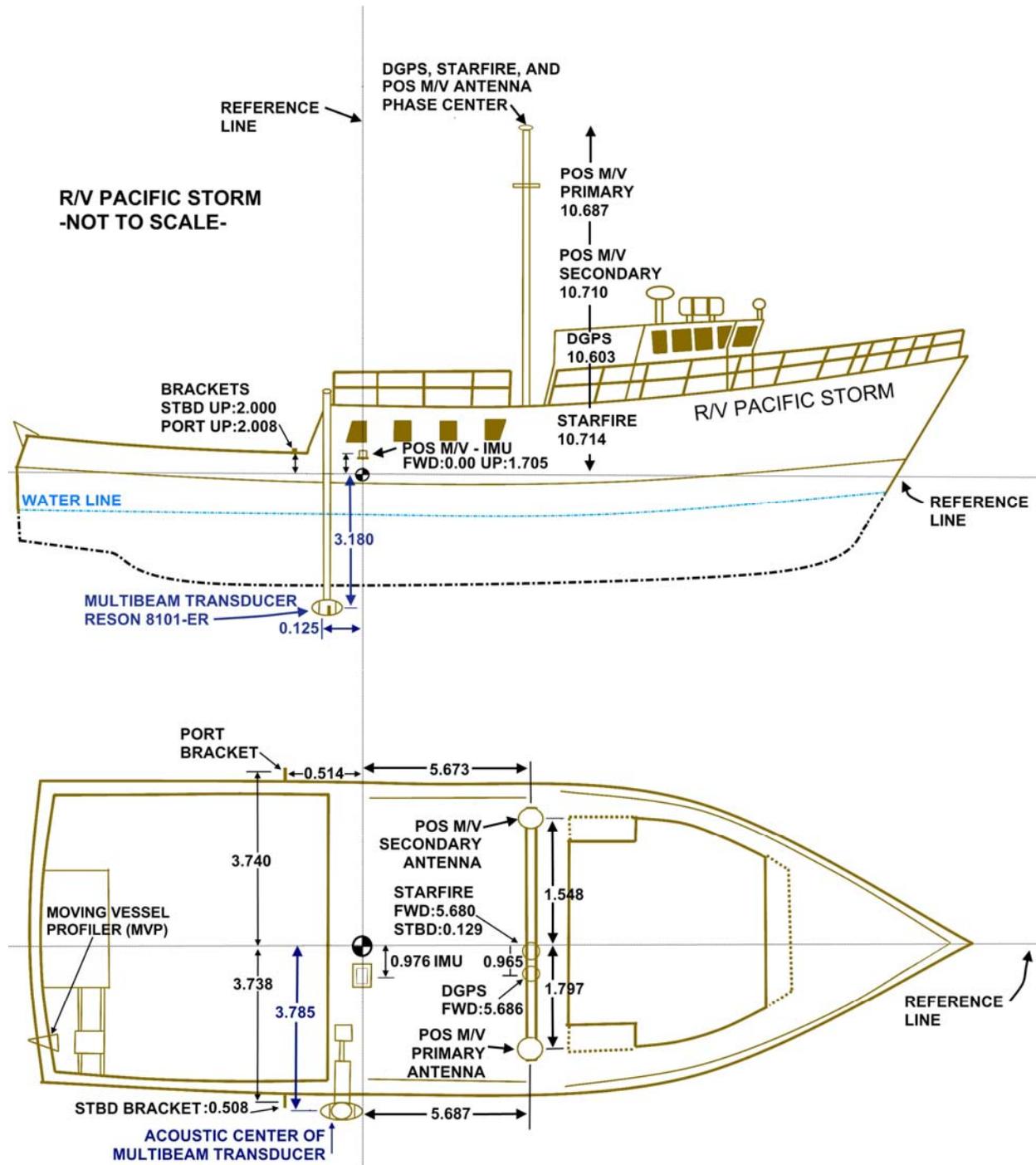A schematic of the vessel and sensor set-up is shown in Figure 4.

Figure 4. Schematic of R/V Pacific Storm and sensor setup (Not to Scale)

C5.   Patch Tests

Multibeam patch tests were conducted for the R/V Pacific Storm to measure alignment offsets between the IMU sensor and the multibeam transducer and to verify delay times applied to the time-tagged sensor data. Patch tests were performed at the beginning of the project, before and after raising the sonar, subsequent to any impact of the sonar or sonar pole, and periodically throughout the survey. Each patch test consisted of a series of lines run in a specific pattern, which were then used in pairs to analyze roll, pitch, and heading alignment bias angles.

Due to the tight time synchronization of the multibeam and the POS/MV, very little timing latency was expected. The initial patch test showed that no discernable timing latency was present. Latency was checked in following patch tests by evaluating the residuals from wave-induced vessel roll and pitch over a flat or smoothly sloping bottom. Offsets in pitch were determined by running reciprocal lines over an identifiable feature on the seafloor. Offsets in roll were determined by evaluating reciprocal lines over a flat or smoothly sloping bottom. Offsets in yaw were determined by evaluating two lines of reciprocal headings, each over a seafloor feature but offset from one another by less than the total swath width. All lines were run at approximately 4 to 6 knots. With the exception of the initial patch test, patch tests were run in the local survey area.

Selected pairs of lines were analyzed in HIPS Calibration editor to measure the angular sensor bias values. The analyst's measurements of each sensor bias were independently verified by a different qualified hydrographer. Results are reported in Table 12.

Table 12. *R/V Pacific Storm* Offsets and Biases

DN	Latency (s)	Pitch (°)	Yaw (°)	Roll (°)	X (m)	Y (m)	Z (m)	Comments
206	0.000	-2.113	-1.319	0.326	3.785	-0.125	3.180	Initial Patch Test
222	0.000	-0.915	-2.315	0.560	3.785	-0.125	3.180	
222	0.000	-1.980	-2.050	0.578	3.785	-0.125	3.180	
223	0.000	-1.613	-1.788	0.574	3.785	-0.125	3.180	
224	0.000	-1.750	-1.750	0.600	3.785	-0.125	3.180	
226	0.000	-1.436	-1.540	0.576	3.785	-0.125	3.180	End Acquisition

C6.   Tide and Water Level Corrections

The application of SBET navigation positioned soundings vertically on the NAD83 (CORS96) ellipsoid. VDatum version 2.24 and the region file Oregon – Central Oregon (version 01) was used to build the separation model used to reduce soundings from NAD83 to MLLW in CARIS. To generate the model file, a three-second grid with zero elevations at all nodes was created which encompassed the entire survey area. VDatum was used to compute NAD83 elevations relative to MLLW of all nodes in the grid file. GEOID03 was selected during the VDatum

transformation. The output was then converted to the same format as geoid grid models generated by the NGS, which can be used by Hypack and Caris HIPS to convert ellipsoid heights directly to a mapping datum. In order to provide a check to the grid values, at a select point the MLLW to NAD83 separation was independently computed by using VDatum to transfer from MLLW to NAVD88, and then Corpscon to transfer from NAVD88 to NAD83. The resulting elevations compared to the original grid points within 0.0004m. The model file, *SOrgGRS.bin*, has been included with the survey's digital deliverables.

As a confidence check on the GPS tide computation, GPS tide readings were recording for one hour while at berth in Newport, Oregon, near to CO-OPS tide gauge at South Beach, Oregon (943-5380). GPS measurements were processed using techniques identical to processing for all collected survey data, and then compared to verified tide data. The resulting GPS-derived water level differed by an average of 0.016m with a standard deviation of 0.012m over the one hour period.

C7.   Sound Velocity Correction

While underway during data acquisition the MVP-30 was deployed as needed to obtain an adequate number of sound velocity profiles to properly correct the multibeam data during data processing. To capture the high degree of sound velocity variability on the Oregon coast, casts were usually taken at 10-minute intervals. The location of casts along the survey tracklines were varied to ensure adequate spatial coverage. If significant cast-to-cast variability was observed, the casting interval was reduced. All casts extended to at least 80% of water depth, with at least one deep cast (extending to 95% of depth) taken per day.

In addition to these periodic comparisons, weekly check casts were taken to verify proper performance of the MVP 30. For this check, a SeaBird Instruments SBE 19 – CTD profiler was deployed in tandem with the MVP. Corrections for the speed of sound through the water column were computed for each sensor. Sound speed profiles were imported and overlaid for comparison into an Excel file. Data were binned into half meter bins to allow direct comparison between the MVP and CTD. The average difference and standard deviation were computed for each profile. The maximum average difference was 0.35 meters per second and the maximum standard deviation was 0.58 meters per second. Each sensor had been calibrated prior to the start and at the end of the survey. Factory calibration results are included in Separate II Sound Speed of the Descriptive Report.

The sound speed correction was applied to each line using the nearest in distance within "time (two hours)" option in the HIPS SVP correct routine. All casts were concatenated into a daily HIPS SVP file for each survey day. Daily HIPS SVP files were concatenated into a sheet wide file. Time, position, and sound speed for each profile were included in the HIPS file.

D. LETTER OF APPROVAL

LETTER OF APPROVAL

M-M928-KR-09
DATA ACQUISITION AND PROCESSING REPORT

This report and the accompanying data are respectfully submitted.

Field operations contributing to the accomplishment of M-M928-KR-09 were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and associated data have been closely reviewed and are considered complete and adequate as per the M-M928-KR-09 *Statement of Work* dated June 2009, and *Project Instructions* received on August 20, 2009.

_____
Jonathan L. Dasler, PE (OR), PLS (OR,CA)
ACSM/THSOA Certified Hydrographer
Chief of Party

_____
Jason Creech
Lead Hydrographer

David Evans and Associates, Inc.
September 2009