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

Data Acquisition & Processing Report

Type of Survey *Side-Scan Sonar, Singlebeam Sonar and Interferometric Sonar*

Project No. *S-J977-KR-SAIC*

Time Frame: *09 January 2007 – 02 June 2007*

LOCALITY

State *Louisiana*

General Locality *Lake Borgne*

2007

CHIEF OF PARTY

Paul L. Donaldson
Science Applications International Corporation

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DATE____________________

NOAA FORM 77-28 (11-72)

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

HYDROGRAPHIC TITLE SHEET

REGISTRY NO.

H11612
H11613
H11614
H11615

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**. A, B, C, D**

State: Louisiana

General Locality: Lake Borgne

Sublocality: *North, East, South and West*

Scale: 1:20,000 Date of Survey 09 January 2007 - 02 June 2007

Instructions Dated: October 18, 2006 Project No. S-J977-KR-SAIC

Vessel *M/V Thomas R Dowell AL1534AH* and *F/V Lacey Marie LA6708FC*

Chief of Party: Paul L. Donaldson

Surveyed by: *Brian Biggert, Louie Cust, Gary Davis, Kevin Davis, Rick Davis, Travis Daniel, Paul Donaldson, Fred George, Sean Halpin, Karen Hart, Chuck Holloway, Jason Infantino, Fred Jordon, John Kiernan, Meme Lobecker, Rick Nadeau, Chris Pinero, Gary Parker, Evan Robertson, Jeremy Shambaugh, Deb Smith, Mike Tappia and Justin West*

Soundings taken by **echo sounder**, hand lead, pole: Odom Echotrac CV, GeoAcoustics GeoSwath Plus

Graphic record scaled by

Graphic record checked by Automated plot

Verification by

Soundings in fathoms, feet**, meters** at MLW, **MLLW**

REMARKS: **Contract**: DG133C-05-CQ-1088
Contractor: Science Applications International Corp., 221 Third Street; Newport, RI 02840 USA
Subcontractors: Williamson & Associates, 1124 NW 53rd Street, Seattle WA 98107; Rotator Staffing Services, PO Box 366, 557 Cranbury Rd, E. Brunswick NJ 08816; Lowe Engineers, 2000 River Edge Parkway, Suite 400, Atlanta, GA 30328; John Oswald & Associates, LLC. 2000 E. Dowling Rd, Suite 10, Anchorage, AK 99507.
Times: All times are recorded in UTC
Purpose: To provide NOAA with accurate hydrographic survey data suitable for item detection and debris mapping in the assigned areas: Sheets A (H11612), B (H11613), C (H11614) and D (H11615) in Lake Borgne, Louisiana.

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ACRONYMS

Acronym	Definition
ASCII	**A**merican **S**tandard **C**ode for **I**nformation **I**nterchange
CMG	**C**ourse **M**ade **G**ood
CTD	**C**onductivity, **T**emperature, **D**epth profiler
CUBE	**C**ombined **U**ncertainty and **B**athymetric **E**stimator
DGPS	**D**ifferential **G**lobal **P**ositioning **S**ystem
DPC	**D**ata **P**rocessing **C**enter
DR	**D**escriptive **R**eport
EPF	**E**rror **P**arameters **F**ile
GPS	**G**lobal **P**ositioning **S**ystem
GSF	**G**eneric **S**ensor **F**ormat
GS+	**G**eo**S**wath **Plus**
GUI	**G**raphical **U**ser **I**nterface
IMU	**I**nertial **M**easurement **U**nit
ISO	**I**nternational **O**rganization for **S**tandardization
ISS-2000	**I**ntegrated **S**urvey **S**oftware 2000
ISSC	**I**ntegrated **S**urvey **S**ystem **C**omputer
JD	**J**ulian **D**ay
KW	**K**ilo**w**att
MVE	**M**ulti-**V**iew **E**ditor
MVP	**M**oving **V**essel **P**rofiler
NAS	**N**etwork **A**ttached **S**torage
NMEA	**N**ational **M**arine **E**lectronics **A**ssociation
NOAA	**N**ational **O**ceanic and **A**tmospheric **A**dministration
PFM	**P**ure **F**ile **M**agic
POS/MV	**P**osition **O**rientation **S**ystem/**M**arine **V**essels
RDF	**R**aw **D**ata **F**ormat
SABER	**S**urvey **A**nalysis and area **B**ased **E**dito**R**
SAIC	**S**cience **A**pplications **I**nternational **C**orporation
SAT	**S**ea **A**cceptance **T**ests, or **S**wath **A**lignment **T**ool
SDF	**S**onar **D**ata **F**ormat
SSP	**S**ound **S**peed **P**rofile
SV&P	**S**ound **V**elocity and **P**ressure Sensor
SWP	**Sw**ath **A**mplitude
TPE	**T**otal **P**ropagated **E**rror
TPU	**T**ransceiver **P**rocessing **U**nit
UPS	**U**ninterruptible **P**ower **S**upply
XTF	e**X**tended **T**riton **F**ormat

A. EQUIPMENT

For the Lake Borgne, Louisiana debris mapping surveys, Science Applications International Corporation (SAIC) employed two survey vessels each with different data acquisition systems. The *M/V Thomas R. Dowell* used an Odom CV singlebeam sonar, Klein 3000 side-scan sonar, and a SBE 19-01 CTD for data collection. The *F/V Lacey Marie* used the GeoAcoustics GeoSwath Plus 250 kHz interferometric sonar and a SBE 19-01 CTD for data collection. Both vessels used a POS/MV 320 version 4 for vessel attitude and positioning. Further details about the vessels, acquisition systems and software, and processing software are provided in the sections below.

THE SURVEY VESSELS

The *M/V Thomas R. Dowell* (Figure A-1) and the *F/V Lacey Marie* (Figure A-2) were the vessels used for all survey operations. Vessel characteristics for both platforms are presented in Table A-1.

Table A-1. Survey Vessel Characteristics, *M/V Thomas R. Dowell* and *F/V Lacey Marie*

Vessel Name	LOA	Beam	Draft	Max Transit Speed	Max Survey Speed
M/V Thomas R. Dowell	32’	7’	2.5’	30 kts	9 kts
F/V Lacey Marie	41’	12’	2.5’	14 kts	7 kts

Figure A-1. *M/V Thomas R. Dowell*

Figure A-2. ***F/V Lacey Marie***

SINGLEBEAM SYSTEM AND OPERATIONS ON THE *M/V THOMAS R. DOWELL*

The Odom CV singlebeam sonar was installed on the *M/V Thomas R. Dowell*. SAIC's **ISS-2000** software provided navigation, system control and collected the singlebeam data in Generic Sensor Format (GSF).

Confidence checks of the singlebeam depths were made using a bar that was lowered to a known depth directly below the transducer. Depths displayed by the Odom controller and SAIC's **ISS-2000** system are verified and entered into a bar check log. The following procedure was established to make a bar check comparison:

1. Take and apply a CTD cast
2. Set the Odom draft to 0.0 in the ISS-2000.
3. Disable tide corrector
4. Set RPM to 0
5. Set the bar to 1 meter under the transducer.
6. Verify that the tide corrector in the MB Manager window is 0 and the depth corrector is 0.
7. Open the sbcdtc.exe Video32 display from the task bar
8. Open the ODOMCV DTC Display. Verify tide correct is 0, transducer offset is 0, and applied squat is 0.
9. In the Odom Controller window go to the calibrate tab and enter the bar depth.
10. Enter the time bar depth, depth in the video 32 display, ODOM CV DTC display, and the channel 1 depth in the Odom Controller.

11. In the MB Manager display select Display/Examine Data and look at the last depth values in the recorded file. Also verify tide and depth correctors in the file are 0.
12. Set the bar to 2 meters and repeat steps 9-11 changing the bar depth in the Odom controller calibrate window to 2.
13. Repeat at 1 meter intervals for as deep as possible.

Bar checks were taken approximately once per week during the survey.

SIDE-SCAN SONAR SYSTEMS AND OPERATIONS ON THE *M/V THOMAS R. DOWELL*

The side-scan system installed on the *M/V Thomas R. Dowell* included the following:

- Klein 3000 digital Side-Scan Sonar Towfish which was bow mounted
- Klein 3000 Windows XP computer for data collection and logging of side-scan sonar data with Klein **SonarPro** version 9.6 software
- Klein 3000 Transceiver Processing Unit (TPU)
- Uninterrupted power supplies (UPS) for protection of the computer system

The Klein 3000 is a conventional dual frequency side-scan towfish. At a range scale of 25 meters, a ping rate of 30 pings/second is set by the transceiver. With 30 pings/second and a maximum survey speed of 9 knots, a minimum of three pings per meter in the along-track distance was ensured, allowing for the detection of objects that measure 1.0 x 1.0 meters horizontally and 1.0 meter vertically (from shadow length measurements). During the survey operations on all sheets, a range scale of 25-meters was consistently used.

During survey operations, digital side-scan sonar data from the Klein 3000 TPU were sent directly to the Klein 3000 computer for display and logging by Klein **SonarPro** software. Raw digital sonar data from the Klein 3000 were collected in eXtended Triton Format (XTF) and maintained at full resolution, with no conversion or down sampling techniques applied. Side-scan data file names were changed automatically every hour and manually at the completion of a survey line. At the end of each survey day (i.e. Julian Day, JD) the raw XTF side-scan data files were backed up on USB hard drives.

Towfish positioning was provided by **ISS-2000** through a program module called "rtcatnry." This program used the offsets of the bow mounted side-scan sonar from the POS/MV IMU and the vessel heading to compute the side-scan positioning in a catenary format file.

Due to the towfish being hull mounted and the extremely shallow waters the surveys were conducted in, the towfish altitude was rarely between the recommended 8% and 20% of the range (2-5m for 25m range).

GEOSWATH PLUS SYSTEM AND OPERATION

The GeoAcoustics GeoSwath Plus (250 kHz) interferometric sonar was installed on the *F/V Lacey Marie*. GeoAcoustics **GeoSwath Plus** (**GS+)** software, on a Windows XP machine, acquired the interferometric data (both bathymetry and imagery) in a single proprietary Raw Data File (RDF) format file. The system was operated at a 25-meter range scale for 100% side-scan bottom coverage. Vessel speed was controlled so that there were more than three pings per meter along track for object detection. The bathymetry was used for least depths. While the full swath data provided full bottom coverage for imagery, there were areas where the full swath bathymetry data were not used in the final Bathymetric Attributed Grids (BAGs) as a result of the total propagated error on the outer swath exceeding IHO Order 1 maximum allowed errors. This occurred for data collected from JD 124 (04 May 2007) through JD 132 (12 May 2007) when the Velport SSV was not functioning and the Seabird CTD data were used for surface sound velocity.

Confidence checks of the interferometric depths were made using a bar that was lowered to a known depth directly below the transducer. Depths displayed by the GeoAcoustics system were verified and entered into a bar check log. The following procedure was established to make a bar check:

1. Take a draft. Apply the draft (negative value) in **GS+** under Vessel Settings.
2. Take a CTD cast. Apply the CTD in **GS+**
3. Load a “zero” tide file in **GS+**.
4. Create a Raw Data File in the **GS+** project. Make this the active.
5. Two people will lower the bar over one side of the vessel and carefully position the bar underneath the transducer.
6. Once the bar is underneath the transducer, position it so that the yellow tape marks on the chains are at the water’s surface. The yellow tape marks indicate the 2m mark.
7. After the bar is in position, start recording.
8. The **GS+** operator will confirm that the echo sounder reading in the Status section of **GS+** (lower left) is about 2 meters.
9. Enter the echo sounder reading into the spreadsheet.

Bar checks were taken approximately once per week during the survey.

DATA ACQUISITION AND PROCESSING SOFTWARE

Navigation data acquisition and survey control for both vessels was carried out using the SAIC **ISS-2000** software on a Windows XP computer. **ISS-2000** was also used on the *M/V Thomas R. Dowell* to acquire singlebeam sonar data. **ISS-2000** version 3.11.3 was the software version used on the *M/V Thomas R. Dowell* until JD 076 (17 March 2007) when 3.11.4 was installed. **ISS-2000** version 3.11.4 was the software version used for the duration of the survey on the *F/V Lacey Marie*.

Klein's **SonarPro** version 9.6, running on a Windows 2000 platform, was used for Klein side-scan data acquisition on the *M/V Thomas R. Dowell* for the entire survey.

GeoAcoustics' **GeoSwath Plus** version 3.15a, running on a Windows XP computer, was used for GeoSwath Plus interferometric sonar data acquisition on the *F/V Lacey Marie* for the entire survey.

Survey planning, data processing and analysis were carried out using the SAIC **Survey Planning** and **SABER** software packages on LINUX operating systems. SABER version 4.1.2 was used from the beginning of the survey until JD 039 (08 February 2007), when version 4.1.5 was installed. On JD 065 (06 March 2007) SABER version 4.1.6 was installed and used until JD 101 (11 April 2007) when SABER version 4.1.9 was installed. On JD 155 (04 June 2007) SABER version 4.1.12 was installed and used until JD 288 (15 October 2007) when SABER version 4.1.16 was installed.

GeoAcoustics' **GeoSwath Plus** version 3.15a, running on a Windows XP computer, was used for initial processing of GeoSwath Plus interferometric sonar data.

Isis version 6.06, running on Windows XP, was used for side-scan data quality review, and contact identification.

B. QUALITY CONTROL

A systematic approach to tracking data has been developed to maintain data quality and integrity. Several forms and checklists identify and track the flow of data as it is collected and processed. These forms are presented in the Separates section included with the data for each survey.

During data collection, the watch standers continuously monitor the systems, checking for errors and alarms. Thresholds set in the **ISS-2000** system alert the watch stander by displaying alarm messages when error thresholds or tolerances are exceeded. These alarms, displayed as they occur, are reviewed and acknowledged on a case-by-case basis. Alarm conditions that may compromise survey data quality are corrected and then noted in both the navigation log and the message files. Warning messages such as the temporary loss of differential GPS, excessive cross track error, or vessel speed approaching the maximum allowable survey speed are addressed by the watch stander and automatically recorded into a message file. Approximately every 1-2 hours the real-time watch standers complete checklists to ensure critical system settings and data collection are valid.

Following data collection, initial processing was performed in the field data center at Shell Beach, LA. This included the first level of quality assurance:

- Initial swath editing of singlebeam data flagging invalid beams
- Filtering of GeoSwath Plus bathymetry data and conversion to Generic Sensor Format (GSF)

- Conversion of GeoSwath Plus imagery data to intermediate file format and further conversion to extended triton format (XTF)
- Identification of items for investigation
- Turning unacceptable data “offline”
- Turning additional data “online”
- Identification and flagging of obstructions and wrecks
- Track plots
- Preliminary bathymetry coverage grids
- Crossline checks
- Generation of preliminary side-scan coverage mosaics

On a daily basis the data were binned to average depth layers. The following binned grids were created and used for crossline analysis. Results of this analysis were reviewed to determine adequacy of data and sounding correctors.

- Main scheme, item, and holiday fill survey lines
- Crosslines

Approximately once a week, a complete backup of all raw and processed bathymetry data and side-scan data were sent to the Newport, RI Data Processing Center. Analysis of the data at the Newport facility includes the following steps:

- Generation of bathymetry and side-scan track line plots
- Generation of side-scan Contact Files and Contact Plot
- Calculation and application of verified tide correctors to bathymetry data
- Application of delayed heave to the singlebeam data
- Application of settlement / squat correctors to the GeoSwath bathymetry data
- Calculation of Total Propagated Errors on the GeoSwath bathymetry data
- Generation of PFM CUBE surface(s) of the GeoSwath bathymetry data
- Set designated soundings on wrecks and obstructions
- Convert PFM(s) to BAG(s)
- Generate S-57 Feature File
- Coverage plots of bathymetry data
- Crossline analysis of bathymetry data
- Comparison with existing charts
- Quality control reviews of side-scan data and contacts
- Final coverage mosaic plots of side-scan sonar data
- Correlation of side-scan contacts with bathymetry data
- Final quality control of all delivered data products

Processing and quality control procedures for bathymetry and side-scan data acquisition are described in detail in the following pages.

ODOM CV DATA PROCESSING

Odom singlebeam files were collected in Generic Sensor Format (GSF) within the **ISS-2000** software with predicted tides, sound speed profile (SSP) data, attitude data and draft applied in real-time. Singlebeam data were then processed within **SABER**. Data were transferred from the survey vessel to the field processing center at Shell Beach, LA via a USB hard drive on a daily basis. File lists were made, track lines created, and tracks reviewed for appropriate on-line and off-line flags as well as any navigation errors. Files were then reviewed using **SABER's Multi-view Editor** for fliers and navigational errors. After corrections were made for delayed heave and verified tides, the singlebeam data were gridded into 5-meter binned minimum grids. Selected soundings were generated (at chart scale) from the 5-meter minimum grids and these selected soundings were included in the S-57 Feature File for each sheet. The minimum grid was also exported as an XYZ file.

GEOSWATH PLUS DATA PROCESSING

The GeoSwath interferometric system recorded the bathymetry and imagery data into a proprietary Raw Data File (RDF) format. This data format contains the rawest measurements of the interferometric system including travel time, return angle and amplitude, all navigation and attitude data, and all surface sound speed data. All information required for ray-tracing and application of correctors are contained within this single file.

The data were transferred from the survey vessel daily via USB hard drive for initial processing, data conversion and quality control at the field processing center in Shell Beach, LA. The RDF file contains both the bathymetry and imagery data in a single file. For the data processing pipeline used by SAIC, the bathymetry data were exported into a separate file from the imagery data. The final data format for the bathymetry data were Generic Sensor Format (GSF) and the final data format for the imagery data were in eXtended Triton Format (XTF). Data conversion to GSF and XTF format was done through the **GeoSwath Plus** version 3.15a software. The GeoSwath bathymetry processing is discussed in more detail in the section below. See the Side-Scan Sonar Data Processing section for further discussions of the GeoSwath Plus imagery processing.

GEOSWATH PLUS BATHYMETRY DATA PROCESSING

Using GeoAcoustics **GS+** version 3.15a software, the GeoSwath Plus bathymetry data were converted from RDF files to another proprietary intermediate file format - CUBE File (CBF). During the conversion process filters were applied to the raw data to reduce the amount of noise in the data as a result of outliers within the data. The **GS+** software has several filter options available. The filters used for the generation of the CBF data files included an amplitude filter which flagged data based on set ranges of the minimum and maximum amplitude values within the RDF file. The range of amplitude which was flagged included data which was less than 1% and greater than 94% of the return amplitude value. A limit filter was also used which limits the extents of data values. This filter was set such that range values greater than the acquisition range (25m) would be flagged. The minimum and maximum depth range limits varied based on depth variation within the data but were generally set so only gross outliers would be flagged. An examples of a depth limit filter used was to set a maximum value of 2 meters deeper than the water depth and a minimum value of 0.5 meters. An across track learning filter was the last filter method used during the generation of the CBF file. This filter was set 30 cm above and below the bottom depth with a vertices approximately every 1.5 meters of across track distance and a learn rate of 75%. This filter would use the data values which fall within the adjacent bins created by the across track vertices to aid in determining the depth value of data contained within bins. The 75% learn rate weighted the values of the current bin to be higher than the values contained within the adjacent bins which were used for comparison.

Many different filter configurations were tested and evaluated. The aggressive settings noted above were determined to be the best for this data set. This was due to excessive noise seen in much of the data. The increased noise was a result of the shallow waters, soft bottom and reduced transmit power. When collecting both imagery and bathymetry from a single system the user must balance the settings during acquisition to optimize both imagery and bathymetry. The priority of this survey was placed on imagery quality as it was a debris mapping survey with target detection occurring primarily from the imagery data. Therefore the transmit power was reduced slightly to reduce the over saturation of imagery return values. If an object was identified during the review of the imagery data that was clipped by a filter, the depth data were restored. In addition to filters, a zero sound speed profile, vessel draft, and a zero tide value were applied while converting the data from RDF to CBF. Tide correctors were set to zero as verified tides were applied within the **SABER** software. However, in the event a SSP had to be reapplied to the data it was necessary to start with the RDF file and repeat all steps.

The CBF files were then converted to Generic Sensor Format files using SAIC's **SABER** software. All further processing of the files occurred with SAIC's **SABER** software. As the raw data were collected within the **GS+** software, which does not flag data based on online and offline status, it was necessary to create time windows to apply to the GSF files. This was accomplished by reading the message files created by **ISS-2000** for the start and end of line times. This information was then used to create a time window file which was applied to the GSF data file to flag data offline prior to the start of lines and after the end of lines. Track lines of the GSF files were then created and reviewed to confirm data were flagged on and off appropriately. After corrections were made for settlement and squat and verified tides, the **SABER Errors** program was run to calculate the Total Propagated Error for each sounding. Once error attribution was complete, CUBEd PFM grids were generated and the data were reviewed and appropriate edits to the data were made. After all edits and corrections to the CUBEd PFM grids were complete, the grids were exported to Bathymetric Attributed Grids (BAGs).

While the results of each survey are discussed in the Descriptive Reports, the GeoSwath interferometric sonar has noisier bathymetry data (compared to traditional multibeam sonars), but since the GeoSwath has large data densities, this sonar did provide a good estimate of the true seafloor when used with a "best estimate" of the seafloor data product (i.e. CUBE and BAG).

Survey System Error Model (*F/V Lacey Marie*)

The Total Propagated Error (TPE) model that SAIC has adopted had its genesis at the Naval Oceanographic Office (NAVOCEANO), and is based on years of work by Rob Hare and others. The fidelity of any error model is coupled to the applicability of the equations that are used to estimate each of the components that contribute to the overall error that is inherent in each sounding. SAIC's approach to quantifying the TPE is to decompose the cumulative errors into their individual components and then compute their effects on the horizontal and vertical error components. The model then combines the horizontal and vertical error components to yield an estimate of the system error as a whole. This cumulative system error is the Total Propagated Error (TPE). By using this approach, SAIC can more easily incorporate future error information provided by sensor manufacturers into the model. This also allows SAIC to continuously improve the fidelity of the model as our understanding of the sensors increases or as more sophisticated sensors are added to a system. For the Lake Borgne surveys, SAIC added an error model for the GeoAcoustics GeoSwath Plus 250 kHz interferometric sonar.

In the conventional "beamforming" sonar systems, many of the error terms are functions that combine the geometric and acoustic properties, of the particular scenario, that were in effect at the time the soundings were made. The GeoSwath Plus sonar system is somewhat different in that it is an interferometric sonar as opposed to a beamforming sonar. This means that instead of creating several narrow athwartship beams, and looking for arrivals within each beam to decide where the seafloor is located, the acoustic time-series samples from one receiver are compared to acoustic time-series samples from a neighboring receiver, and the time delay is converted to an angle. From the time delay and angle, the seafloor depth is determined.

The uncertainties associated with these two measurements can be independently defined and incorporated into the same TPE model as is used for conventional beamforming multibeam sonars. In both sonar cases, there is an uncertainty in the arrival angle and arrival time, which is converted to a range, by multiplying by a sound speed, and expressing the result as a range in meters. These uncertainties are referred to as "dTheta" and "dR", respectively. With guidance from GeoAcoustics, Inc., the manufacturer of the GeoSwath sonar, SAIC have explicitly declared "dTheta" to be 0.02 degrees and "dR" to be 0.04 meters (the approximate pulse length). These values were inserted into the TPE model and the resulting horizontal and vertical error curves, in the athwartship direction, were comparable to conventional multibeam sonar curves. The curves show that in the GeoSwath data most of the sonar related errors the inner part of the swath, are driven by the uncertainty in the range, "dR", and most of the uncertainty in the outermost part of the swath is driven by the uncertainty in angle, "dTheta". In between these two regimes the transition is fairly smooth. These curves do not necessarily represent the sonar specific errors as measured in the field, however. Field measurements completed by GeoAcoustics indicated that the near nadir error and those errors at the outer part of the swath were underestimated when using the traditional error model. Additional tests, completed by SAIC, using Accutest data, also indicated some divergence from the modeled TPE values with field data, collected at the Lake Borgne survey site.

Therefore, an alternate approach was taken to more accurately predict the error over the entire swath. One way to do this was to correlate the footprint area, of the ensonified portion of the seafloor, into the model. When this was done, the error values at both extremes of the swath were accentuated, while the mid-portion of the swath remained only moderately higher. The overall results tended to more closely agree with the field data.

The footprint related TPE approach was implemented by estimating the area of ensonfication as defined by the athwartship distance of a 'beam" multiplied by its along-track distance, at the depth of the sounding, as projected onto a flat seafloor. The athwartship "beam" angle was then perturbed by "dTheta", and the slant range was similarly perturbed by "dR". The athwartship distance was then computed with and without perturbation. The difference between each perturbed and unperturbed distance was then found. Finally, the footprint was computed for each beam across the swath. The athwartship distance used in the footprint calculation was based on the larger of the two perturbed distances computed earlier for each beam. Thus, the errors in the near nadir regime were mainly driven by the differences in the projected distances due to "dR", while the errors at the outer part of the swath were mainly due to distance differences due to "dTheta". There is a transition point somewhere in the middle of the swath where the "dTheta" uncertainty factor overtakes the "dR" uncertainty. The along-track distance, based on the beamwidth, was then multiplied by the larger of the two athwartship distances to obtain the footprint area. This footprint area was then multiplied by the horizontal or vertical error, obtained from the model, yielding the final TPE values. Although the overall pattern of the footprint corrected TPE results agreed with the field measurements obtained by GeoAcoustics, the magnitude did not. So, a "Model Tuning Factor" (MTF) was used to adjust the amplitude of the TPE values to be more in line with the Accutest results. This MTF parameter is used as a multiplicative factor to raise or lower the footprint TPE any amount deemed appropriate. The MTF value was set to match the results of SAIC's field Accuracy Test (Accutest).

Accutest is a quality test performed during system Sea Acceptance Tests and at other times during a survey if deemed necessary. In this test, a cross pattern is surveyed multiple times over a flat bottom. A CUBE depth surface is generated of the multiple passes to provide a robust estimate of the seafloor. Then comparisons are made between each valid beam in the unedited, "full swath" bathymetry data files, to determine the magnitude of differences between the beam data and the reference surface. This tool is often used by SAIC to determine/verify appropriate cutoff angles. The Accutest results are presented in Figure B-1. As the reference surface was surveyed in a short duration and is a CUBE depth surface, the errors associated with tides, draft, etc. are minimized. This surface thus can be used to approximate the errors associated with the sonar only. SAIC used the Accutest results to provide a guide for developing the GeoSwath Total Propagated Error model. Note that due to filtering/editing the scatter of points that is seen at nadir is not represented in the Accutest results.

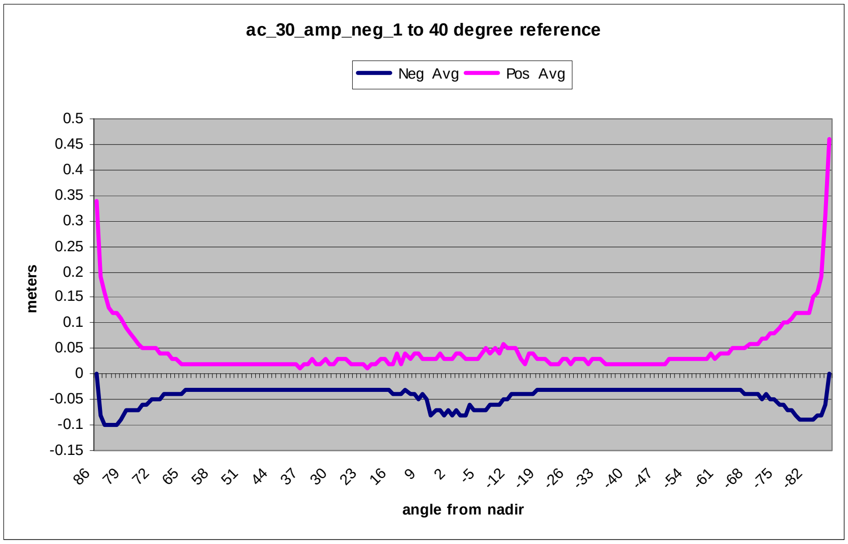

Figure B-1. GeoSwath Plus Accutest Results – Angle Versus Difference in Meters to Reference Surface.

Figure B-2 presents calculated errors for a single ping of Lake Borgne GeoSwath Plus data. The red data points represent just the sonar specific errors using a traditional error model with just fixed range and angle uncertainties. The inner and outer swath are underestimated and the overall shape of the vertical errors do not match the real uncertainties as demonstrated by the Accutest results. The green data points represent just the sonar specific errors calculated for the same ping with the fixed range and angle uncertainties and the additional footprint correction added to the model (with a Model Tuning Factor set to 10). The green points closer approximate the repeatability results of the Accutest. The blue data points in Figure B-2 represents the Total Vertical Error for the same ping (includes all error components and not just those that are sonar related).

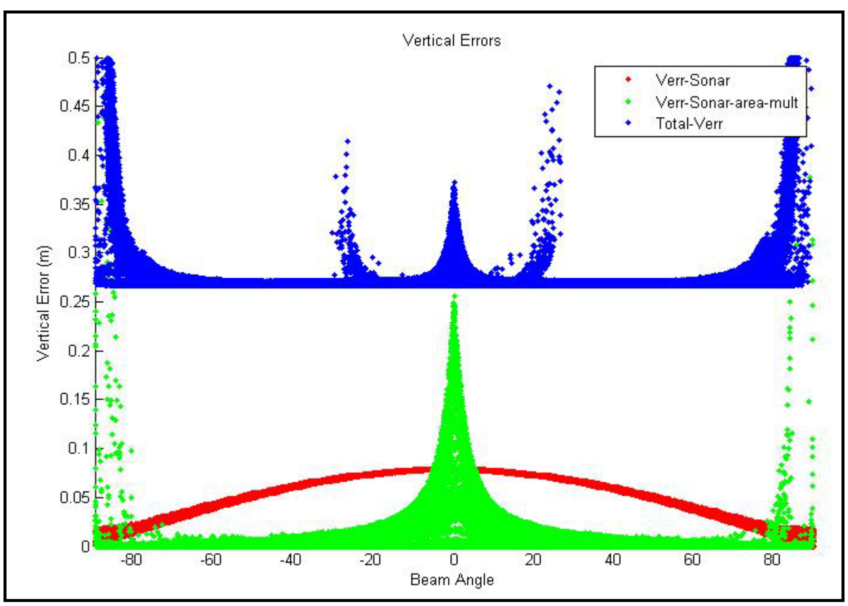

Figure B-2. GeoSwath Plus Error Model Results for a Single Ping.

The data needed to drive SAIC's error model (such as the Model Tuning Factor) are captured as parameters within the Error Parameters File (EPF), which is an ASCII text file typically created during survey system installation and integration. The parameters are also obtained from values recorded in the GSF file(s) during data collection and/or processing. While the input units vary, all error values that contribute to the cumulative TPE estimate are converted to meters by **SABER's Errors** program or have units of meters to begin with. The cumulative TPE estimates are separated into a horizontal and vertical component, and are recorded as the Horizontal Error and Vertical Error records for each sounding in the GSF file. These error values are at the two sigma or 95% confidence level. The intent is to use these error estimates to gauge the accuracy of each sounding's coordinates and depth.

Table B-1 and Table B-2 show the values entered in the Error Parameters File used for the Lake Borgne surveys. All parameter uncertainties in these files are entered at the one sigma level of confidence, but the outputs from **SABER's Errors** program are at the two sigma or 95% confidence level. Sign conventions are: X = positive forward, Y = positive starboard, Z = positive down.

The values presented in Table B-1 and Table B-2 were used for the duration of the survey with the exception of the Surface Sound Speed Error (SSSV_measurement_error). On Julian Day 124 (04 May 2007) at 15:25:05 UTC the surface sound speed sensor on the *F/V Lacey Marie* (25 mm stand off Velport SSV) was damaged. The SSSV_measurement_error used to calculate TPE for all soundings from the beginning of the survey until JD 124 at 15:25:05 was 0.20 meters. From JD 124 at 15:25:05 through JD 132 (12 May 2007) the **GS+** software used the surface sound speed data collected by the Seabird SBE-19 CTD to correct the interferometric data. The associated SSSV_measurement_error used during this time was 5.0 meters. On the evening of JD 132 (12 May 2007), a new Surface Sound Speed sensor was installed and used for the duration of the survey. The new SSP sensor was a 50 mm Velport sensor, however, and therefore a SSSV_measurement_error value of 0.12 was used from JD 133 (13 May 2007) until the end of the survey.

Table B-1. 2007 *F/V Lacey Marie* Error Parameters

Parameter	Value	Units
static_draft	1.20	Meters
draft_error (uncertainty)	0.02	Meters
squat_error (uncertainty)	0.02	Meters
fixed_heave_error_component (uncertainty)	0.05	Meters
perc_swellheave_err_component (uncertainty)	5.00	Percent
roll_measurement_error (uncertainty)	0.02	Degrees
pitch_measurement_error (uncertainty)	0.02	Degrees
heading_measurement_error (uncertainty)	0.02	Degrees
speed_measurement_error (uncertainty)	0.056583999999999995	meters/second (m/s)
SSSV_measurement_error (uncertainty)	0.20, 0.12 or 5.00*	meters/second (m/s)
predicted_tide_measurement_error (uncertainty)	0.18	Meters
observed_tide_measurement_error (uncertainty)	0.12	Meters
tide_zone_error (uncertainty)	0.10	Meters

Parameter	Value	Units
positioning_device_x_offset	-9.914	Meters
positioning_device_xoffset_err (uncertainty)	0.02	Meters
positioning_device_y_offset	-1.00	Meters
positioning_device_yoffset_err (uncertainty)	0.02	Meters
positioning_device_z_offset	-4.842	Meters
positioning_device_zoffset_err (uncertainty)	0.02	Meters
VRU_device_x_offset	-0.17	Meters
VRU_device_x_offset_error (uncertainty)	0.005	Meters
VRU_device_y_offset	0.09	Meters
VRU_device_y_offset_error (uncertainty)	0.005	Meters
VRU_device_z_offset	0.33	Meters
VRU_device_z_offset_error (uncertainty)	0.005	Meters
gps_latency	0.00	milliseconds (msec)
vru_latency	0.00	milliseconds (msec)
gps_latency_error (uncertainty)	1.00	milliseconds (msec)
vru_latency_error (uncertainty)	1.00	milliseconds (msec)
horizontal_navigation_error (uncertainty)	0.75	Meters
svp_measurement_error (uncertainty)	0.75	meters/second (m/s)

* See explanation regarding SSSV_measurement_error in previous paragraph.

Table B-2. SONAR Parameters GeoSwath Plus

Parameter	Value	Units
transducer_device_x_offset	0.00	Meters
transducer_device_xoffset_error (uncertainty)	0.02	Meters
transducer_device_y_offset	0.00	Meters
transducer_device_yoffset_error (uncertainty)	0.02	Meters
transducer_device_z_offset	0.00	Meters
transducer_device_zoffset_error (uncertainty)	0.02	Meters
roll_offset_error (uncertainty)	0.05	Degrees
pitch_offset_error (uncertainty)	0.05	Degrees
heading_offset_error (uncertainty)	0.05	Degrees
sounder_latency	0.00	milliseconds (msec)
sounder_latency_error (uncertainty)	1.00	milliseconds (msec)
model_tuning Factor	-10	Unitless
amplitude_phase_transition	1	Unitless
sounder_installation_angle	60	Degrees
sounder_fore_aft_beamwidth	1.00	Degrees
sounder_athwartship_beamwidth	0.02	Degrees
range_sampling_res	0.017	Meters
pulse_length	0.064	Meters

The fore/aft beamwidth used in calculation of the Total Propagated Errors was 1.0 degree. While the product specifications for the GeoAcoustics GeoSwath Plus 250 kHz system state that the system has a 0.5 degree fore/aft beamwidth, all correspondence with GeoAcoustics regarding error attribution used a 1.0 degree value. Tests run by SAIC using a 0.5 degree value in the error model show that horizontal errors were not impacted by this parameter change. The vertical errors did show a difference of up to 2 cm using a 0.5 degree fore/aft beamwidth compared to 1.0 degree beamwidth.

All soundings that have horizontal or vertical errors which are greater than the IHO Order 1 maximum allowed values are flagged as invalid by the **SABER Errors** program. Therefore all individual soundings that were applied to the Bathymetric Attributed Grids (BAGs) meet the horizontal position accuracy and vertical accuracy specified in the NOS Specifications and Deliverables. There are, however, areas where the BAG node uncertainties exceed the IHO Order 1 allowable values. These high uncertainty nodes often occur at the edge of a swath where there is no additional overlapping coverage from adjoining lines. Various tests were conducted to determine if there was an optimal swath cutoff angle to significantly reduce or eliminate nodes which exceed the specified uncertainty values. It was determined that by reducing the swath angle we were able to reduce the number of high uncertainty nodes, however, this required flagging an excessive amount of low uncertainty data as invalid in the process. Therefore it was decided to retain the full swath data for production of the Bathymetric Attributed Grids. A **SABER** process called "**Check PFM Uncertainty**" flags nodes which exceed specified uncertainty limits. The output of this process produces text files which list node positions, depth and uncertainty values for nodes which failed the specified uncertainty. These text files are included in Appendix V of each sheet's Descriptive Report.

SIDE-SCAN SONAR DATA PROCESSING

On the *M/V Thomas R. Dowell* side-scan data were collected with a Klein 3000 side-scan sonar. In real-time, the Klein 3000 digital data were recorded in XTF format on the hard disk of the Klein's **SonarPro** acquisition system. Side scan data files collected each day were backed up onto USB hard drives for transfer to the field Data Processing Center.

As stated above, on the *F/V Lacey Marie* a GeoAcoustics GeoSwath Plus interferometric sonar was used to collect side-scan imagery in RDF format. The side-scan imagery data were extracted from the RDF file into an intermediate **GS+** proprietary file as Swath Amplitude Files; pronounced swamp (SWP). The SWP file was then exported into an eXtended Triton Format (XTF) file using the GeoAcoustics **GS+** software where it was down sampled to 1,024 samples per channel. Once the GeoSwath imagery data were in XTF format, those data and the Klein 3000 data were treated the same for further data processing.

Initial processing of the XTF data took place at the field processing center in Shell Beach, LA, and included re-navigating the towfish to apply more accurate towfish positions using the **SABER navup** routine. This routine replaced the towfish position recorded in the original side-scan XTF file with the towfish position recorded in the real-time catenary data file recorded by **ISS-2000**. This program also computed a unique position and heading for each ping record. Additional processing included generation of towfish track plots and generation of initial mosaics for coverage verification and quality control. All original and processed side-scan data files were then backed up onto USB hard drives for transfer to the Newport, RI Data Processing Center.

Once the side-scan data files arrived at the Data Processing Center in Newport, the data were reviewed on a line-by-line basis and a side-scan review log was generated. This review log contains information about each file, including the line begin and line end times, survey line name, corresponding bathymetry and side-scan file names, line azimuth, data gap information, and notes pertaining to hazards of navigation (i.e. contacts), and other points of interest (e.g. large schools of fish that may partially obstruct data). Other pertinent information regarding the interpretation of the imagery was also logged in the spreadsheet.

Side-Scan Quality Review

A processor conducted a quality review of each side-scan file using Triton **Isis** to replay the data. During this review the processor assessed the quality of the data and defined holidays in the data where the quality was insufficient to determine the presence of contacts. The times of these data holidays were entered into the side-scan review log. Data holidays were generally characterized by:

- Surface noise (vessel wakes, sea clutter, and/or waves)
- Towfish motion (yaw and heave)
- Electrical noise
- Acoustic noise
- Schools of fish
- Density layers (refraction)
- Turbidity clouds

Side-Scan Coverage Analysis

A time window file listing the times of all valid online side-scan data were created for the 100% coverage mosaic. The time window file and the file lists were then used to create towfish track lines and mosaics in **SABER.** The mosaics were viewed using tools in **SABER** to verify swath coverage and to plan further survey lines to fill in any data holidays. These additional lines were run and appended to the mosaics. There were no remaining coverage holidays.

Charted wrecks, rocks and obstructions in depths that SAIC anticipated conducting survey had an additional survey lines planed. A 2^{nd} 100% side-scan coverage was obtained for a radius of 100 meters around their charted position. A separate mosaic was made of these charted wrecks, rocks and obstructions.

Side-Scan Contact Analysis

During side-scan review, sonar contacts were selected and measured using the **Isis Target** utility. Significant side-scan contacts were chosen based on size and height or a unique sonar signature. In general, contacts with a height greater than or equal to 50 centimeters were selected. Contacts with a unique sonar signature (e.g. size, shape, and reflectivity) were typically selected regardless of height. Contact information was saved in a ".CON" file, which included a snapshot of the image and the following information regarding the acquisition of the target data:

- Year and JD
- Time
- Position

- Fish Altitude
- Slant range to contact (Note: port = negative #, starboard = positive #)
- Contact length, width, and height (based on shadow length, fish altitude, and slant range)

Note that when digitizing contacts within Triton **Isis**, the length measurement is always the along track dimension and the width measurement is always the across track dimension. Therefore you can have a width measurement that is longer than the length measurement.

Wrecks and large objects were positioned at their highest point. Additional contacts were made on other man-made objects such as piles, pipelines, and platforms. Additional information regarding objects not included as contacts but still noted in the side-scan review log include descriptions of other non-significant objects. The side-scan review log is included in Separates I of the Descriptive Report for each sheet.

The **Isis** contact files (*.CON) were converted into a side-scan contact (*.CTV) file using a **SABER** program called **isis2ctv**. The resulting CTV is a text file that documents all of the contact attributes contained in the individual contact files. In addition a tiff image file is made of each individual contact sonar image. In **SABER**, the CTV file was displayed and side-scan contacts were correlated to bathymetry data by overlaying them on the gridded depth layer. By comparing bathymetry data with the side-scan contact data, significant features were selected for the sheets S-57 Feature File. Positions and depths of these features were determined directly from the bathymetry data (when available) in SAIC's **MVE** swath editor by flagging the shoalest depth as a feature. A feature file (*.CNT) was created using the **SABER get_features** routine which extracted flagged features from the GSF bathymetry data. The final correlation process updated the CNT file with the type of feature (obstruction, wreck, etc.) and the CTV file with the feature-to-contact correlation.

There were contacts identified where there was not a least depth recorded within any bathymetry record. In these cases the least depth of the object was estimated using the side-scan record to estimate the least depth. The object was measured for length, width and height based on the sonogram. The measured height was then subtracted from the depth recorded within bathymetry record adjacent to the object yielding the estimated least depth of the object.

Weekly deliveries of side-scan contacts were made for the Lake Borgne surveys. These weekly deliveries were preliminary data products. The final results of the survey are presented with each sheet. Discussions regarding differences between the weekly deliveries and the final delivery are included in each sheet's Descriptive Report.

S-57 FEATURE FILE

Based on the unique nature of the Lake Borgne Debris Mapping surveys and discussions with the Atlantic Hydrographic Branch SAIC attributed the S-57 Feature Files for each sheet in the following manner:

1. For contacts with no least depth available (i.e. depth was estimated from side-scan instead) the QUASOU attribute was populated with a value of 9 (Value reported, not confirmed).
2. The M_COVR and M_QUAL objects were made from the outer perimeter of the combined bathymetry (GeoSwath interferometric and Odom singlebeam).
3. A single M_QUAL object was made for an entire sheet. The CATZOC attribute of the M_QUAL object was populated with a value of 2 (ZOC A2 - Full seafloor ensonification or sweep. All significant seafloor features detected and depths measured). This attribution was chosen because there was full ensonification by side-scan and all features do have depths measured except where noted (see QUASOU of 9 above).
4. The TECSOU attribute of the single M_QUAL object for each sheet was populated with a value of 1, 2 and 3 (found by echo sounder, found by side-scan and found by multi-beam, respectively).

C. CORRECTIONS TO ECHO SOUNDINGS

The GeoSwath Plus interferometric data and Odom CV singlebeam data are submitted fully corrected, therefore the CARIS vessel file will be all zeros. The GeoSwath data are also attributed with horizontal and vertical error values for each sounding. GeoAcoustics **GeoSwath Plus** interferometric GSF format data is fully compatible with Caris 6.1 with hot fix 6.

VESSEL CONFIGURATION PARAMETERS (*M/V THOMAS R. DOWELL*)

The *M/V Thomas R. Dowell* sensor configuration and offsets are tabulated in Table C-1 and depicted in Figure C-1. The reference point for the entire system is located at the top centerline of the POS/MV IMU. The Odom transducer was hull-mounted and the Klein 3000 Towfish was bow mounted. The POS/MV IMU was mounted 0.905 meters above, 2.080 meters forward, and 0.290 meters port of the transducer.

The SAIC Integrated Survey System (**ISS-2000**) and the POS/MV utilize a coordinate system where “z” is considered to be positive down, “x” is considered to be positive forward, and “y” is considered to be positive athwartship to starboard. Sensor offsets are entered into either the POS/MV or **ISS-2000** and all sensors connected to **ISS-2000** have their coordinate system transformed to match the one used by **ISS-2000**.

Table C-1. *M/V Thomas R. Dowell* Antenna and Transducer Offsets (Meters) Relative to the POS/IMU Reference Point

Sensor	Offset in ISS-2000		Offset in POS/MV	
Odom Transducer Hull Mount			X	-2.080
			Y	-0.290
			Z	+0.905
Vessel Center of Rotation			X	-2.031
			Y	0.00
			Z	0.00
POS/MV Master GPS Antenna			X	-2.381
			Y	-1.266
			Z	-1.830
Trimble GPS Antenna	X	-2.031		
	Y	-0.266		
	Z	-1.804		
Side-Scan Bow Mount	X	+4.522		
	Y	-0.126		
	Z	+1.698		

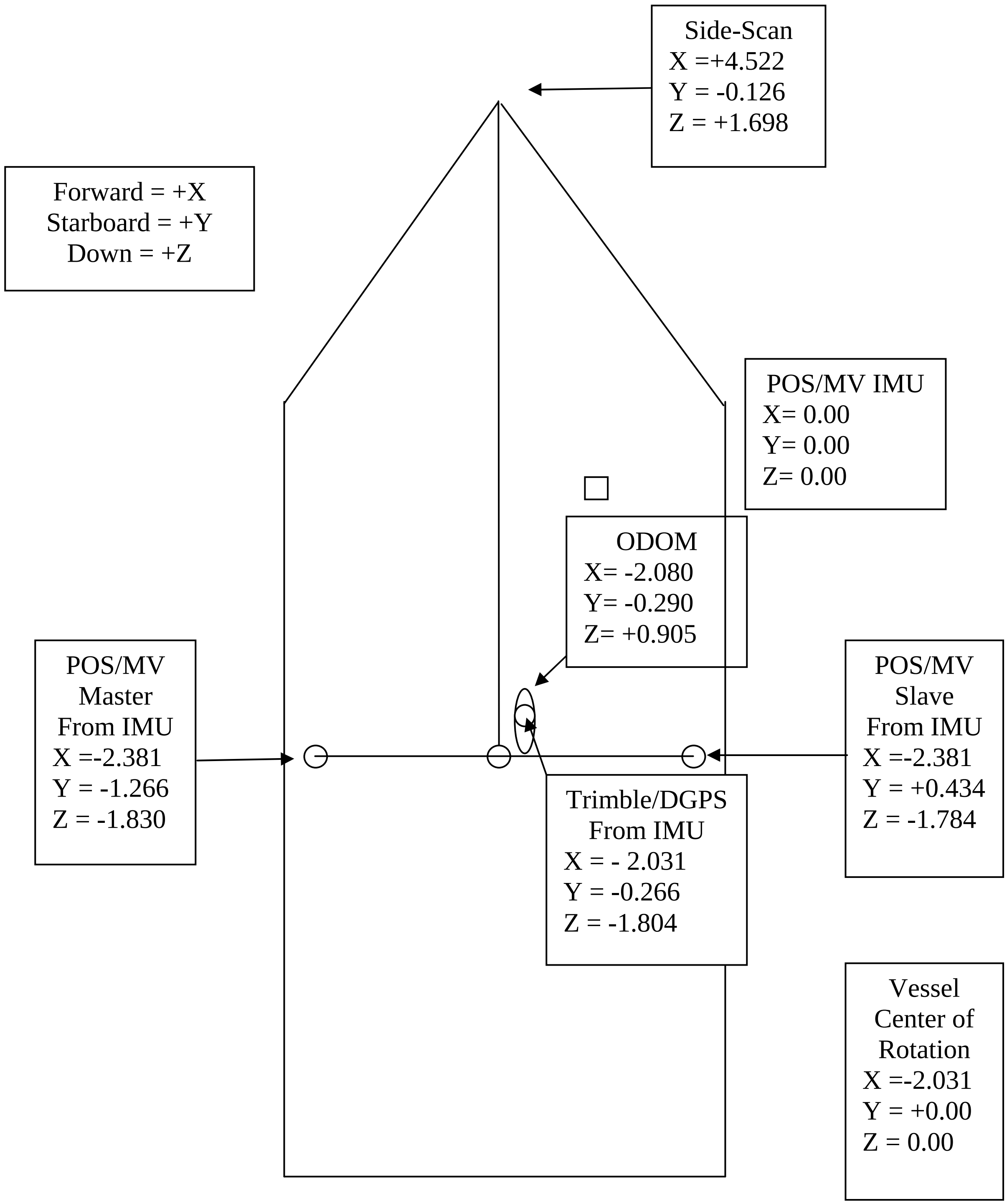

Figure C-1. Configuration and Offsets of the *M/V Thomas R. Dowell* Sensors (measurements in meters)

VESSEL CONFIGURATION PARAMETERS (*F/V LACEY MARIE*)

The *F/V Lacey Marie* sensor configuration and offsets are tabulated in Table C-2 and depicted in Figure C-2. The reference point for the entire system is located at the top centerline of the POS/MV IMU. The GeoSwath transducer was pole-mounted off the bow on the vessel centerline and 3.31 meters below the mounting plate. The POS/MV was mounted 0.330 meters directly above the transducer.

Table C-2. *F/V Lacey Marie* Antenna and Transducer Offsets (Meters) Relative to the POS/IMU Reference Point

Sensor	Offset in ISS-2000		Offset in POS/MV		Offset in GS+	
Center of V plate to Transducers					X	0.00
					Y	0.09
					Z	0.00
Center of V plate to Singlebeam Transducer					X	0.31
					Y	0.04
					Z	0.00
Center of V plate to MRU					X	-0.170
					Y	0.000
					Z	0.330
Vessel Center of Rotation			X	0.00		
			Y	0.00		
			Z	0.00		
POS/MV GPS Master Antenna			X	-9.914		
			Y	-1.000		
			Z	-4.842		
Trimble GPS Antenna	X	-9.914				
	Y	+0.000				
	Z	-4.843				

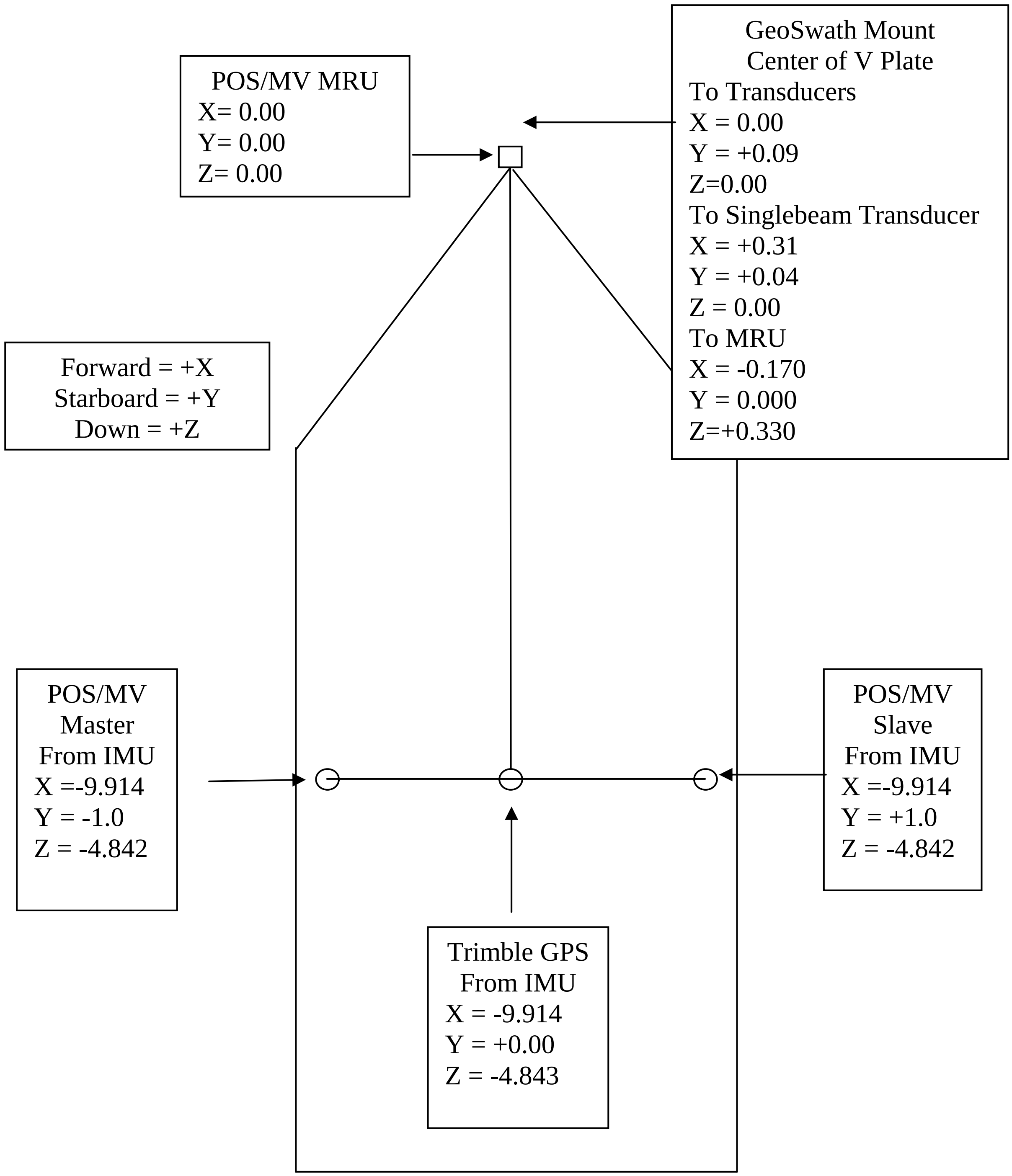

Figure C-2. Configuration and Offsets of the *Lacey Marie* Sensors (measurements in meters)

STATIC AND DYNAMIC DRAFT MEASUREMENTS

M/V Thomas R. Dowell Static Draft

Figure C-3 shows the draft calculations for the *M/V Thomas R. Dowell*. Depth of the transducer's acoustic center below the deck (1.26 meters) was determined from measurements made while the boat was hauled in January 2007. By subtracting the measured distance from the main deck to the waterline on both sides of the vessel, and averaging the two values, the transducer distance below the water surface (static draft) was determined.

Static draft measurements for the *M/V Thomas R. Dowell* were taken from amid ship, where the singlebeam transducer was mounted, both before departure and after arrival to the dock each day. The draft value was then recorded in the real-time Navigation Log. If the static draft value changed from the previously noted value, the new value was entered into the **ISS-2000** system. The observed static draft for each survey is included with the survey data in Section I of the Separates of each Sheet's Descriptive Report.

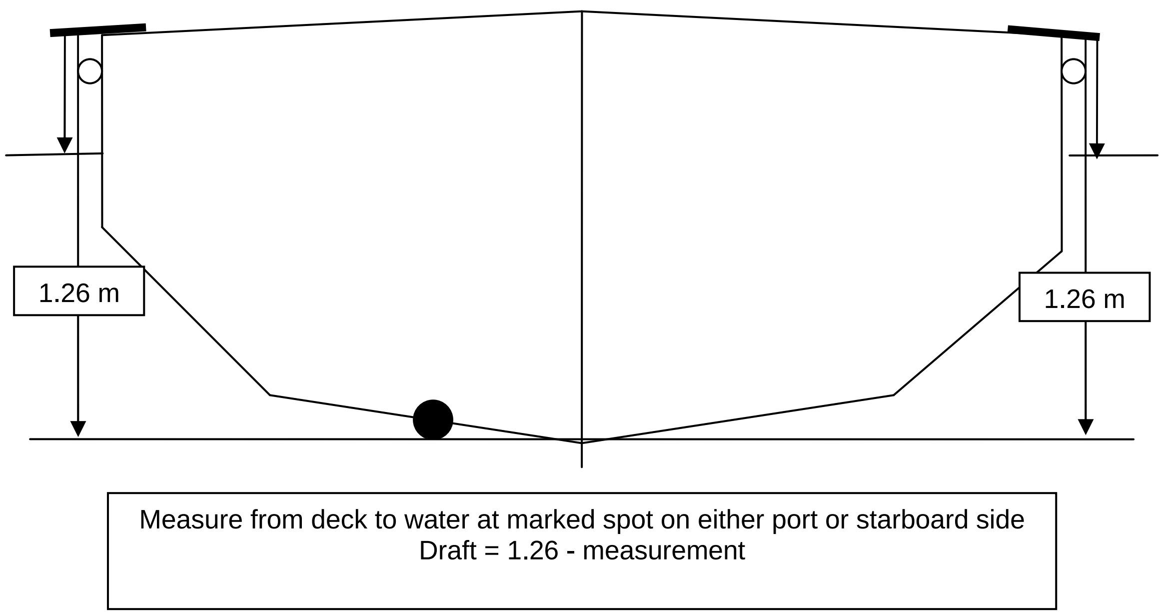

Figure C-3. *M/V Thomas R. Dowell* Draft Determination

F/V Lacey Marie **Static Draft**

Figure C-4 shows the draft calculations for the *F/V Lacey Marie*. Depth of the GeoSwath Plus transducer's acoustic center below the mounting plate (3.312 meters) was determined from measurements made during system installation in January 2007. By subtracting the measured distance from the mounting plate to the waterline from 3.312 meters the transducer distance below the water surface (static draft) was determined.

Static draft measurements for the *F/V Lacey Marie* were taken from the bow, where the transducers were mounted, both before departure and after arrival to the dock each day. The draft value was then recorded in the real-time Navigation Log. If the static draft value changed from the previously noted value, the new value was entered into the **GS+** software. The observed static draft for each survey is included with the survey data in Section I of the Separates of each Sheet's Descriptive Report.

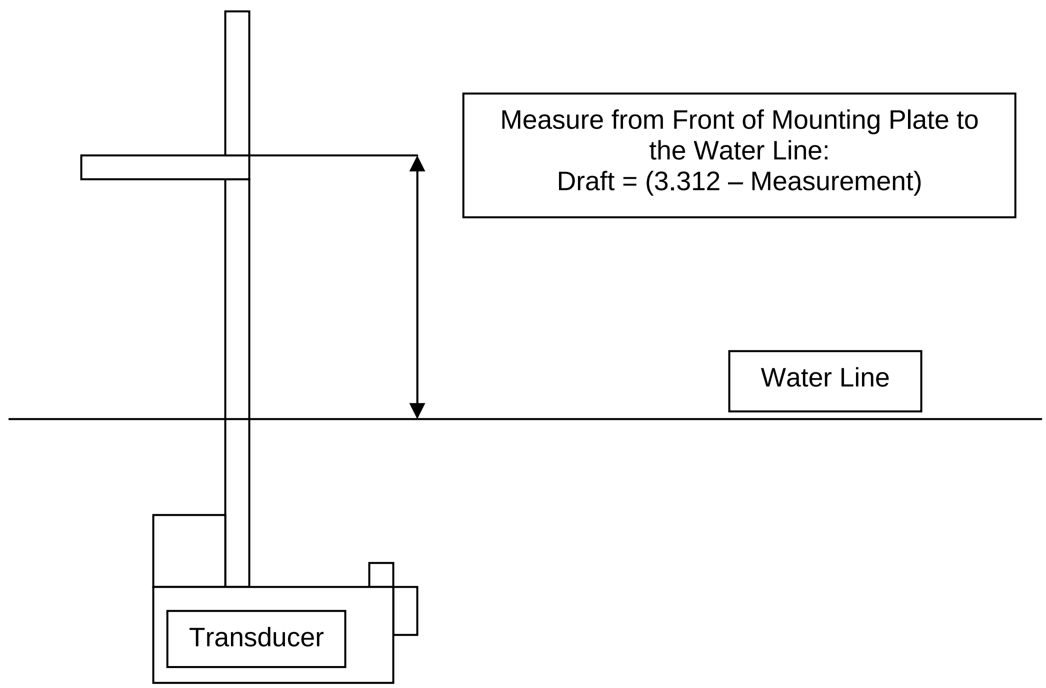

Figure C-4. *F/V Lacey Marie* Draft Determination

M/V Thomas R. Dowell Settlement and Squat – Dynamic Draft

The *M/V Thomas R. Dowell* settlement and squat values were determined on Julian Day 006 and confirmed on Julian Day 008 of 2007. On Julian Day 006 the POS/MV heave filters were not set properly on the *M/V Thomas R. Dowell*. However, the winds were light and variable with flat clam sea conditions. This allowed for the removal of the erroneous heave correctors when the depths for each RPM run were compared to the drift line. An average difference was computed for each RPM as presented in Table C-3. These values were then entered into the **ISS-2000** vessel configuration file and the test repeated on Julian Day 008. Table C-3 also show the results of the verification runs from Julian Day 008. The *M/V Thomas R. Dowell* did not have an RPM sensor interfaced to **ISS-2000** and therefore the RPM value was manually entered in the system for proper computation of the settlement and squat corrector.

Table C-3. *M/V Thomas R. Dowell* Settlement and Squat Determination

Shaft RPM	Depth Corrector	Average Speed (Kts)	Files Julian Day 006	Verification Files Julian Day 008
0	0.00	0	tdsbh07006.d22	tdsbh07008.d14
1000	0.03	3.7	tdsbh07006.d23 tdsbh07006.d24	tdsbh07008.d15 tdsbh07008.d17
1400	0.05	5.0	tdsbh07006.d25 tdsbh07006.d26	tdsbh07008.d18 tdsbh07008.d19
1800	0.06	6.2	tdsbh07006.d27 tdsbh07006.d28	tdsbh07008.d20 tdsbh07008.d21
2200	0.09	7.1	tdsbh07006.d29 tdsbh07006.d30	tdsbh07008.d22 tdsbh07008.d23
2600	0.08	7.7	tdsbh07006.d32 tdsbh07006.d33	tdsbh07008.d24 tdsbh07008.d25
3000	0.06	8.5	tdsbh07006.d34 tdsbh07006.d35	tdsbh07008.d26 tdsbh07008.d27

F/V Lacey Marie Settlement and Squat – Dynamic Draft

Settlement and Squat values for the *F/V Lacey Marie* were determined on JD 009 during the January 2007 SAT. A soundings reference was established by bringing the vessel to "all stop" and drifting. Two drift lines, reference lines, were established for the settlement and squat determination. One drift line was established at the start of the process (lm_009_d01) and another drift line was established at the conclusion of the process (lm_009_d13). A transect was created along the center line of drift line lm_009_d01. This transect was run in reciprocal headings for each of the 5 shaft RPM settings generating 2 separate files for each RPM setting. The data for each file was isolated based on the transducer acquisition (port or starboard). An average grid was then created for each file for port and starboard transducers. Difference grids were created in **GS+** software using the drift line as the reference surface and subtracting the various RPM lines. This produced 40 different comparisons. Ten comparisons for each channel for both drift lines. The mean value for each difference grid was calculated and recorded.

The swath data were then reduced in swath angle to use data falling approximately between 3 meters and 8 meters to reduce noise and eliminate outer beams. Difference grids were then generated again in the same manner as before producing another 40 comparisons. Mean values for the resulting difference grids were then computed and recorded. Comparisons were made of the mean value based on shaft RPM and transducer used to acquire the data. No significant differences were noted between swath angles or transducers at the same RPM. Therefore a single mean difference values for each shaft RPM was calculated from the mean difference values for each individual deference grid generated for a given RPM, i.e. a mean value was calculated from the mean values for each drift line, for each transducer, and for each swath angle based on a given RPM. The values for an RPM of 735 differed based on the vessels heading. This is due to the vessel being closer to plane speed at an RPM of 735. When heading into the seas and wind the vessel remained in a displacement state, and while running with the wind and seas the vessel started to plane. These values were averaged and put into the settlement and squat table (Table C-4) however the maximum speed for the survey was limited to 7.0 knots which is well below this 735 RPM value.

Table C-4. *F/V Lacey Marie* Settlement and Squat Determination

RPM	Depth Corrector	Average Speed (Kts)	Files Julian Day 009
0	0.00	0	lm_009_d01 lm_009_d13
480	0.02	5.7	lm_009_d04 lm_009_d05
566	0.03	6.6	lm_009_d06 lm_009_d07
640	0.05	7.5	lm_009_d08 lm_009_d09
735	0.02	8.1	lm_009_d10 lm_009_d11

SPEED OF SOUND

Seabird Electronics SBE-19 CTDs were used to collect sound speed profile (SSP) data on both vessels. SSP data were obtained at intervals frequent enough to reduce sound speed errors. The frequency of casts was based on observed sound speed changes from previously collected profiles and time elapsed since the last cast. Multiple casts were taken along a survey line to identify the rate and location of sound speed changes. Subsequent casts were made based on the observed trend of sound speed changes. As the sound speed profiles changed, cast frequency and location were modified accordingly.

A table including all SSP casts made on each vessel is located in Section II of the Separates of each sheet's DR. These tables include the Julian Day, location, and maximum depth.

On the *M/V Thomas R. Dowell*, SSP casts were copied to **ISS-2000** where the profiles were reviewed for quality and compared to the preceding cast. After review, the cast was "applied" to the system. Once applied, **ISS-2000** used the cast for speed and ray tracing corrections to the singlebeam sounding data. If sounding depths exceeded the cast depth, the **ISS-2000** used the deepest sound speed value of the cast to extend the profile to the maximum depth.

On the *F/V Lacey Marie*, SSP casts were copied to **ISS-2000** where the profiles were reviewed for quality and compared to the previous cast. After review the cast was copied to the **GS+** computer and applied within the **GS+** software. Once applied, **GS+** used the cast for speed and ray tracing corrections to the interferometric sounding data.

Weekly confidence checks were obtained using consecutive casts with two different Seabird SBE-19 CTDs. After downloading the SSP casts, graphs and tabulated lists were used to compare the two casts for discrepancies.

Serial numbers and calibration dates for the CTD units used on these surveys are listed below. Sound speed data and calibration records are included with the survey data in Section II of the Separates for each sheet's Descriptive Report.

- Seabird Electronics, Inc., CTD, Serial Number 2710
  Calibration Dates: 01 November 2006 and 14 June 2007

- Seabird Electronics, Inc., CTD, Serial Number 0648
  Calibration Dates: 01 November 2006 and 12 June 2007

- Seabird Electronics, Inc., CTD, Serial Number 0565
  Calibration Dates: 03 November 2006 and 23 June 2007

On the *F/V Lacey Marie*, a Velport surface sound velocimeter was used in conjunction with the sound speed profiles for collection of interferometric data. These speed of sound correctors were recorded and applied in real time by the GeoAcoustics **GS+** software. On Julian Day 124 (04 May 2007) at 15:25:05 UTC the surface sound speed sensor on the *F/V Lacey Marie* (25 mm stand off Velport SSV) was damaged. From JD 124 at 15:25:05 through JD 132 (12 May 2007) the **GS+** software used the surface sound speed data collected by the Seabird SBE-19 CTD to correct the interferometric data. On the evening of JD 132 (12 May 2007), a 50-mm Velport sound speed sensor was installed and used for the duration of the survey.

SYSTEM BIAS DETERMINATION

Timing Bias – *M/V Thomas R. Dowell*

A ping-timing test was completed on 07 January 2007 to verify that no timing errors exist within the survey system installed on board the *M/V Thomas R. Dowell*. The fundamental measurement tool is the event marking capability of the Symmetricom BC635PCI IRIG-B card. An event is characterized by a positive-going TTL pulse occurring on the event line of the IRIG-B connector on the back of the ISSC. The pulses of interest are the transmit trigger of the Odom CV and the 1PPS timing pulses from the POS/MV. This test demonstrated that the average of the GSF ping times compared to the corresponding IRIG-B event times was 1.77 milliseconds with a standard deviation of 4.5 milliseconds. The times in each file were compared and the results are plotted in Figure C-5. Timing tests of **ISS-2000** were successfully completed prior to any other calibration tests.

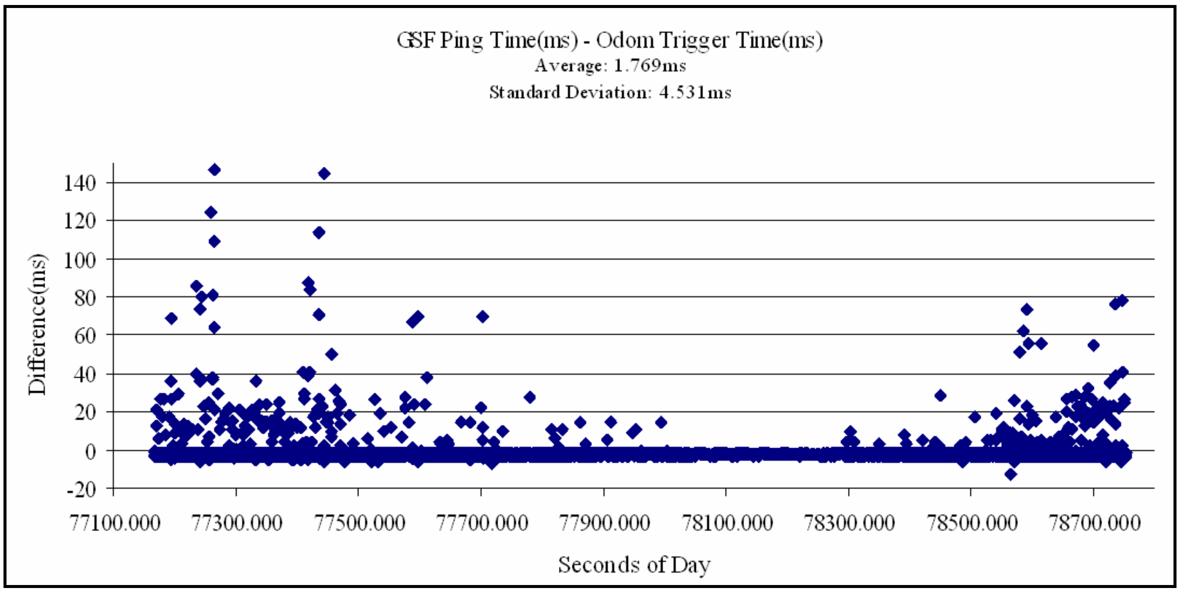

Figure C-5. Timing Test Results *M/V Thomas R. Dowell*

Timing Bias – *F/V Lacey Marie*

A ping-timing test was completed on 07 January 2007 to verify that no timing errors exist within the survey system installed on board the *F/V Lacey Marie*. The fundamental measurement tool is the event marking capability of the Symmetricom BC635PCI IRIG-B card. An event is characterized by a positive-going TTL pulse occurring on the event line of the IRIG-B connector on the back of the ISSC. The pulses of interest are the transmit trigger of the GeoSwath Plus and the 1PPS timing pulses from the POS/MV. The GeoSwath timing test is designed to ensure that minimal hardware latency exists between trigger and GSF time. This test is conducted by collecting a RDF file in the **GS+** software, converting the file into an intermediate file type (CBF), then finally converting the CBF file to a GSF file with the **SABER cbftogsf** program. This test demonstrated that the average of the GSF ping times compared to the corresponding IRIG-B event times was less than one millisecond with a standard deviation of less than one millisecond. The times in each file were compared and the results are plotted in Figure C-6. Timing tests were successfully completed prior to any other calibration tests.

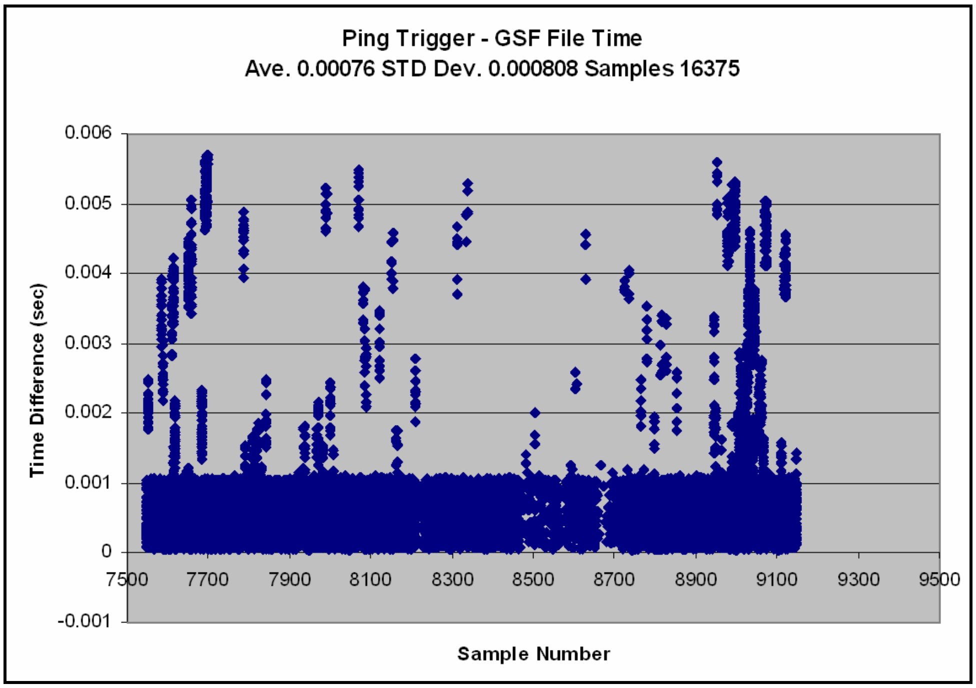

Figure C-6. Timing Test Results *F/V Lacey Marie*

Interferometric System Bias Determination

GeoSwath alignment calibrations were performed on JD 015 (15 January 2007) prior to commencing survey operations. The alignment was performed over a slope located along the Mississippi River Gulf Outflow (MRGO) in approximately 29° 51' 38.399"N 089° 41' 37.529"W NAD83 and ranged in depth from 1.69 meters to 12.23 meters. Calibration lines were run a several times so various comparisons could be made. Comparisons were made such that port data were compared to port data and starboard data to starboard data. The roll calibration utilized a flat section at the bottom of the slope in the deepest part of the calibration area.

Before running bias calibration lines, all instrument offsets were entered into **ISS-2000** and the **GS+** system as appropriate and all bias values were set to values obtain during previous system testing conducted in Newport, RI. Bias values are not retained in the RDF file for use in the export to CBF process. Each time an RDF file is processed and exported to a CBF file the offsets within the **GS+** Calibration Offset file must used. Various methods of data review were utilized to determine the GeoSwath alignment values. The alignment tools within the **GS+** software were used as well as **SABER's Swath Alignment Tool** (SAT), **MultiView Editor**, and **PFM** grids were used to determine the final alignment values. Examples of the final alignment values are depicted in images of **SABER's Swath Alignment Tool** (Figure C-7 through Figure C-12) as well as in tabular form in Table C-5.

Table C-5. Final Interferometric Files Verifying Alignment Bias Calculated using the Swath Alignment Tool (SAT)

Component	**Interferometric files (pairs)**		**Result**	
			Port	**Stbd**
Pitch	lmmba015_001.d01	lmmba015_001.d02	0.00	0.00
Roll	lmmba015_001.d01	lmmba015_001.d02	-0.10	0.10
Gyro	lmmba015_001.d01	lmmba015_001.d02	-2.40	-2.40

Pitch Alignment

Two sets of lines were collected for pitch bias calculation. All lines were such that port transducer was compared to port transducer and starboard transducer to starboard transducer. Several samples were viewed for each set of comparison lines in order to determine an accurate measurement of the pitch bias. Figure C-7 and Figure C-8 are images of the SAT tool depicting data processed from RDF to GSF with the 0.00 port and starboard pitch biases. The SAT tool pitch value of zero therefore indicates zero additional bias is required.

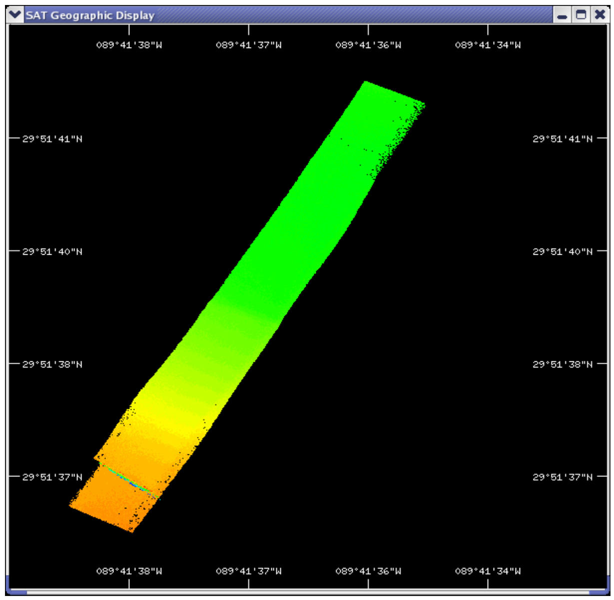

Figure C-7. SAT Tool, Plan View Depicting 0.00 Pitch Bias

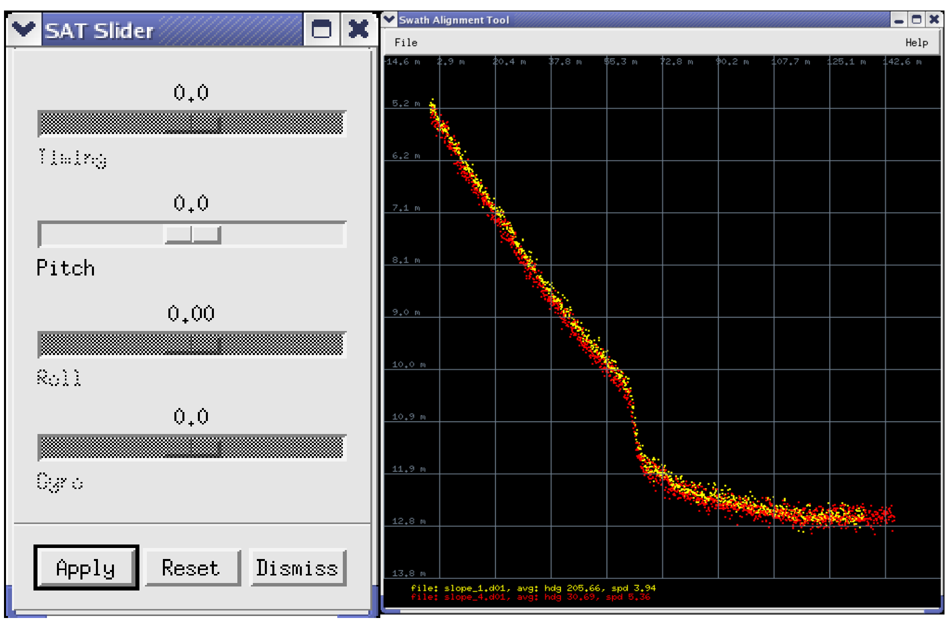

Figure C-8. SAT Tool, Depth vs. Distance Plot Depicting 0.00 Pitch Bias

Roll Bias

Two sets of lines were collected for roll bias calculation. All lines were such that port transducer was compared to port transducer and starboard transducer to starboard transducer. Several samples were viewed for each set of comparison lines in order to determine an accurate measurement of the roll bias. Figure C-9 and Figure C-10 are images of the SAT tool depicting data processed from RDF to GSF with the -0.10 port and +0.10 starboard roll biases. The SAT tool roll value of zero therefore indicates zero additional bias is required.

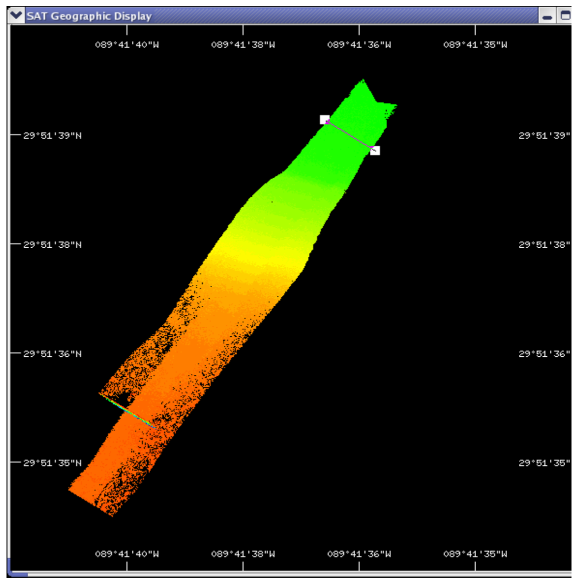

Figure C-9. SAT Tool, Plan View Depicting -0.10 Port & +0.10 Starboard Roll Bias

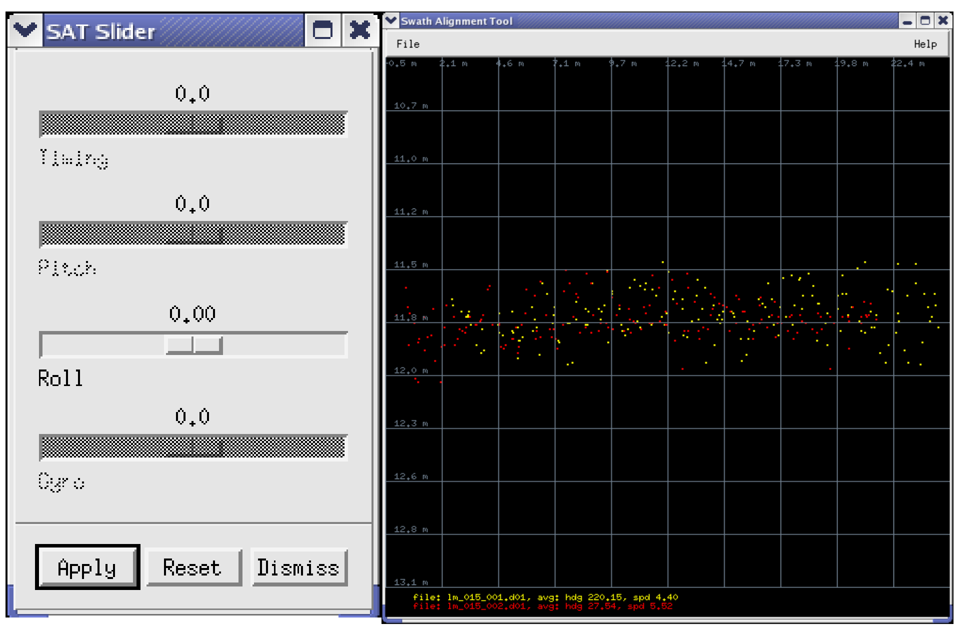

Figure C-10. SAT Tool, Depth vs. Distance Depicting -0.10 Port & +0.10 Stbd Roll Bias

Heading Bias

Two sets of lines were collected for heading bias calculation. All lines were such that port transducer was compared to port transducer and starboard transducer to starboard transducer. Several samples were viewed for each set of comparison lines in order to determine an accurate measurement of the heading bias. Figure C-11 and Figure C-12 are images of the SAT tool depicting data processed from RDF to GSF with the -2.40 port and starboard heading biases. The SAT tool gyro value of zero therefore indicates zero additional bias is required.

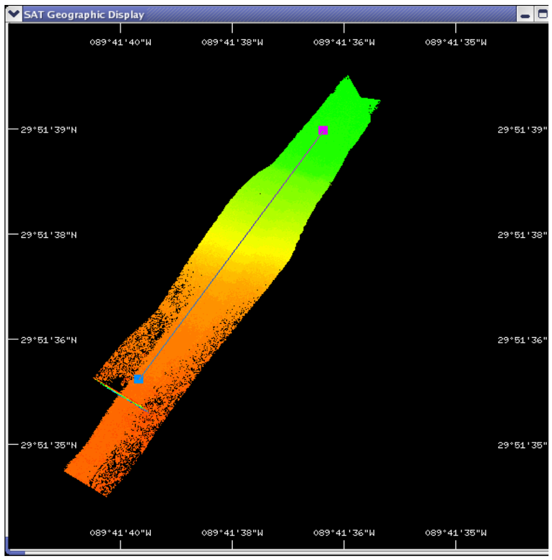

Figure C-11. SAT Tool, Plan View Depicting -2.40 Heading Bias

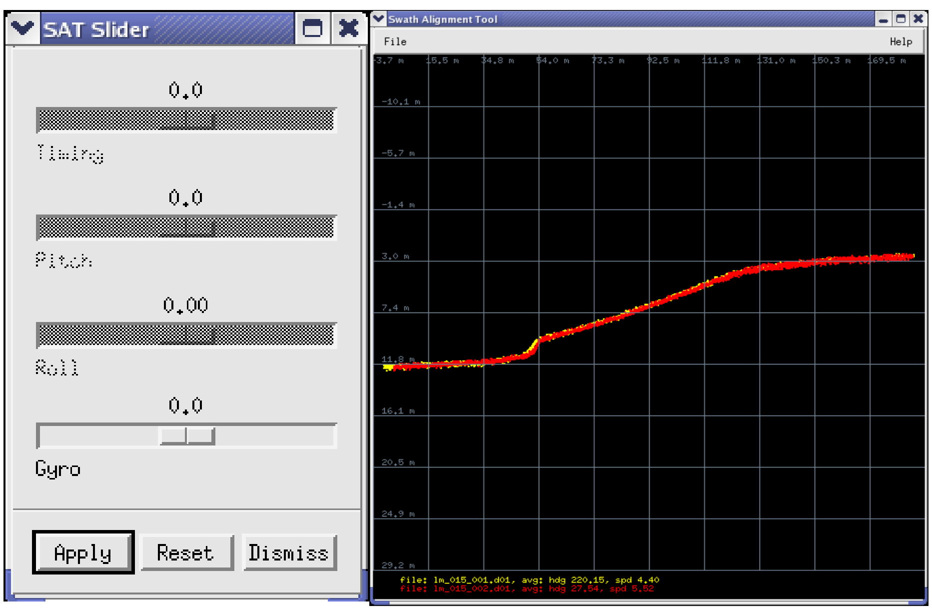

Figure C-12. SAT Tool, Depth vs. Distance Depicting -2.40 Heading Bias

<u>TIDES AND WATER LEVELS</u>

The SAIC tide station in Martello Castle, LA (8761529) was the source for verified water level heights for the Lake Borgne, Louisiana surveys. Water level data were downloaded from the gauges and processed by sub-contractor John Oswald and Associates. The MLLW datum accepted for verified observed tides was based on a four month comparison to the NOAA station in Bay Waveland Yacht Club, MS (8747437). All tide data were in meters and annotated with Coordinated Universal Time (UTC).

Final water level files for each tide zone were created from verified tide data using the **SABER Create Water Level Files** tool. Water level files contained water level heights that were algebraically subtracted from depths to correct the sounding for tides and water levels. These water level files were applied to the bathymetry data using the **SABER Apply Tides** program within the **SABER** software.

When it was necessary to apply updated tide correctors to the GSF files, the program removed the previous tide corrector and applied the new corrector. Each time a routine was run on the GSF data file, a history record was appended to the end of the GSF file. For quality assurance, the **Check Tides** program was run on all GSF files to confirm that the appropriate water level corrector had been applied to the GSF file.

After confirmation that verified water levels were applied to all bathymetry data, grids were created and analyzed using various color change intervals. The color intervals provided a means to check for significant, unnatural changes in depth across zone boundaries due to water level correction errors, unusual currents, storm surges, etc.

The primary means for analyzing the adequacy of zoning was observing zone boundary crossings in the navigated swath editor, SAIC's **MVE**. In addition, crossline analysis using SAIC's **Analyze Crossings** software was used to identify possible depth discrepancies resulting from the applied water level corrector. Discrepancies were further analyzed to determine if they were the result of incorrect zoning parameters or weather (wind) conditions between the tide station and the survey area. The water level zones provided by NOS were adopted spatially, but zoning parameters based on Martello Castle, LA (8761529), Table C-6, were computed by SAIC for application of the observed verified water levels. Table C-7 shows a summary of water level differences across zone boundaries in meters using verified water levels from Martello Castle (8761529).

Table C-6. Tide Zone Parameters Applied on Sheets H11612, H11613, H11614, H11615

Zone	Time Corrector (mins)	Range Ratio	Reference Station
CGM82	-2.18	1.118	8761529
CGM83	-2.06	1.105	8761529
CGM84	-1.54	1.092	8761529
CGM85	-1.35	1.079	8761529
CGM86	-1.18	1.065	8761529
CGM87	-1.06	1.052	8761529
CGM88	-0.48	1.039	8761529
CGM89	-0.30	1.026	8761529
CGM90	-0.12	1.013	8761529
CGM91	-0.00	1.000	8761529

Table C-7. Water Level Differences Across Zone Boundaries, Verified

	82-83	83-84	84-85	85-86	86-87	87-88	88-89	89-90	90-91
Min	-0.039	-0.038	-0.060	-0.059	-0.037	-0.058	-0.057	-0.056	-0.034
Max	0.050	0.050	0.069	0.069	0.048	0.067	0.066	0.065	0.046
Average	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003

D. APPROVAL SHEET

09 November 2007

LETTER OF APPROVAL

REGISTRY NUMBER: H11612, H11613, H11614, H11615

This report and the accompanying digital data for project S-J977-KR-SAIC, Lake Borgne, Louisiana are respectfully submitted.

Field operations and data processing contributing to the accomplishment of this survey, H11613, were conducted under supervision of myself and lead hydrographer Gary R. Davis with frequent personal checks of progress and adequacy. This Descriptive Report, digital data, and all accompanying records are approved, and are submitted as complete and adequate in compliance with the Statement of Work.

Reports concurrently submitted to NOAA for this project include:

Report	**Submission Date**
H11613 Descriptive Report	09 November2007

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

Paul L. Donaldson

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Paul L. Donaldson
Lead Hydrographer
Science Applications International Corporation
Friday, 09 November 2007