NOAA SHIP BELL M. SHIMADA

HYPACK/ME70 INTEGRATION

With Hydrographic Systems and Technology Branch
Multibeam Sonar Acceptance Procedures 1.0

DATES
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Executive Summary

This report documents the current configuration of the Hypack/ME70 system for use in seafloor mapping. This includes the installation and configuration of the ME70 and ancillary systems; validate the current Hypack implementation of the ME70 bottom detection code; and operational guidance to the operators of this system. We accomplished the validation work while the ship was alongside the Marine Operations Center in Newport, OR and acquired the underway portions during a transit from Newport, OR to San Diego, CA. While we have used the Multibeam Sonar Acceptance Procedures as a framework for this analysis, the tests and analysis contained in this report were opportunistic and do not constitute system acceptance work for routine hydrographic survey work as outlined in the Hydrographic Surveys Division Technical Directive on configuration management.

We made significant progress during this cruise to ready the ship for anticipated mapping work, in particular, the POS-MV heading, which had been a point of concern in the past is now functioning nominally.

Significant Findings and Recommendations

1. The Hypack/ME70 on Bell Shimada is appropriately configured for mapping work with the ME70, however the following items must be resolved prior to a major mapping mission:
   a. The power supply voltages in the ME70 were out of specification and the system was only able to run for a limited time.
   b. Configure the remote display. There are dedicated CAT-5 cables between the server rack and the bridge for video feeds. We understand these have been used for Hypack display on the bridge in the past.
2. Correct timing is a continuing challenge due to the architecture of the ME70 systems. We observed significant (~20 s) and variable timing (~0.2 s/hour) during this cruise, even though the ME70 was thought to be controlled by the timeserver. This makes integrating motion corrects in post-processing challenging.
3. The offset and alignment survey conducted during ship construction did not explicitly tie to either the waterline plane, and did not measure the orientation of components. In addition, the IMU and POS antennae were moved since the report. We include a consolidated offsets and alignment report with this report that contains the consolidated, best available offsets and alignments. The oversight and quality control of alignment surveys should be strengthened.
4. Though the ME70 has inputs for offsets and sound speed profiles, the raw data output to Hypack is not corrected for the sound speed profile and is referenced to the transducer face. This output can be optionally stabilized for roll and pitch (via the beam-former), but in all cases (including Matlab based GSF conversions) does need to be corrected for heave, static and dynamic draft, and sound-velocity corrected in post-processing. This is not intuitively obvious.
5. As configured, the Hypack real time gridded bathymetry (the matrix) will typically have a heave artifact. This artifact arises because the ME70 data is typically corrected for pitch and roll, but not heave, and Hypack can correct for all motion or none in the matrix calculation. This does not affect the recorded bathymetric data.
6. Some science parties may prefer to process the recorded ME70 RAW files thorough the Matlab code developed by Dr. Weber or their own code. The Hypack system in no way prevents this. In any case, we recommend using the Hypack system to plan and monitor acquisition.

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1 General Overview

All Oscar Dyson class ships are equipped with Kongsberg ME70 multibeam echosounders. This content and format of this report closely follows the 2016 report on the Hypack/ME70 integration on the NOAA Ship Ruben Lasker [1]. These systems were designed for pelagic fisheries applications, but have also found utility for seabed mapping. In their standard fisheries configuration, these systems do not generate bathymetric solutions, however, the seafloor can be extracted from the raw data in post-processing (e.g. [2] [3]). Dr. Tomas Weber of the Center for Coastal and Ocean Mapping at the University of New Hampshire developed Matlab based code to extract bottom detections from the logged raw data files. A number of NOAA Fisheries Science Centers have used this code to extract bathymetry from ME70 data, some of which have been submitted for navigational charting applications in addition to the habitat mapping goals of the science centers (e.g. [4], [5]). The Hydrographic Systems and Technology Branch (HSTB) of the Office of Coast Survey has led an effort to incorporate this research code in Hypack, a commonly used commercial hydrographic planning and acquisition tool. The intent of this project is to provide additional capability to fisheries scientist interested in incorporating bathymetric mapping applications into their cruises on the FSVs. HSTB’s objective during this work was to verify the installation and configuration of this system, validate the current Hypack implementation, and provide operational guidance. Initially planned for a gear-selectivity cruise in early March 2017 this work was split between an alongside portion in early March and a underway portion during a late March transit from Newport, OR to San Diego. We anticipate the next use of the Hypack/ME70 system to be a cruise in the Channel Islands in April 2017.

The Kongsberg ME70 is a highly configurable system originally designed for quantitative water column mapping work. The system features a fully populated array and can form multiple split-beams at user configurable frequencies and steering angles. As a development of the Kongsberg fisheries scientific sounders series, the ME70 exhibits high gain stability and large linear dynamic range. Because of these features and the ability of this system to position a point target in three dimensions using the only sonar
itself, the ME70 is capable of being absolutely calibrated. While absolute calibrations of these systems have been demonstrated [6] and we are aware of at least one calibration of a NOAA ME70 [4], the ME70 systems in the NOAA fleet are not routinely calibrated in this fashion and we are unaware of a current calibration for the Shimada ME70.

The ME70 transducer array is flush mounted in the hull in the sonar room, slightly to port of centerline and approximately one-quarter of the hull length aft of the bow. The analog signal to and from the transducer is carried by a cable bundle to the topside processing unit located in the IMU room. A rack-mounted computer located in the acoustics lab runs the ME70 control software. Figure 2 shows images of the transducer, the sonar sea chest, and the topside processing unit.

![Figure 2: The ME70, left: transducer face, middle: sonar sea-chest in sonar room, right: topside processing unit](image)

2 Overview of schedule and conditions

2.1 Preplanning
Prior to the cruise, we gathered and read the offset diagrams, survey reports, and available equipment commissioning reports. We reviewed the status of updates to the Hypack ME70 implementation with Hypack representatives, and accordingly installed the 2017 version of Hypack, which includes all pending improvements to the ME70 driver.

2.2 Executed Schedule
- Thursday, March 2 to Wednesday, March 8 - Newport, OR – Greenaway, Validated offsets and configurations, etc.
- Sunday, March 19 – Devereaux, Departed Newport, OR
- Monday, March 20 - transit
- Tuesday, March 21 – transit
- Wednesday, March 22 – transit
- Thursday, March 23 – patch test
- Friday, March 24 – transit
- Saturday, March 25 – arrived San Diego, Devereaux departed.
3 Pre-Installation Testing

3.1 Test Data Processing Workflow
We upgraded Hypack to 2017 version current as of March 6. Because the Hypack- ME70 workflow has previously been integrated on this and other platforms, the full workflow was not tested prior to data acquisition.

3.2 Determine data rates and file size
To estimate data rates for this system used in a mapping application, we looked at data rates from the patch test conducted by Lasker (with similar hardware same set up) off San Francisco. For this test, the other sounders were secured and the ME70 run at the minimum ping interval. This test was run in approximately 150 meters of water with the record size set to 700 meters. Table 1 shows the results. As expected, the full water-column in the ME70 .raw file dominates the data volume. The additional bottom detections from the Hypack process did not add significantly to the raw data collection. For mapping operations, a rough estimate of 1.2 GB/ hour or approximately 30 GB/ day should provide a useful idea of the approximate data rates for this system.

Table 1: Experimental Data Rates

<table>
<thead>
<tr>
<th>File</th>
<th>Data Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME70 .raw</td>
<td>950 MB/ hour</td>
</tr>
<tr>
<td>Hypack .raw</td>
<td>117 MB/ hour</td>
</tr>
<tr>
<td>Hypack .HSX</td>
<td>75 MB/ hour</td>
</tr>
<tr>
<td>Raw POS Observables (10hz)</td>
<td>85 MB/ hour</td>
</tr>
<tr>
<td>Total</td>
<td>1,230 MB/ hour</td>
</tr>
</tbody>
</table>

3.3 Operational hazards
No current safety regulations or hazards restrict use of this multibeam echosounder.

3.4 Determine user configurable system settings
The most significant configurable setting, and one unfamiliar to many multibeam operators, is the ability to configure the beam pattern. The beam geometry, center frequencies, and ping order can be configured using the beam administration function with the parameters are stored in an xml file. The configuration often used for mapping work is b31_sec120_xmitbyDecreasing. Dr. Weber developed a configuration (is b31_sec120_xmitbyDecreasing ) that other FSV’s have used for mapping work. While many beam configurations do work with the Hypack bottom detection application, not all do, and the selection of beam patterns should be carefully considered before mapping work.

The range and gain settings in the user settings window of the ME70 console window only change the display and do not change the recorded or broadcast raw data. The range setting of the system is controlled by the ‘data output’ section of the settings configuration. This must be manually set to an appropriate range for the working area. Additionally, the transmit power can be set at max, -6db, and -12 dB through the ‘Tx Power’ section of the operation configuration. The Tx power was kept at max throughout this cruise.

Another unique aspect of this configuration is that Hypack makes the seafloor detections from the raw ME70 water-column data sent over the network. Typically, mapping systems perform a bottom
detection with proprietary algorithms and Hypack, or some other acquisition program, simply logs this data. The raw ME70 water-column data can also be logged directly from the ME70 and processed through stand-alone code such as the ME70_Raw2GSF.exe developed by Dr. Weber. In either case, the range of the transmitted or logged data must include the seafloor. The range setting in the “ME70 File Output” tab controls the range of the logged data and the range gate in the Hypack ME70 Controller constrains the bottom detections (Figure 3). The multi-detect flag in the Hypack controller allows for multiple bottom detections per beam. We strongly recommend enabling this feature.

3.4.1 Vessel Survey and Reference Frames
An offset survey was conducted during the build, but we recommend some caution when figuring the offsets. The antennae used by the POS-MV attitude and motion systems were moved from the original positions (Figure 4) and a new IMU installed in 2016. We estimated revised positions for the antennae using a post-processed kinematic (PPK) approach in Applanix POSPac to determine the new offsets, which agreed with rough measurements taken from the benchmarks on the flying bridge. We also verified the new IMU location by measuring from the nearest benchmark. These measurements agreed with the net change in height of the new IMU design and the additional mounting plate.
Figure 4: (left) POS antennae were moved to new location on awning support in 2016 (solid arrows). Old location was forward of windscreen (hollow arrow). Looking to port and forward on flying bridge. (Right) New IMU is mounted on same support as old IMU, additional mounting plate partially offsets lower height of new IMU design. Height of reference mark validated from benchmark on deck.

Consolidated offset tables with the best currently available information from all sources is included as an appendix to this report and in the excel file ‘SH_Offsets_and_Alignments.xlsx’ distributed with this report.

During the construction of the ship, the Master Reference Plate (i.e. the granite block) was installed parallel to the measured pitch roll plane of the ship as constructed (Figure 6). The reference system is a right-handed system with x forward, y to starboard, and z down. Although this survey also reported the orientations of the IMU, ME70, and ADCP, the values do not agree with previous patch test results, and were not used here to adjust the offsets to align with any particular frame, that is, we are using the offsets in the granite block frame.
We configured the POS-MV to output position and attitude valid at the granite block. Note that this is a change from previous configuration, which output positions at the IMU and used the ‘sensor 1’ field to translate motion to the ME70. We have assumed that the IMU is aligned with the granite block (based on the original survey of the previous IMU, the IMU was aligned within approximately 0.1 degrees). That is, the alignment angles and offsets of the antennae and IMU are such that the reported position from the POS is the position of the granite block and the reported attitude (heading, pitch, roll) is the attitude of the granite block with respect to a north-aligned, gravity level frame. We entered no offsets into the ‘center of rotation’ field. As discussed in [7], the location of the origin of the reference system, the alignment of that frame, and the designated ‘center of rotation’ are largely arbitrary, however it is imperative that the chosen system is applied consistently. In particular, the designation of the ‘center of rotation’ means that the heave filter is applied at this location- i.e. the double integrated vertical acceleration (the raw heave) measured at the IMU is mathematically translated to the ‘center-of-rotation’, the high-pass heave filter is applied, and the filtered heave re-translated to the reference point- in our case, the granite block. It also means that any dynamic draft correction must be valid for the location of the ‘center-of-rotation.’ We made no measurement of the dynamic draft of Shimada, but have used the 2013 values determined for Henry Bigelow, a sister ship of the class [8]. While the Bigelow values were measure at the IMU, the difference is likely negligible. The location of the major system components is shown in Figure 6.

Previous installations had used the ‘Sensor 1 Lever Arm’ and ‘Sensor 1 Frame w.r.t. Ref. Frame’ values to output position and attitude in the ME70 frame. The disadvantage of this approach is complexity. With entries in the ‘sensor 1’ field, the binary POS output (e.g. the TSS attitude record) can be in the sensor 1 frame; the NMEA messages will be in the POS reference frame; and the Ethernet real time (e.g. to Hypack) could be in either. We intentionally zero these fields to ensure that all outputs from the POS will be in a consistent frame. Any patch test values can be either dealt with in post-processing (e.g. in the CARIS HVF file) or by putting entries (of opposite sign) in the ‘reference frame to IMU’ rotation field.
We did not configure any offsets in the ME70 installation parameters because these have no apparent effect on the logged raw data files of interest to mapping.

We did not configure any lever arm offsets in Hypack. This does mean the real-time bathymetric grid will be depths below transducer and there will be a slight (less than a meter) offset in the real-time gridded position. This does not affect the logged data and is likely insignificant for the intended work of this platform.

We did enter the offsets between the granite block (the reference point) and the transducer in the CARIS HVF file used for this report. This HVF file is included as an appendix.

3.4.1.1 Draft and Water Line Offsets

Unfortunately, the vessel offset survey did not include any of the ship’s draft marks or any other method to easily reference the vessel reference frame to the water surface. This offset is required to conduct mapping operations with vertical control based on water levels. We tied the granite block frame to the waterline using post-processed kinematic (PPK) derived GPS heights of the vessel and the observed water level at a NOAA permanent gauge.

We based the PPK method on the approach outlined in [9]. On March 4, we logged raw POS observables while the ship was alongside the pier and no major loading or ballasting operations were underway. We processed the logged file through Applanix POSPAC MMS using IN-Fusion Single Base processing on base station P367, approximately 5 km from the pier. This yielded a time series height of the vessel reference point with respect to the reference ellipsoid (in this case the GRS80 ellipsoid used with ITRF2008). A simultaneous water level observation relative to MLLW was obtained from NOAA water level station in Newport, OR (9435380) less than 1 km from the pier. No zoning corrections were applied, and the water levels were referenced to the ellipsoid by applying the VDatum ITRF2008 to MLLW correction (-24.409 m) at the location of the water level station. The two time series and the difference are shown in Figure 7. The difference between these two time series is distance from the reference point to the
water surface (i.e. the reference point draft) during the measurement. Based on these measurements, the derived draft of the granite block was 3.94 m. We compared this GPS derived draft to the observed draft on two observable draft marks (one on the transom, one forward on the starboard bow). Based on a level roll trim and a plane-fit through these marks, the observed vessel draft (base line to water surface) at the location of the granite block during the experiment was 5.58 m. The design draft of the ship is 5.90 m, so correcting for the loading of the ship during this experiment, we calculate a 4.04 m draft of the granite block when the vessel is sailing at its design draft of 5.90 m. Note that because the keel of the ship is not level with respect to the waterline (or baseline) the draft of the ME70 transducer when the ship is at design draft of 5.9 m is 4.99 m (see Figure 6). The dominant uncertainty in this result is from the observation of the draft marks, which is at best 0.05 m.

![Reference Point Draft](image)

**Figure 7:** Reference point (RP) draft from difference between ellipsoid referenced water level (green line in top plot) and ellipsoid referenced height of RP (blue line in top plot). The difference of the two is the observed draft of the reference point. The vessel was at the pier at the duration of this record.

### 3.4.2 Data Flow Configuration

The wiring diagram and basic connections between equipment is illustrated in Figure 8. Only the components directly related to the ME70 are shown. The attitude data from the POS is fed into the ME70 using the Simrad 3000 format on COM1. The ME70 requires attitude on this com port and passes this directly to the beam-former circuitry for active stabilization of the beams. This port is not configured using the ME70 I/O module. Communications between the TRU and the ME70 workstation are over two dedicated Ethernet connections. Other navigation, triggering, and surface sound speed inputs are handled by the ME70 I/O module and are configured as shown.
A dedicated switch connects the ME70 to the Hypack computer, and both the ME70 and the Hypack computer are connected to the science network with independent NIC cards. The raw data from the ME70 can be recorded to a portable USB drive or to a location on the network. Portable drives plugged directly into USB ports on the ME70 machine will likely be the solution of choice given the rotating science missions using the platform. The raw data can also be broadcast, but only to one port at a time. This broadcast is set up in the `server` tab in the ME70 `remoting` configuration; the `client` tab interfaces to the TRU (Figure 9).
For the mapping work, we set this data broadcast to the card connected to the Hypack computer. Other applications (e.g. the Simrad TD50 real time water-column visualization software) may require the broadcast to be on the science network. While it is possible to receive the data packets from the ME70 on the Hypack machine via the science network, we do not recommend this configuration for mapping work because of the unknown capacity and possibly variable latencies over this network.

The POS navigation and attitude data is passed to the Hypack computer via a switch. The Hypack software receives the raw full water-column beam-angle and power datagram from the ME70 and calculates bottom detections using code based on code developed by Dr. Tom Weber. These bottom detections are saved in the RMB message in the Hypack HSX file.

3.4.2.1 Important Timing Aspects for This System

The ME70 does not handle time synchronization like a modern multi-beam. It does not accept a ZDA-PPS input to ensure the precise discipline of the internal clock, and uses the computer clock for a time source. This can cause problems with matching attitude and position to bathymetry. The timestamp of the Hypack RMB record (i.e. the bathymetry) is from the time in the ME70 datagram header. These timestamps are from the ME70 computer system time. The timestamps of the navigation and motion data recorded in the HSX file come from the POS timestamping at the source. If these two clocks (the ME70 system clock and POS) do not agree, significant artifacts will manifest in the processed bathymetry. Unlike most modern bathymetric systems, the fisheries mode ME70 does not have an input for time or a GPS pulse per second (PPS) input to discipline the internal clock. Left alone, the internal clock can drift significantly with the result that the bathymetry time stamps drift out of line with the motion time stamps from the POS system. Shimada does have a timeserver, but the ME70 had not been on the same network and had not been receiving time corrections. We corrected this during this work and configured the ME70 clock to fall under the control of the timeserver. We strongly recommend confirming that the ME70 time is identical to the POS time during mapping work.

For the data logged on this cruise, the time difference between the ME70 time stamp and the NMEA message time (from the POS) from the ME70 logged .raw file is shown in Figure 10. The time difference was approximately 21 seconds at the start of data acquisition and drifted approximately 0.2 seconds per
hour. In addition, jitter of ± 0.02 seconds is common. During this acquisition, the operator confirmed that the ME70 system clock matched the POS time within a second. The root-cause of this 21 second offset is currently unknown.

![Figure 10: Time difference between the ME70 time stamp and the NMEA time stamp. Initial difference was 21 seconds with a drift rate of approximately 0.2 seconds per hour.](image)

Although the full data rate NEMA attitude record is logged in the raw ME70 record, the ME70_Raw2GSF.exe code uses the heave, pitch, and roll from the raw ping header. The time stamping of this attitude data is from the header time, which is also from the ME70 system clock. As a result, even if there are significant time mismatches between the ME70 and POS clocks, the time stamps of the attitude and bathymetry will match; they might be wrong, but they will be consistently wrong. This is the primary reason that Hypack logged data from these systems has had significant motion artifacts in situations where the Matlab processed GSF data did not. Disciplining the ME70 clock with the timeserver should remedy this mismatch. This approach of using only the ping-header motion data does mean that the motion record in the Matlab/GSF processing route is necessarily at the ping rate, which can be quite slow, especially if pinging with the ME70 alternates with other sensors. This slow attitude data rate may cause data artifacts, particularly with the roll correction, if the system is not roll and pitch stabilized in the beam former. For mapping work, we recommend stabilizing the system for roll and pitch.

3.5 Ancillary equipment setup

3.5.1 Position and Attitude

The POS M/V was configured to send navigation (NMEA GGA string) and attitude (Simrad 3000 (Tate-Bryant)) to the ME70 via serial cables. The navigation and attitude was passed to the Hypack machine via Ethernet. Configuration screen shots are documented in the appendix. As discussed earlier, the POS-MV antennae were moved above the awning. While this position is vastly better than the previous position below the awning structure, the multipath environment is far from ideal. Figure 11 shows satellite availability metric for both the Shimada and Rainier for a common time period. Rainier was berthed on the same pier so the local environment most likely causes differences in satellite observations. Shimada saw much higher cycle slips, across all satellites, and at higher elevations.
Figure 11: GNSS Satellite observable statistics for common four-hour window from Shimada (left) and Rainier (right). Both vessels on same pier. Cycle slips indicate multipath. From top to bottom, panels are: cycle slips by satellite, cycle slips by elevation, number of available satellites, satellite availability for primary receiver, and satellite availability for secondary receiver. Cycle slips, indicated by hashes on the bottom two panels, are much higher on Shimada.

Because of the relatively high multipath environment, the GPS aided heading system (GAMS) in the POS-MV had difficulty maintaining a precise heading solution. During alongside testing and during the first days of the cruise, the GAMS status would go offline and the heading accuracy drift up to 0.7° before re-converging. We installed an upgraded version of the POS-MV firmware (v9.13) on August 23. This upgrade includes improvements to the GAMS processing, and resulted in complete elimination of the heading excursions (Figure 12).

Figure 12: Heading performance with older POS firmware (left) and current release firmware (right). The new firmware greatly improves heading performance in a poor multi-path environment. Top panels show reported heading accuracy (note difference in scales). With older firmware heading uncertainty excursions were common. Bottom left panels are histograms of heading accuracy, bottom right panels are cumulative histograms.
3.5.2 Surface Sound Speed
Surface sound speed was provided to the ME70 by SCS. The personnel aboard were uncertain of the sensor and sensor location providing this measurement. We did get values into the ME70, but recommend validating this input with comparison to a cast.

3.5.3 Hypack
Hypack takes POS motion and attitude via a LAN distribution hub, raw bathymetry data from the ME70 workstation dedicated network, and is connected to the ship science network for data transfer.

3.5.4 Horizontal and Vertical control
The POS was configured to accept the WAAS corrector signal and thus the horizontal and vertical GPS based positions are relative to WGS84. The vertical reference for acceptance work was the real time water level. Generally, data were collected in water deep enough that tidal effects were not significant enough to warrant the effort to attempt tidal corrections for the work in this report. For mapping work, we recommend using either an Ellipsoid Referenced Survey approach or using water level correctors. In the latter case, and depending on the accuracy desired, we recommend making draft observations before departure. We have based the HVF in the appendix on a design draft of 5.9 meters.

4 Alongside Testing
4.1 User interface and system control
Once configured, the ME70 user interface is straight forward, with the exception of setting the beam configuration and logging range, there are few operational adjustments required.

4.2 System health self-tests
The ME70 built in test environment (BIST) allows visualization of the element level output either as a time series (B-scan view) or as average value matrix by element location. Examples are shown in Figure 13. This view is useful in evaluating the overall correct operation of the system. The initial view (as shown in Figure 13) with apparently dead elements was resolved by restarting the TRU.

Figure 13: BIST test views showing selection from receive cycle. B-scan (left) shows a time series (vertical axes) by element number. Matrix (right) shows time averaged intensity over selected range. In this case, two boards (dark elements) had not started correctly.
4.3 Evaluate stave data
With the exception of the BIST test view, no element level data was recorded or analyzed.

4.4 Backscatter quality assessment
Backscatter quality was not assessed while alongside.

5 Underway Testing
5.1 Patch Test
Three patch test lines were run over the head of pioneer Canyon off San Francisco (Figure 14). This is the same area the NOAA Ship Fairweather was patch tested in 2014 and NOAA Ship Ruben Lasker in 2016; good reference data is available. Unfortunately, the beam configuration selected for this test (NWFSC_AcousticsHake) was limited in overall swath width (approximately 66° open angle compared to the 120° opening angle of the b31_sec120_xmitbyDecreasing beam configuration typically used for mapping). We also observed a significant timing error (approximately 20 seconds) between the bathymetry and the motion records logged in Hypack. Re remedied this for this test by loading the NMEA position and attitude from the ME70 raw file with the time stamp of the ME70 system. Issues of timing are discussed in more detail in section 3.4.2.1.

Three lines were run, two reciprocal lines for roll and patch and one offset for yaw. We used the reciprocal lines over flat sections of seafloor to solve for roll bias, and the same lines with the steep canyon walls to solve for pitch bias. The lack of overlap between the adjacent swaths due to the inappropriate beam configuration limits the usefulness of this test for resolving a yaw bias. We used parallel lines and the canyon wall to solve for the yaw bias, but the standard deviation of the experimental result was larger than the average offset, so we leave the yaw offset as zero.

Figure 14 - The patch test lines across the head of Pioneer Canyon. (left) shows general location southwest of San Francisco. (right) shows detail of three lines. Data is cleaned, corrected, and colored by depth. Chart background is 18680 with soundings in fathoms.
Table 2: Patch Test results. Bias is average of five measurements, uncertainty is from standard deviation. Yaw measurement hampered by lack of overlap between lines. Sign convention is per Caris HVF file.

<table>
<thead>
<tr>
<th>Patch Test Offsets</th>
<th>Bias (degrees)</th>
<th>Uncertainty (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roll</td>
<td>0.28</td>
<td>0.05</td>
</tr>
<tr>
<td>Pitch</td>
<td>-1.14</td>
<td>0.23</td>
</tr>
<tr>
<td>Yaw</td>
<td>-0.09</td>
<td>1.8</td>
</tr>
</tbody>
</table>

5.2 Acquire Reference Data Set
Because of the limited operational status of the ME70, no reference set was acquired.

5.3 Noise floor testing
Because of the limited availability of the system, no dedicated noise floor tests involving only the ME70 were conducted and no measurements of noise levels as a function of speed or equipment operation were conducted due to the limited nature of this cruise.

5.4 Target detection and recognition
No specific target detection or recognition tests were conducted during this cruise. However a wreck on the patch test lines off San Francisco was observed in the ME70 data. This wreck sits in 190 meters of water and is approximately 50 meters long. The wreck was clearly detected by the lines passing nearly over the wreck. Figure 15 shows a section of the eight meter surface over the wreck for both the ME70 and the Fairweather EM710 for comparison. While both systems are nominally 100 kHz multibeam systems, the resolution from the systems are significantly different. This is expected; the ME70 beam widths are 3-5 degrees, the EM710 has beam widths 0.5-1 degrees.

![Figure 15: Wreck at head of pioneer Canyon (190 meters depth) was detected by ME70 lines near nadir (left), though only half covered by logged data; Data from FA EM710 (right) shown for comparison. 2 x vertical exaggeration.](image)

5.5 Sonar Performance Parameters
The useable swath width as a function of depth is important to survey planning, survey quality, and survey efficiency. Because of the limited availability of the system, we conducted no specific tests of the swath width as a function of depth. Figure 16 shows the results from the Lasker, which should be comparable to this system.
5.6 Backscatter quality assessment
No backscatter was logged with the patch test lines.

6 Data Workflow Integration
6.1 Test application of post processed correctors
Post processing was conducted in Caris HIPS 10.0. The bathymetry data logged in the Hypack .HSX file is relative to the ME70 transducer face. As configured, the ME70 beam-former uses the surface sound speed and is stabilized for roll and pitch; however no other corrections are applied by the ME70 or Hypack during the bathymetric detection process. This is confusing because the ME70 accepts inputs for instrument offsets, heave, and sound velocity profiles. Adding to the confusion, many Kongsberg mapping systems do compensate for instrument offsets, heave, and do ray trace the bathymetric solutions to account for a given sound speed profile. Without the SIS bathymetry module, the ME70 does not. These inputs in the ME70 presumably do affect some available output records (e.g. the NMEA DBT telegram), but do not affect the data logged either in the ME70 .raw file or the Hypack logged .HSX file.

We configured the Caris HVF file to apply these offsets in Caris. The HVF used for the analysis in this report is included in the appendix. The reference point for the HVF matches the ship frame discussed in section 3.4.1 and is the granite block. Because the navigation and attitude are valid at this point, there are no offsets to these sensors. We recommend compensating for roll and pitch in the beam-former, and thus the ‘apply’ flag should typically be set to ‘no’ for these sensors. The patch test lines were acquired without stabilization, so for processing these lines, we set the ‘apply’ flag to yes. The ‘apply’ flag is set to ‘yes’ for heave and waterline because these are not corrected for elsewhere.
Heave is potentially problematic because of the timing issues discussed in section 3.4.2.1. The roll and pitch inputs to the ME70 are typically used to stabilize the beam former in real-time. The navigation and heave, however, are recorded in the HSX file with the POS timestamp. The bathymetry from the ME70 is recorded with the ME70 timestamp. If the POS and ME70 are synchronized to a common clock (e.g. the GPS constellation), the heave and bathymetry will be appropriately matched. If the ME70 is not synchronized to the POS time, the data records will not be appropriately matched during Caris processing. The MATLAB based code available to process ME70 bathymetry avoids this issue by using the navigation and heave logged in the .RAW file with the ME70 timestamp. Thus even if the ME70 clock is wrong, it is consistently wrong with all records.

Because of these issues, it is imperative that the ME70 is under the control of a timeserver synchronized to GPS based time.

The real time gridded display in Hypack (the Matrix) can be either corrected for heave, pitch, and roll or with corrected for motion at all; the ability to individually select only heave correction (as is needed here) is not available. With no corrections applied and beam stabilization enabled in the ME70, this will result in an apparent heave artifact in the real time data. This should not affect the extents of the coverage shown and does not cause any issue with downstream processing. Selecting to correct for roll, pitch, and heave will result in large motion artifacts in the real time display. Some application using the ME70 for concurrent quantitative water-column work, may wish not to stabilize the beams because of the variable effect on beam calibrations. This will work, but will require changes to the HVF (apply yes for heave, pitch, and roll), the real-time gridded display correction (correct for heave, pitch, and roll) and will make the system more sensitive to timing errors. This is because swath bathymetry is more sensitive to roll timing errors than any other input. For general mapping work, we recommend using beam stabilization.

6.2 Test data resolution and density
With the exception of the brief discussion in section 5.4, we conducted no specific resolution analysis.

6.3 Test bottom detection repeatability
Bottom detection repeatability was not performed.

6.4 Test total propagated uncertainty
The Hypack bottom detection algorithm does not determine real time uncertainty of the bottom detection, so a vessel model was used in Caris. The Caris device model does not appear to take into account the multiple phase detections within the across-track beam, which results in anomalously high uncertainty with the horizontal beam width set to the nominal 2.8 degrees. As discussed in [1], we obtain more reasonable results with a beamwidth of 1.5 degrees.

This approach is admittedly very crude. A more mature approach would model the uncertainty of each bottom detection. Dr. Weber’s Matlab based code does have this functionality, but was not tested here.

The device model updated with the 1.5 degree beam width is shown in Table 3. For use in Caris, this entry needs to be appended to the file devicemodels.xml (in Caris 10: C:\Program Files\CARIS\HIPS and SIPS\10.0\modules\HIPS and SIPS\support\devicemodels.xml)
7 Difference Surface
No difference surface with an established data set was performed.

8 Concluding Summary
We were able to successfully integrate the ME70 on the Bell Shimada with the necessary ancillary systems and conduct a very limited field verification. Some significant items should be addressed and tested before any dedicated mapping work is undertaken with this system; in particular:

1. The reliability and robustness of the ME70 hardware are a concern. We acquired very little data during this cruise because of power supply problems with the system.
2. Timing is an ongoing concern, and the root cause of the 21 second offset observed here is unknown.

The overall performance of the system was not well explored during the limited availability of the system. Should these systems become important components of mapping efforts, we recommend a dedicated effort to quantify performance and regular effort to ensure configurations and systems performance remains nominal. This is in keeping with idea and efforts of the Multibeam Advisory Committee in support of the academic research fleet (see: http://mac.unols.org/) and similar efforts by HSTB in support of the NOAA fleet supporting Coast Survey mapping efforts.

If the highlighted deficiencies are addressed and tested before the next scheduled operational use of this system for mapping purposes, the system may provide adequate performance as outlined in this report.
9 Works Cited


10 Appendices

Vessel Offsets – XYZ

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<tr>
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<tr>
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Note: center coordinates of ADCP and ME70 were determined at rim where bolts are mounted

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Calculations for HVF

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<th>down</th>
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Bell Shimada Draft Calculator

10.1 Vessel Offsets – Draft Calculations

Note: This derivation of draft based on GPS and draft marks observations 3/4/77

Design Draft: 5.90 m

Difference: 0.00

Residual Draft Correction: Positive value means ship is lower in water than design draft

4.04 m ERS determined water line to granite block at design draft of 5.90 m

-4.04 m distance from granite block to waterline - negative because block is below water.

Enter this as the waterline height in the Caris HFV

March, 2017, S. Greenaway

No connection was made in surveyed offsets to waterline - draft marks were not surveyed in to determine time.
10.2 Configuration Screen Grabs

10.2.1 ME70
To stabilize for roll and pitch (recommended), make sure these boxes are checked
10.2.2 POS M/V

Note: only COM1 and COM3 are used by the ME70.
10.3 Caris HVF

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10.4 Acquisition Logs

None