OPR-K354-KR

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

DATA ACQUISITION AND PROCESSING REPORT

Type of Survey: Hydrographic Multibeam & 200% Sidescan

Project Number: OPR-K354-KR-09

Time Frame: July 2009

LOCALITY

State: Louisiana

General Locality: Gulf of Mexico

2010

CHIEFS OF PARTY
Scott Croft, John Baker

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DATE:

NOAA FORM 77-28 (11-72)	U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION	REGISTRY No: H12048 OPR-K354-KR-09
HYDROGRAPHIC TITLE SHEET **Data Acquisition and Processing Report**		
		FIELD NUMBER: Sheet A

State: Louisiana

General Locality: Gulf of Mexico

Locality: Entrance to Terrebonne Bay

Scale: 1:20,000 Date of Survey: July 2009

Instructions Dated: May 2009 Project Number: OPR-K354-KR-09

Vessels: M/V *Inez McCall*

Chiefs of Party: Scott Croft, John Baker

Surveyed by: C&C Technologies Personnel

Soundings taken by echosounder, hand lead line, or pole: Simrad EM3002 Multibeam Echosounders

Verification by: C&C Technologies Personnel

Soundings in: Feet: X Fathoms: _____ Meters: _____ at MLW: _____ MLLW: X

Remarks: Multibeam Hydrographic Surveys
Data collection in meters, referenced to MLLW, later converted into feet
200% side scan sonar coverage
UTC time
Grab samples
Tidal Zones and Correctors from NOS, CO-OPS

NOAA FORM 77-28 SUPERSEDES FORM C & GS - 537

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A. EQUIPMENT

The major operational systems used to acquire hydrographic data were the Simrad EM3002 multibeam echo sounder, the Klein 5000 side scan sonar. A combination of PCs and Sun Workstations were used to collect and process the data. All computers were networked to allow for precise time tagging and georeferencing of the data, and for efficient data transfer.

System	Manufacturer	Model
Multibeam Sonar	Simrad	EM3002
Side Scan Sonar	Klein	5000
Single Beam Sonar	ODOM	Echotrac DF3200 MK II
Motion Sensor	Applanix	POS MV
Primary Positioning System	CNAV	2050
Secondary Positioning System	CNAV	2050
Tertiary Positioning System	Applanix	POS MV
Sound Speed at Transducer	Endeco	YSI
Sound Velocity Profiler	Seabird	SBE19 Plus

A.1 SURVEY VESSELS

Survey operations were conducted aboard the *Inez McCall.* This 108-foot survey vessel was leased from Cameron Offshore Boats, of Cameron, Louisiana. A vessel diagram and specifications chart is included in Appendix A. The diagram shows all offsets from the vessel center reference points to the antennas and to all survey equipment. The specifications of the vessel include the registration number, capacity, and equipment.

A.2 SINGLE BEAM SONAR OPERATIONS

An Odom Echotrac was used to collect single beam data. This data was continuously recorded and monitored in real-time as an independent check of the nadir beam (bottom-detect) of the multibeam sonar system.

A.3 MULTIBEAM SONAR OPERATIONS

Survey operations were conducted using a single head Simrad EM 3002. The transducer head was mounted at the base of a pole attached to the bow of the vessel. Multibeam sonar operations were conducted in a manner such that the accuracy and resolution standards set forth in Section 5.2 of the Specifications and Deliverables document were met. The swath was reduced to an angular sector of 45° to 60°, which provided over 2 times water depth of coverage and ensured that the detection criteria of being able to detect a 2 x 2 x 1 meter object was met. The survey speed was generally held to under 8.5 knots, and with a ping rate of 10-15 per second, the criterion of 3.2 beam footprints per 3 meter along track distance was easily met.

C&C Technologies' proprietary Hydromap software was used for multibeam data collection, quality assurance, and quality control. Simrads SIS (Seafloor Information System) software was used as the control software for the multibeam. This software allowed sound velocity, attitude, and position to be applied realtime. Data was then sent to Hydromap to be recorded. During data collection, the quality of the data was monitored in real time. The display included a coverage map, several ping display waterfalls, and other parameter displays. These tools allowed the operator to monitor coverage, compare between single beam and multibeam depths, compare between the different positioning systems, and identify any ray-bending effects in real time. Corrective measures were made whenever necessary, ensuring that only quality data was collected. In cases where reruns were necessary due to degraded quality of data or due to lack of coverage, this was recorded and the data later rerun.

A.4 SIDE SCAN SONAR OPERATIONS

The Klein 5000 side scan sonar was operated in a towed configuration. The tow point was at the stern of the boat, 17.97 meters astern of the vessel reference center.

Survey operations were conducted at speeds between 4 and 8.5 knots, exceeding the requirement that a 1-meter target be ensonified a minimum of three times per pass. The side scan sonar was operated at a range scale of 100 meters for all main lines, and was reduced to 50 meters for investigation work. Due to the shallowness of the water, the side scan sonar was frequently towed at heights of less than the required 8 to 20 percent of the range scale. Confidence checks were performed a minimum of once a day.

Chesapeake Technologies SonarWiz software was used for data collection and processing of the side scan sonar data.

B. QUALITY CONTROL

B.1 MULTIBEAM

All multibeam and single beam data collected for OPR-K354-KR-09 was processed using Caris Hips and Sips 6.1. Prior to importing any sounding data into Caris, a Hips vessel file (.hvf) was created. This vessel file includes significant physical dimensions of the vessel, as well as error estimate values for all major equipment integral in the collection of the data. Error estimates assigned to the survey equipment utilized in determining the ships dimensions and physical offsets between equipment were based upon the manufacturers specifications. Error estimates assigned to major survey equipment used in determining water depths and horizontal positions were based upon manufacturers specifications as listed within the TPE resource link provided on the Caris web page. The vessel file used for this project is included in the Caris project submitted in conjunction with this report.

In order to allow for more efficient processing of the data, subareas were treated as independent surveys. Following the completion of processing of all subareas

within a survey, the areas were combined into a single project on an external USB hard drive for submission to the Atlantic Hydrographic Branch for review.

Caris project directory structures were created according to the format required by Caris. All lines converted were assigned a project, vessel, and day.

Multibeam data collected was reviewed in the swath editor, and erroneous bathymetry was rejected from the project.

Separate BASE surfaces were created for each subarea. BASE surfaces were named as recommended by the NOAA Specs and Deliverables. All BASE surfaces were created as uncertainty surfaces with a single resolution of 2 meters. All BASE surfaces were created based upon the IHO Order 1 standards.

The standard deviation layers of the BASE surfaces were used as a basis for data cleaning. Areas of high standard deviation were investigated by all means appropriate, including the subset editor, swath editor, and comparison to side scan sonar data. If data was found to misrepresent the seafloor, it was rejected.

All contact investigation data was cleaned in the swath editor before being incorporated into a BASE surface. After data was cleaned in swath editor, the data was reviewed in the subset editor and, if needed, a designated sounding was assigned to the least depth sounding of an identified contact.

After all data had been cleaned, and all least depths on contacts had been designated, all BASE surfaces were finalized for submission.

B.1.2 PARAMETERS

During collection the swath width was ran between 100 and 110 degrees. A high-density setting was used in the SIS software to increase the ping rate during collection, and no angular restrictions were used. Multibeam coverage requirements were greatly exceeded.

B.2 SIDE SCAN

B.2.1 REVIEW PROCESS

All sidescan data was reviewed at least twice. The side scan operator reviewed all data during collection and noted in the survey logs any significant features or surface/water column effects. The data was then reviewed for a second time by a geoscientist.

The reviewer first decided the order in which to view the lines. Since we were producing mosaics as proof of coverage it was best to view all lines in the first 100% first and then the remaining lines second. This way the coverage map that was generated during the review process contained only the data for the lines that were to be used for that particular mosaic (first or second 100% coverage).

B.2.2 CONTACT SELECTION

As each line was reviewed sonar contacts were tagged and recorded. All contacts with shadows were recorded. All existing infrastructure, such as pipelines, wells, platforms, and buoys was tagged, as were other features. All contacts which displayed a height of 1 meter or greater, calculated from shadow length, were deemed to be significant within water depths of 20 meters or less, per Attachment #1 of the Statement of Work; Specifications and Deliverables. Other contacts may have been deemed significant based on their characteristics (dimensions, strength of return, etc.). Contacts were tagged, recorded and plotted in AutoCAD.

Sonar contacts from adjacent lines were correlated and noted in the sonar contact table.

B.2.3 PROOF OF COVERAGE

As the geoscientist reviewed the data a coverage map was produced. Any gaps in coverage were noted, logged in the rerun log, and brought to the attention of the party chief and the operators on shift.

For the coverage map requirement of the interim and final deliverables, we submitted side scan sonar mosaics. A mosaic for each 100% of coverage was submitted. These mosaics served as another quality control tool. The mosaics were not only used for coverage but could be used to correlate contacts seen on adjacent lines. The mosaic images were also overlain with the nautical charts, sonar contact plot and bathymetry data to give a full picture of the survey area.

C. CORRECTIONS TO ECHO SOUNDINGS

C.1 INSTRUMENT CORRECTIONS

No instrument corrections were necessary.

C.2 VESSEL CONFIGURATION CORRECTIONS

Prior to survey operations, offsets to the antennas and other survey equipment were measured. Offsets were measured from the Central Reference Point (CRP) to all relevant points on the survey vessel (bow, stern, antennas, transducers, etc.) using traditional survey techniques incorporating plumb bobs, tape measures, and digital levels. CRPs were established as an arbitrary point on the central along track axis of the vessel within one meter of the multibeam, and single beam echo sounders.

The results of the vessel survey are shown in diagram form in Appendix A.

C.3 STATIC AND DYNAMIC DRAFT CORRECTIONS

A Settlement and squat test was performed before the start of survey operations. The vertical corrections applied to the data, described in the following chart, varied with speed. All values were post applied in Caris.

Inez McCall (07/08/2009) – Performed south of Cameron, LA in the Gulf of Mexico

Vertical Correction (m)	Speed (m/s)
0.029	1.54
0.034	2.06
0.095	3.09
0.156	4.12

The *Inez McCall* is equipped with a draft tube, which was read at least once daily while at sea. Water level/draft entries were updated in the system as required.

Lead lines were performed on a daily basis aboard the vessel. In larger sea conditions and water depths greater 10-12 meters, leadlines were not taken in order to avoid misreadings.

C.4 VESSEL MOTION CORRECTIONS

A POS/MV motion sensor was integrated with the multibeam echosounder aboard the *Inez McCall* to provide real-time heave, pitch, and roll corrections. The POS MV also provided Tertiary navigation for the vessel.

Prior to the survey, a standard patch test was performed to determine correctors for latency, pitch, roll, and heave. Patch tests were performed in the following manor.

Latency:

Two lines were run directly over the same target. The line was run once at a slow speed (<4 knots) and again at a fast speed (>8 knots). The location of the target was

inspected and had there been a difference in its location on each of the passes, latency would have been calculated. No timing error was detected.

Pitch:

A set of reciprocal lines was run over the target at a low speed.

Heading:

Two sets of collinear reciprocal lines were run

Roll:

A set of collinear, reciprocal lines were run.

The results of these tests are shown in the table below.

Inez McCall (June.10, 2009 – South of Port Fourchon, La.):

Roll	Pitch	Heading
-4.557°	9.3°	3.28°

C.5 SOUND VELOCITY CORRECTIONS

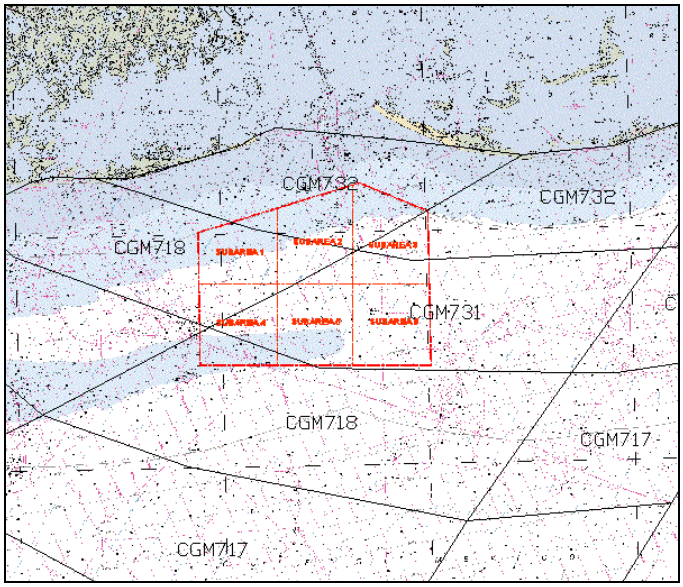
A Sea Bird Electronics 19plus CTD was used for speed of sound measurements. Casts were performed at least once daily and more often as needed. The multibeam data was corrected for the water column sound velocity in real-time. The mean water column sound velocity was applied to the single beam echosounder data. Endeco YSI sound speed profiles were used to determine sound speed at the transducers.

C.6 TIDE AND WATER LEVEL CORRECTIONS

Tide and water level corrections were applied as set forth in the Statement of Work.

Tides were applied to all data in Caris using tidal data downloaded form the NOAA CO-OPS website, and corrected using a tidal zone definition file (.zdf) supplied by NOAA. This zone file, called K354KR2009CORP.zdf, uses station number 8762075 (Port Fourchon, LA) as the primary gauge, and station number 8761724 (Grand Isle, LA) as the secondary gauge. Because there were no gauge outages during the survey, station 8761724 was not used for any tide corrections.

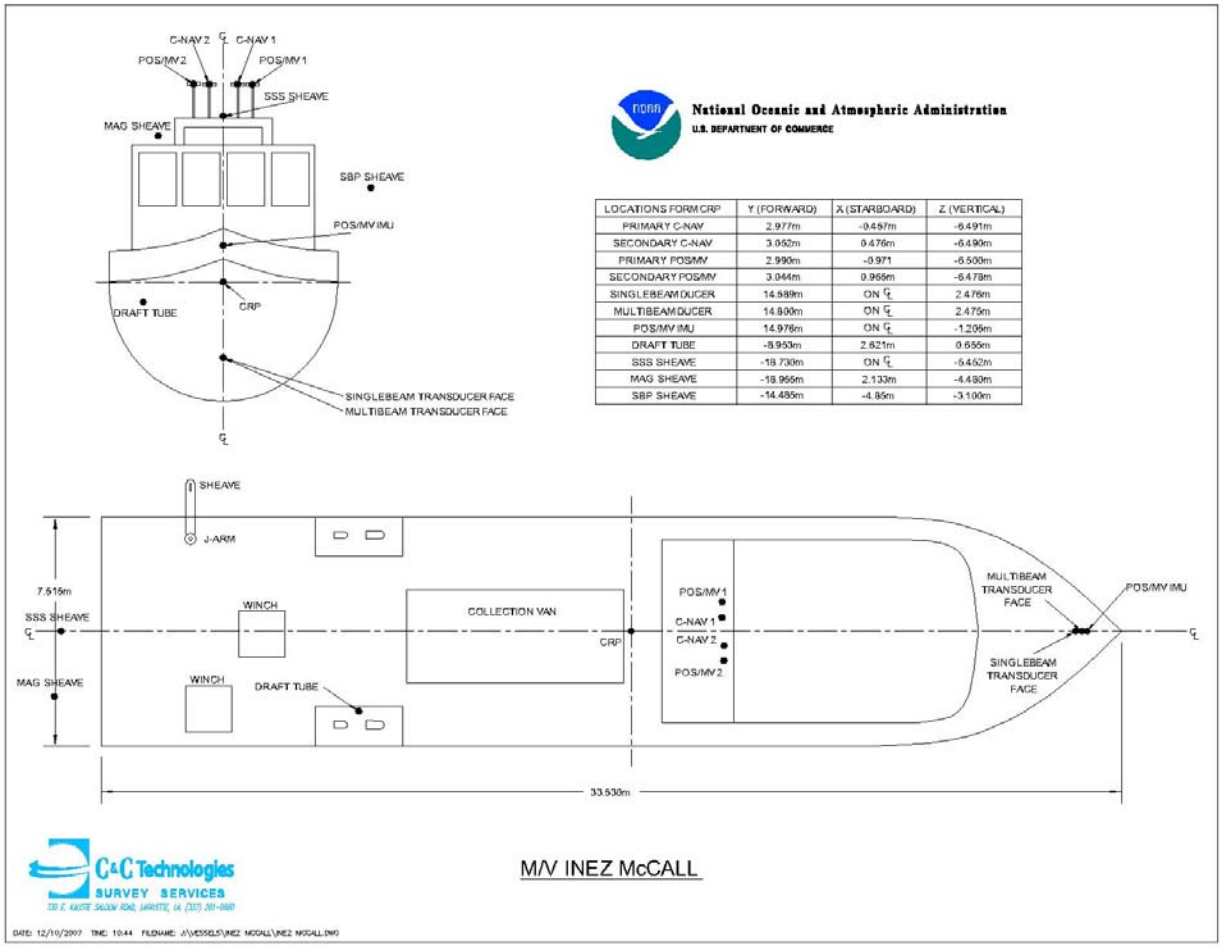
The image below shows the layout of the tide zones within the survey area.



The tide (.tid) and zone definition (.zdf) files are included in the Caris projects submitted in conjunction with this report.

APPENDIX A - VESSEL DESCRIPTIONS

INEZ McCALL



LOCATIONS FORM CRP	Y (FORWARD)	X (STARBOARD)	Z (VERTICAL)
PRIMARY C-NAV	2.977m	-0.457m	-6.491m
SECONDARY C-NAV	3.052m	0.476m	-6.490m
PRIMARY POS/MV	2.990m	-0.971	-6.500m
SECONDARY POS/MV	3.044m	0.966m	-6.478m
SINGLEBEAM DUCER	14.989m	ON ℄	2.476m
MULTIBEAM DUCER	14.900m	ON ℄	2.475m
POS/MV IMU	14.976m	ON ℄	-1.206m
DRAFT TUBE	-8.953m	2.621m	0.655m
SSS SHEAVE	-18.730m	ON ℄	-5.462m
MAG SHEAVE	-18.955m	2.133m	-4.480m
SBP SHEAVE	-14.485m	-4.85m	-3.100m

VESSEL PROFILE

Vessel Name	INEZ McCALL

Owner/Operator	Cameron Offshore Vessels
Flag/Home Port	USA/Cameron, La
US Coast Guard Official Number	648625
Year Built	1982
Place Built	Biloxi, MS
Hull Material	Steel
Official Number	648625
Intended Service	Supply Vessel
Operational Area	Gulf of Mexico
Tonnage Certificate	Issued by ABS
Loadline Certificate	Issued by ABS
Certificate of Classification	Issued by ABS full hull & machinery

SPECIFICATIONS

Length	108 ft. LOA
Breadth	24 ft
Depth	11.5 ft
Draft (summer load)	8 ft
Gross Tonnage	92 US regulation tons
Net Tonnage	63 US regulation tons

APPENDIX B – EQUIPMENT DESCRIPTIONS

ODOM ECHOTRAC DF3200 MK II SINGLE BEAM ECHOSOUNDER

This dual frequency survey echo sounder employs a high-resolution thermal printer, microprocessor, DSP techniques, and flat screen displays.
The sonar transceiver, echo processor, graphical operator interface and hardcopy recorder are all housed in one portable, splash-proof case. The unit is suited to table top, bulkhead, or rack mounting and is equally for small survey launches as it is on large ships. Well suited for use in the shallows of rivers and harbors, the mission variable unit is also capable of working to depths of over 2,000 meters.

Features

FREQUENCIES: Either single or dual frequency configurations of the unit are available: Standard frequencies are 200 and 24khZ or 210 and 33kHz.

Optional frequencies:

High – 100kHz to 1MHz
Low – 10kHz to 60 kHz

PRINTER: The high-resolution thin-film thermal print head measures 216mm. (8.5") wide. Resolution is 8 dots/mm. (023/in) along the print axis and 8 lines/mm along the paper axis. The unit is capable of printing up to 16 shades of gray.
DISPLAY: The Graphical LCD module (320 x 200 pixels) measures six inches diagonally (156.4mm). Fluorescent Back Lighting (CFL) of the paper white display provides excellent visibility in all light conditions. In dual frequency operation, both high and low frequency depth values are displayed continuously.
KEYPAD: a 16 NEMA 12 sealed unit with tactile feedback is used by the operator for parameter selection and numerical value entry. Ten digits, Up, Down, Left, and Right arrow keys, Decimal Point/Help and Enter keys are provided.

DIGITIZER: The bottom tracking capabilities of the unit are enhanced by utilizing the DSP capabilities of the digitizer processor. These DSP algorithms yield reliable bottom detection even in the presence of high ambient noise and multiple returns.

Communications

INTERFACING & ANNOTATION: **Four bi-directional RS-232 serial ports are standard. Depth information is output after each sounding cycle with the standard string including values for both the high and low channels in dual frequency operation. Output strings conforming to other major echo sounder formats are available. In addition, system parameters can be configured via comm1. The ECHOTRAC accepts annotation of up to 80 characters (printed on the Fix Mark Line). Standard NMEA formats from GPS receivers as well as proprietary strings from positioning and navigation systems can also be annotated on the chart. Interfacing to data acquisition systems is asynchronous and does not require handshaking.**

Controls

ANALOG CONTROLS: **Immediate access to critical analog controls is via front panel potentiometers and switches. They include: Receive Sensitivity, AGC (Automatic Gain Control) Transmit Power, and Threshold (digitizer level). Also mounted on the front panel are controls for the printer including: Chart ON/OFF, Paper advance, Paper Take-up, and Mark.**

Specifications:

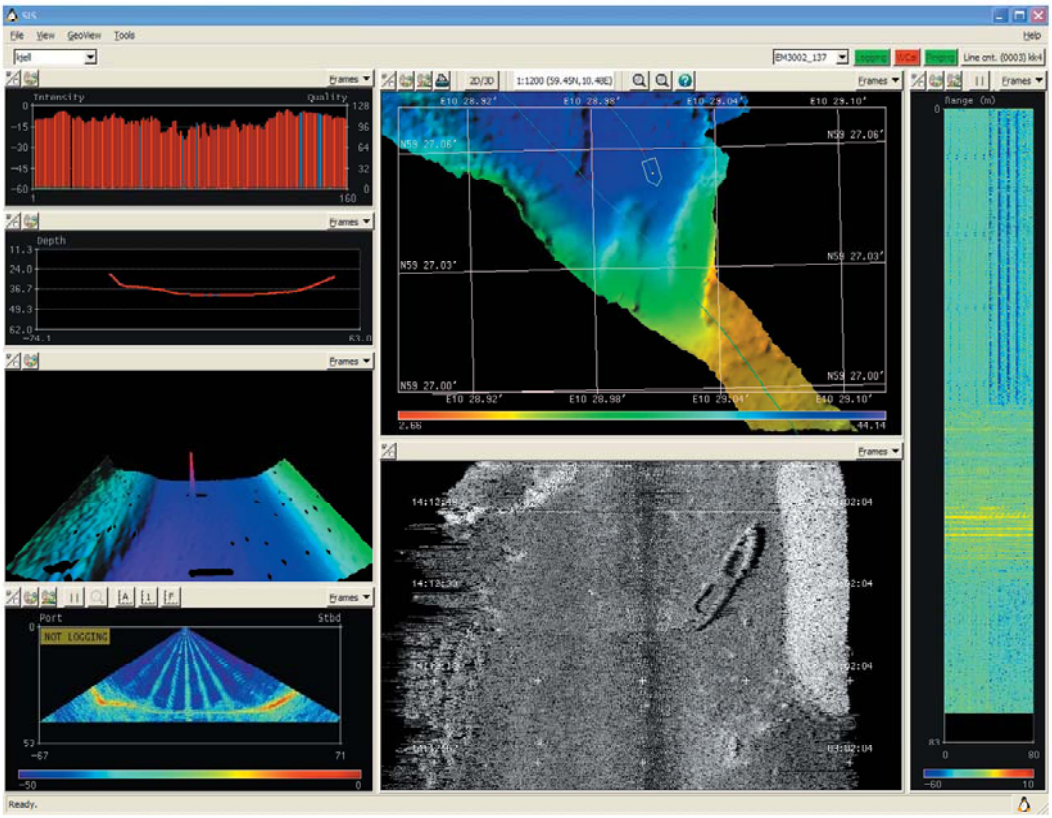
Frequency	200 kHz
Output Power	500 Watts
Power Requirement	18-32 VDC 110/220 VAC (50/60 Hz.)
Ports	RS 232

EM 3002

KONGSBERG

Multibeam echo sounder

The new generation high performance shallow water multibeam



(855-164771 / Rev.D / March 2004)

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SURVEY SERVICES

System description

Key facts

The **EM 3002** is a new advanced multibeam echo sounder with extremely high resolution and dynamically focused beams. It is very well suited for detailed seafloor mapping and inspection with water depths from less than 1 meter up to typically 150 meters in the ocean. Maximum depth capability is strongly dependant on water temperature and salinity, up to 300 meters is possible under favorable conditions. Due to its electronic pitch compensation system and roll stabilized beams, the system performance is stable also in foul weather conditions.

The spacing between soundings as well as the acoustic footprints can be set nearly constant over the swath in order to provide a uniform and high detection and mapping performance. Dynamic focusing of all receive beams optimizes the system performance and resolution for short range applications such as underwater inspections.

Typical applications

- Mapping of harbours, inland waterways and shipping channels with critical keel clearance
- Inspection of underwater infrastructure
- Detection and mapping of debris and other underwater objects
- Detailed surveys related to underwater construction work or dredging
- Environmental seabed and habitat mapping
- Mapping of biomass in the water column

Features

The EM 3002 system uses one of three available frequencies in the 300 kHz band. This is an ideal frequency for shallow water applications, as the high frequency ensures narrow beams with small physical dimensions. At the same time, 300 kHz secures a high maximum range capability and robustness under conditions with high contents of particles in the water.

EM 3002 uses a new and very powerful sonar processor in combination with the same sonar head used with the popular and highly acclaimed EM 3000 system. The increase in processing power makes it possible to apply sophisticated and exact signal processing algorithms for beamforming, beam stabilisation, and bottom detection. The bottom detection algorithm is capable of extracting and processing the signals from only a part of each beam, thus making it possible to obtain independent soundings even when beams are overlapping.

EM 3002 will in addition to bathymetric soundings, produce an acoustic image of the seabed. The image is obtained by combining the acoustic return signals inside each beam, thus improving signal to noise ratio considerably, as well as eliminating several artifacts related to conventional sidescan sonars. The acoustic image is compensated for the transmission source level, receiver sensitivity and signal attenuation in the water column, so that reliable bottom backscatter levels in dB are obtained.

The acoustic seabed image is compensated for acoustic raybending and thus completely geo-referenced, so that preparation of a sonar mosaic for a survey area based upon data from several survey lines is easy. Objects observed on the seabed image are correctly located and their positions can be readily derived.

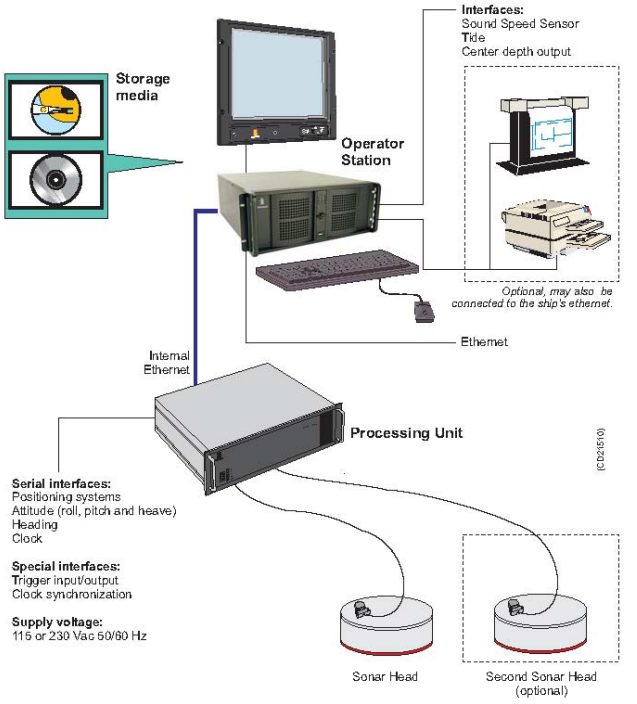
Operator Station

The Operator Station is a ruggedized PC workstation running on either Linux® or Microsoft Windows XP®. The Operator Station software, SIS, has been completely redesigned and expanded compared to the EM 3000 software, adding 3D graphics, real-time data cleaning and electronic map background.

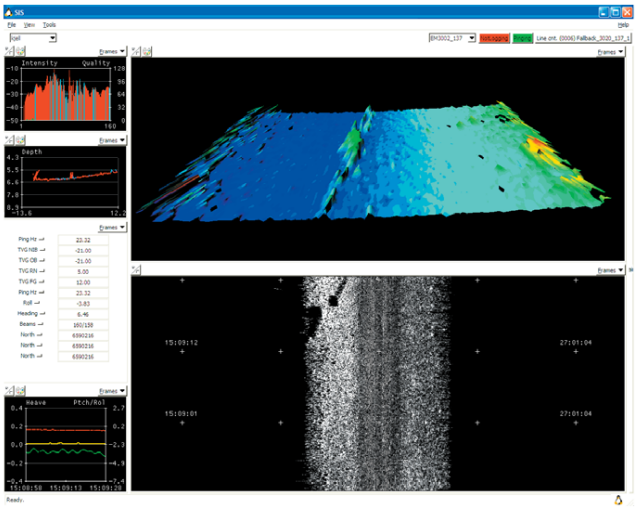
The EM 3002 can be set up to use other operational software than SIS, for example QPS "QINCy" or Coastal Oceanographics "HYPACK Max", and is also supported by software from Triton Elics International, EIVA and others.

Note that Kongsberg Maritime AS does not take any responsibility for system malfunction caused by third-party software.

- Full swath width accuracy to the latest IHO standard
- Swath width up to 10 x water depth or 200 m
- Depth range from < 1 meter to > 150 meters
- Bottom detection by phase or amplitude
- 100% bottom coverage even at more than 10 knots vessel speed
- Real-time ray bending and attitude compensation
- Seabed image (sidescan) data output
- Sonar heads for 500 or 1500 meters depth rating



Typical system configuration with desktop Operator Station, Processing Unit and one or two Sonar Heads.



This is an example on how the SIS software can be used.

Advanced functions

- Bottom detection uses a combination of amplitude and phase processing in order to provide a high sounding accuracy over the whole swath width.
- All beams are stabilized for pitch and roll movements of the survey vessel, by electronically steering the transmit beam as well as all receive beams.
- Dynamic focusing of the receive beams is applied in order to obtain improved resolution inside the acoustic near-field of the transducer.
- Swath coverage with one sonar head reaches 130 degrees, but can be manually limited while still maintaining all beams inside the active swath. For deeper waters the swath width will be reduced due to reduced signal-to-noise margin. The system will automatically re-locate all beams to be within the active swath.
- With two sonar heads the swath width will reach 200 degrees to allow for inspection of constructions up to the water surface, as well as for efficient mapping of beaches, rivers and canals.
- Operator controlled equidistant or equiangular beam spacing.
- Real time compensation for acoustic raybending is applied.
- Imaging of objects in the water column is offered as an option.

C&C Technologies
SURVEY SERVICES

Technical specifications

Operational specifications

Frequencies ..... 293, 300, 307 kHz
Number of soundings per ping:
- Single sonar head ..... Max 254
- Dual sonar heads ..... Max 508

Maximum ping rate ..... 40 Hz
Maximum angular coverage:
- Single sonar head ..... 130 degrees
- Dual sonar heads ..... 200 degrees

Pitch stabilisation ..... Yes
Roll stabilisation ..... Yes
Heave compensation ..... Yes
Pulse length ..... 150 µs
Range sampling rate ..... 14, 14.3, 14.6 kHz
Depth resolution ..... 1 cm
Transducer geometry ..... Mills cross
Beam pattern ..... Equidistant or equiangular
Beamforming:
- Time delay with shading
- Dynamically focused receive beams

Seabed image data

- Composed from beamformed signal amplitudes
- Range resolution 5 cm.
- Compensated for source level and receiver sensitivity, as well as attenuation and spherical spreading in the water column.
- Amplitude resolution: 0.5 dB.

External sensors

- Position
- Heading
- Motion sensor (Pitch, roll and heave)
- Sound velocity profile
- Sound velocity at transducer.
- Clock synchronisation (1 PPS)

Environmental and EMC specifications

The system meets all requirements of the IACS E10 specification.The Operator Station, LCD monitor and Processing Unit are all IP22 rated.

Dimensions and weights

Sonar head:
- Shape ..... Cylindrical
- Housing material ..... Titanium
- Diameter ..... 332 mm
- Height ..... 119 mm
- Weight ..... 25 kg in air, 15 kg in water
- Pressure rating ..... 500 m (1500 m option)

Sonar Processing Unit:
- Width ..... 427 mm
- Depth ..... 392 mm
- Height ..... 177 mm
- Weight ..... 14.5 kg

Operator Station:
- Width ..... 427 mm
- Depth ..... 480 mm
- Height ..... 127 mm
- Weight ..... 20 kg

17.4" industrial LCD monitor:
- Width ..... 460 mm
- Depth ..... 71 mm
- Height ..... 400 mm
- Weight ..... 9.2 kg
- Resolution ..... 1280 x 1024 pixels

All surface units are rack mountable. Dimensions exclude handles and brackets.

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KONGSBERG

KLEIN 5000 SIDE SCAN SONAR

Conventional side scan sonar systems use a single sonar beam per side to generate an image of the seafloor. The physics of this type of sonar results in degradation of image resolution with range and requires speeds of 5 knots or less to insure 100 percent bottom coverage. From a design perspective, both of these shortcomings can be eliminated by designing a side scan sonar that, through beam steering and focusing techniques, simultaneously generates several adjacent, parallel beams per side. This design approach, principally employed by military side scan sonar systems designed for high-speed mine hunting applications, has been prohibitively expensive for commercial operations. Klein Associates is the first commercial company to offer a multi-beam side scan sonar using similar design techniques to military sonars, but at a fraction of the cost.

The two main benefits of the high-speed, high-resolution 5000 systems are: higher towing speeds with no loss of bottom coverage and range independent high-resolution imagery capability. Since operation costs are dependent on the amount of at-sea time required to complete a survey, the new Klein 5000 Multi-Beam Side Scan Sonar Systems with survey speeds more than twice that of conventional side scan sonars, minimize at-sea time, thus greatly reducing survey costs.

The sonar system consists of a towfish, tow cable, transceiver/processor unit (TPU), and a PC display and control unit for viewing data. The stainless steel towfish incorporates two multi-channel acoustic arrays and a pressure bottle that houses all of the electronics and sensors necessary for sonar data acquisition, attitude sensing, system control and telemetry. The sonar and sensor data is transmitted up the tow cable via a high-speed digital telemetry link, requiring only a single coaxial or fiber-optic cable. The surface mounted TPU receives this data, performs all necessary digital processing functions on the acoustic data, and relays control command to the towfish. Processed data is then distributed to one or multiple PC Display and Control Units (DCU) via a 100 Base T Ethernet LAN Network where the tasks of data viewing, storage and analysis can be accomplished.

The Klein 5000 is a 5-beam side scan sonar designed for hydrographic applications requiring high- resolution images of the seafloor and bottom obstructions while operating at tow speeds up to 10 knots and with an overall swath width of 300 meters. Applications of the side scan sonar include hydrographic surveys, mine hunting, pipeline surveys, debris searches, archaeological surveys, geologic surveys and autonomous underwater vehicle surveys. Specifications for the Klein 5000 are outlined below:

Towfish

Number of beams:	5 Port / 5 Starboard
Frequency:	455 kHz
Pulse Length:	50 to 200 usec. (operator selectable)

Resolution Along Track: 20 cm @ 75 meter range, thereafter increasing to a maximum of 36 cm @ 150 meter maximum range
Resolution Across Track: Determined by selected pulse length
Operating Speed Envelope: 2 – 10 knots @ 150 meter maximum range
Sonar Digitization: 12 bit / channel
Maximum Operating Range: 150 meters (300-meter swath)
Array Length: 120 centimeters (47.2 inches)
Body Length: 194 centimeters (76.4 inches)
Body Diameter: 15.2 centimeters (6 inches)
Weight in air: 70 kg (155 lbs.)
Sensors: Heading, pitch, roll, temperature and pressure
Tow Cable: Coaxial or fiber

Transceiver Processor Unit

Width:	19-inch rack mount
Height:	13.2 centimeters (5.2 inches)
Depth:	54.6 centimeters (21.5 inches)
Weight:	12.7 kilograms (28 pounds)
Voltage:	115/240 VAC; 50/60 Hz
Power:	120 Watts
Navigation Input:	NMEA 0183
Data Output:	100 Base-T Ethernet LAN
PC Display/Control Unit:	Klein ruggedized or customer supplied PC

C-NAV DIFFERENTIAL GPS

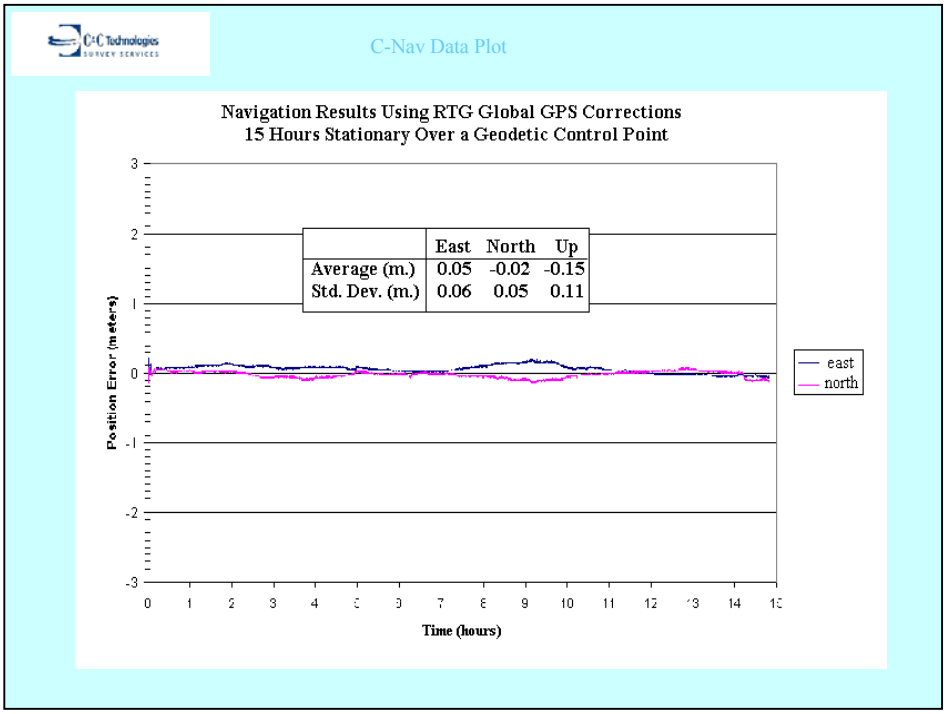
C-Nav is a globally corrected differential GPS system owned and operated by C & C Technologies, Inc. The C-Nav GPS Receiver combines a dual-frequency, geodetic grade, GPS Receiver with an integrated L-BAND communication RF detector and decoder all linked by an internal microprocessor. C-Nav uses monitoring stations strategically located around the globe to provide worldwide accuracies in the order of 0.25m (1 sigma)*.

The technique, developed by the Jet Propulsion Lab for the National Aeronautics Space Administration, uses a global network of reference stations to track the entire constellation of GPS satellites. The raw GPS observations are transmitted via the Internet back to the Network Control Center where the GPS constellation satellite orbital corrections and clock-offset values are calculated and modeled in real-time. These corrections are universally valid and can be applied to GPS measurements from any location on earth.

The multi-function antenna assembly is capable of receiving the L1 and L2 GPS frequencies as well as the Inmarsat L-BAND receive frequency band. The gain pattern of this antenna is designed to be relatively constant even at lower elevations. This allows for an efficient link budget when the unit is operated at higher latitudes where the elevation of the geo-stationary communication satellite is low and close to the horizon. Atmospheric delays are eliminated from local measurements by comparing the L1 and L2 frequencies in the internal GPS receiver.

The C-Nav GPS System provides an output of RTCM (Type 1) pseudorange differential correction messages via a second RS232 interface. Raw GPS observation information can be collected from the C-Nav GPS Receiver system for recording and analysis. The raw GPS observation information can be converted to RINEX ASCII data (observation and navigation) file format as and when required.

The C-Nav GPS Receiver requires at least four (4) usable GPS satellites to compute a three dimensional (3D) solution. The C-Nav GPS Receiver will yield an autonomous horizontal position accuracy of 2 to 5 meters (1 sigma), depending on the GPS satellite geometry configuration and tracking (DOP index values).



Receiver Specifications:
Features
Real-time sub meter accuracy
Single integrated package – simple installation
Rugged, waterproof housing
Wide-range (10-40VDC) power supply
RTCM and NMEA {GGA, GSA, RMC, VTG, ZDA) outputs
Patented multipath mitigation significantly reduces noise
Geodetic quality dual frequency GPS virtually eliminates ionospheric effects
Performance
L-band receiver frequency
Automatically selected 1525 to 1560 MHz
GcGPS Accuracy:
Position (H): <30cm
Position (V): <70cm

{1–sigma and HDOP ≤ 1}
Velocity <0.02m/s
Time to first fix: Cold Start: 90 sec(typical)
Reacquisition
Coast for 30 sec with GPS lock <2sec
L-band loss with less than 30 sec with GPS lock <30 sec

Physical/Environmental

Size: 9.2 in (H) x 7.2 in (D) (24.8 x 18.7 cm)
Weight: 5.5 lbs (2.4 kg)
Power: Input voltages: 10-40 VDC
Consumption: <10W average power
1.2 A max @12 VDC
I/O Connector 8 pin waterproof connector
Temperature: Operating: -20°C to +70°C
Storage: -40°C to 85°C
Humidity: 100% non-condensing

Display Unit Specifications:

Features
4 x 20 character LCD screen
12 key membrane button input pad
Rugged, stainless steel housing
Wide-range (20-40VDC) power supply
RTCM and NMEA and raw data outputs
Physical/Environmental
Size: 9.6 in (L) x 6.7 in (W) x 3.3 in (H) (24.4 x 17.0 x 3.3 cm)
Weight: 3.8 lbs (1.75 kg)
Power: Input voltages: 20-40 VDC
Consumption: <1W average power
100 mA max @28 VDC typical
I/O Connectors: 3 db-9, 1 cat-5 and 1 8 pin waterproof connector
Temperature: Operating: -20°C to +70°C
Storage: -40°C to 85°C
Humidity: 100% non-condensing

APPLANIX POS MV ATTITUDE AND POSITIONING SYSTEM

APPLANIX - THE PREFERRED CHOICE OF MARINE SURVEY

Applanix is transforming the world of marine mobile mapping. As pioneers of the first commercial position and orientation systems for marine survey vessels, and now with over 10 years of established market leadership, we supply superior technology, expertise, and support to customers, partners, and equipment manufacturers around the world. With over 500 systems in use worldwide, the Applanix POS MV is the "industry standard" in positioning and orientation systems for hydrographic vessels.

The APPLANIX Marine Team

We have the industry's most experienced team of marine survey engineers, geospatial experts, and quality assurance personnel – all here to guarantee you the highest quality solution and the highest level of performance. Every Applanix product comes with our company-wide commitment to world-class customer care, so whether you're looking for information on using your system with a new sensor, or just need some expert advice, Applanix is here to serve you in any way.

POS MV™

The Applanix POS MV system is a GPS-aided inertial navigation system which provides a complete set of position and orientation measurements, including exceptional estimates of heave and ellipsoidal altitude. POS MV was launched onto the world market in 1996 and since that time has been the industry leader for users who are serious about making the most of their investment in multibeam technology.

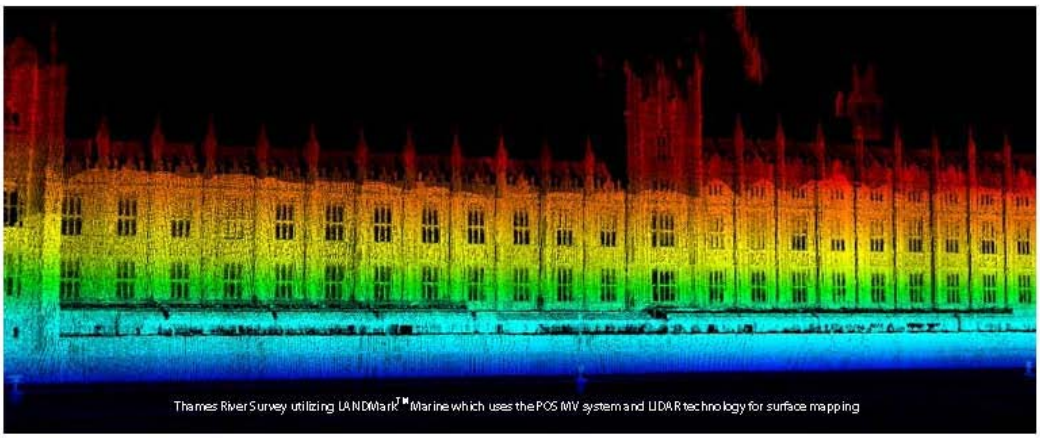
The POS MV 320, POS MV Elite and the POS MV WaveMaster (for smaller survey launches) are tightly-coupled systems which use Applanix' unique approach to Inertially-Aided Real-Time Kinematic (IARTK) technology. They are user-friendly, turnkey systems which maintain positioning accuracy under the most demanding conditions, regardless of vessel dynamics.

With its high data update rate, POS MV delivers a full six degrees-of-freedom position and orientation solution. The POS MV is designed for use with multibeam sonar systems, enabling adherence to IHO (International Hydrographic Survey) standards on sonar swath widths of greater than ± 75 degrees under all dynamic conditions.

The POS MV Elite offers true heading accuracy without the need for dual GPS installation and offers users the highest degree of accuracy in motion measurement for their marine applications

TrueHeave Technology
Applanix has redefined accuracy and reliability of heave data with TrueHeave. Based on advanced two-sided filtering techniques, TrueHeave uses both past and present vertical motion to compute a highly accurate heave estimate.

Hydrographic Mapping on the Ellipsoid
Unmeasured changes in the water level mean difficult challenges for hydrographers. Applanix has paved the way in providing centimetric level accuracy of the ellipsoidal altitude, allowing for coherent sea floor images to be obtained in even the most difficult tidal regimes.



Thames River Survey utilizing LANDMark™ Marine which uses the POS MV system and LIDAR technology for surface mapping

C&C Technologies
SURVEY SERVICES

POS MV BENEFITS

Applanix' POS™ technology was originally developed as part of an extensive military project. This proven technology was enhanced, customized and packaged to yield an off-the-shelf commercial product, uniquely suited to the requirements of precision marine motion sensing, hydrographic surveying and charting. It has been rigorously tested and proven in trials with numerous national hydrographic offices and commercial survey organizations. POS MV delivers:

- Reliable and repeatable performance under all dynamic conditions
  - Very low noise L1 and L2 carrier phase measurements
  - Superior low-elevation tracking performance regardless of latitude
  - Continuous sensor monitoring to compute a robust navigation solution. Continuity of all data is thereby assured when GPS reception is compromised
- Improved accuracy and productivity with "TrueHeave"
  - TrueHeave software enables heave data to meet and exceed the highest marine industry standards. TrueHeave users reap the double benefits of significant improvements in accuracy and productivity.
- Immunity to GPS outages
  - Provides almost instantaneous reacquisition of RTK following GPS signal loss. The system uses accurate inertial data aided by GPS observables from as few as one satellite to compute a robust navigation solution, thereby assuring continuity of all data including position and heading when GPS reception is compromised. Short-term loss of GPS does not significantly degrade the POS MV roll, pitch or heading solution.
- Robust centimetric positioning with Inertially Aided RTK
  - Applanix' proprietary Inertially Aided RTK (IARTK) algorithms enable the rapid re-acquisition of fixed integer RTK positioning. In difficult GPS environments POS MV with IARTK affords a significantly more robust and accurate position solution than can be achieved with stand-alone RTK.
- Operation in a high multipath environment
  - POS MV uses high performance GPS components that enable excellent carrier phase tracking capability even in a high multipath environment. The result is robust, dynamically accurate true heading data to accuracy better than 0.02°.
- Post-Processing Capabilities
  - POS MV is the only marine POS solution with post-processing capabilities.
- Self-Calibration
  - POS MV continually monitors the status of its sensors and if required, automatically reconfigures itself to provide the best navigation solution.
- Upgradeability
  - POS MV uses the latest Trimble BD960 24-channel GNSS receivers with Trimble Zephyr L1/L2 antennas. POS MV offers a low cost upgrade path from DGPS to L1/L2 IARTK (Applanix' unique tightly coupled Inertially Aided RTK technology) without modifying the hardware.

THE COMPONENTS

POS MV provides the functionality of a GPS receiver, gyrocompass and conventional motion sensor in a single, user-friendly, turnkey solution:

POS Computer System (PCS):

The PCS contains firmware to perform all functions necessary to control the IMU and GPS receivers, outputting

data in the correct format to interface with other systems aboard the survey vessel. The processor software functions include the Strapdown Inertial Navigation Algorithm to compute velocity, roll, pitch and true heading from the accelerometer and gyro outputs, a Kalman filter that estimates long term drift in the inertial solution using GPS aiding measurements, and an error corrector that applies the Kalman Filter estimates to the strap-down navigator to continually calibrate the inertial sensor. The PCS also contains a GPS Azimuth Measurement Subsystem for computing true heading from carrier phase measurements output by the dual GPS receivers. The processor firmware and software provide sensor calibration, and also fault detection, isolation and automatic reconfiguration.

Inertial Measurement Unit (IMU):

The IMU contains 3 high quality gyroscopes and 3 high quality accelerometers. The IMU is entirely solid state for high reliability, and is housed in its own rugged, water and salt resistant case. Power for the IMU is provided by the PCS.

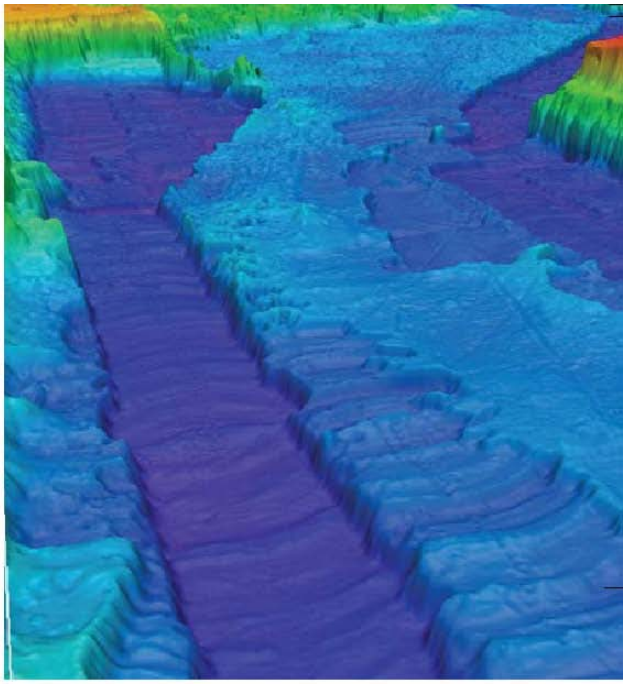
GPS Sub-system:

The GPS subsystem is comprised of two antennas and two low noise, survey grade twelve channel receiver cards embedded in the PCS. The GPS subsystem computes position to 0.02 m with optional RTK, or 1 m or better with standard differential corrections.

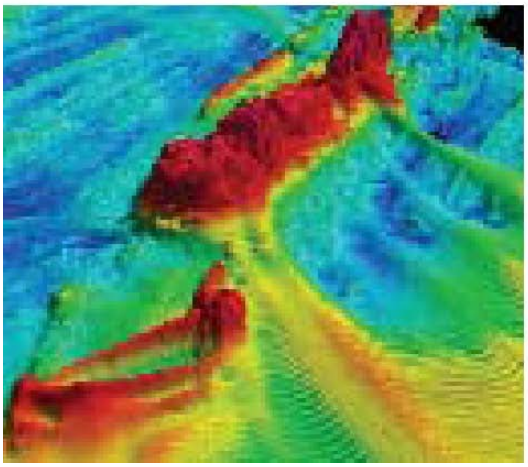
APPLICATIONS

Whether in shallow, narrow or rough waters where the GPS environment may be compromised by large vessels, cranes and other dock-side structures, or in calm and open seas, the POS MV system provides accurate, robust results in the following applications:

- Harbour Mapping
- Seafloor Mapping
- Dredging
- Wreck and Salvage Charting
- Surface Mapping with LIDAR



Above right: Multibeam image of dredged channel.
Bottom right: USCGC Healy in Northern latitudes.
Below left: Multibeam image.



SEACAT Profiler

SBE 19*plus*

The SBE 19*plus* is the next generation *Personal CTD*, bringing numerous improvements in accuracy, resolution (in fresh as well as salt water), reliability, and ease-of-use to the wide range of research, monitoring, and engineering applications pioneered by its legendary SEACAT predecessor. The 19*plus* samples faster (4 Hz vs 2), is more accurate (0.005 vs 0.01 in T, 0.0005 vs 0.001 in C, and 0.1% vs 0.25% — with *seven* times the resolution — in D), and has more memory (8 Mbyte vs 1). There is more power for auxiliary sensors (500 ma vs 50), and they are acquired at higher resolution (14 bit vs 12). Cabling is simpler and more reliable because there are four differential auxiliary inputs on two separate connectors, and a dedicated connector for the pump. All exposed metal parts are titanium, instead of aluminum, for long life and minimum maintenance.

The 19*plus* can be operated without a computer from even the smallest boat, with data recorded in non-volatile FLASH memory and processed later on your PC. Simultaneous with recording, real-time data can be transmitted over single-core, armored cable directly to your PC's serial port (maximum transmission distance dependent on number of auxiliary sensors, baud rate, and cable properties). The 19*plus*' faster sampling and pump-controlled TC-ducted flow configuration significantly reduces salinity spiking caused by ship heave, and allows slower descent rates for improved resolution of water column features. Auxiliary sensors for dissolved oxygen, pH, turbidity, fluorescense, and PAR can be added. For moored deployments, the 19*plus* can be set to *time-series* mode using software commands. External power and two-way real-time communication over 10,000 meters of cable can be provided with the SBE 36 CTD Deck Unit and Power and Data Interface Module (PDIM).

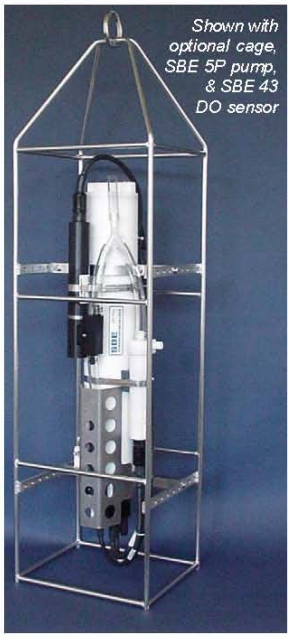
The 19*plus* uses the same temperature and conductivity sensors proven in 5000 SEACAT and MicroCAT instruments, and a superior new micro-machined silicon strain gauge pressure sensor developed by Druck, Inc. Improvements in design, materials, and signal acquisition techniques yield a low-cost instrument with superior performance that is also easy to use. Calibration coefficients, obtained in our computer-controlled high-accuracy calibration baths, are stored in EEPROM memory. They permit data output in ASCII engineering units (degrees C, Siemens/m, decibars, Salinity [PSU], sound velocity [m/sec], etc.).

Accuracy, convenience, portability, software, and support: compelling reasons why the 19*plus* is today's best low-cost CTD.

CONFIGURATION AND OPTIONS

A standard SBE 19*plus* is supplied with:

- Plastic housing for depths to 600 meters
- Strain-gauge pressure sensor
- 8 Mbyte FLASH RAM memory
- 9 D-size alkaline batteries
- Impulse glass-reinforced epoxy bulkhead connectors: 4-pin I/O, 2-pin pump, and two 6-pin (two differential auxiliary A/D inputs each)
- SBE 5M miniature pump with plastic housing for depths to 600 meters, and T-C Duct


Shown with optional cage, SBE 5P pump, & SBE 43 DO sensor

Options include:

- Titanium housing for depths to 7000 meters
- SBE 5M miniature pump with titanium housing in place of plastic housing
- SBE 5P (plastic) or 5T (titanium) pump in place of SBE 5M for use with dissolved oxygen and/or other pumped sensors
- Bulkhead connector for use with PAR sensor
- Sensors for oxygen, pH (for integration in Profiling mode only), fluorescence, light (PAR), light transmission, and turbidity
- Stainless steel cage
- MCBH *Micro* connectors in place of glass-reinforced epoxy connectors
- Nickel Metal Hydride (NiMH) or Nickel-Cadmium (Ni-Cad) batteries and charger
- Moored mode conversion kit with anti-foulant device fittings

SOFTWARE

The SBE 19*plus* is supplied with a powerful Windows 2000/XP software package, SEASOFT®-Win32, which includes:

- SEATERM® — communication and data retrieval
- SEASAVE® — real-time data acquisition and display
- SBE Data Processing® — filtering, aligning, averaging, and plotting of CTD and auxiliary sensor data and derived variables

SBE
Sea-Bird Electronics, Inc.
1808 136th Place NE, Bellevue, Washington 98005 USA
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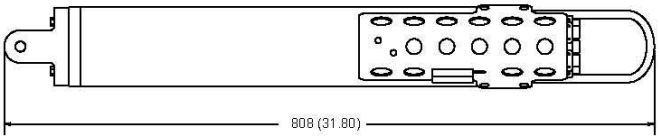
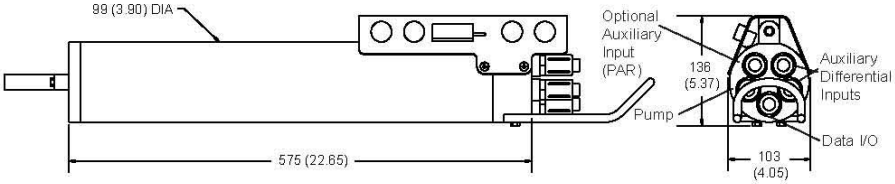
SEACAT Profiler

SBE 19*plus*



Dimensions in millimeters (inches)



SPECIFICATIONS

	Measurement Range	Initial Accuracy	Typical Stability (per month)	Resolution
Conductivity (S/m)	0 to 9	0.0005	0.0003	0.00005 (most oceanic waters; resolves 0.4 ppm in salinity) 0.00007 S/m (high salinity waters; resolves 0.4 ppm in salinity) 0.00001 S/m (fresh waters; resolves 0.1 ppm in salinity)
Temperature (°C)	-5 to +35	0.005	0.0002	0.0001
Pressure	0 to 20/100/350/600/ 1000/2000/3500/ 7000 meters	0.1% of full scale range	0.004% of full scale range	0.002% of full scale range

Memory 8 Mbyte non-volatile FLASH memory

Data Storage

Recorded Parameter	Bytes/Sample
T + C	6
pressure	5
each external voltage	2

Real-Time Clock 32,768 Hz TCXO accurate to ±1 minute/year

Internal Batteries 9 alkaline D-cells (Duracell MN1300, LR20) provide 60 hours profiling; optional 9-cell NiMH battery pack provides 40 hours profiling per charge; optional 9-cell Ni-Cad battery pack provides 24 hours profiling per charge

External Power Supply 9 - 28 VDC; consult factory for required current

Power Requirements

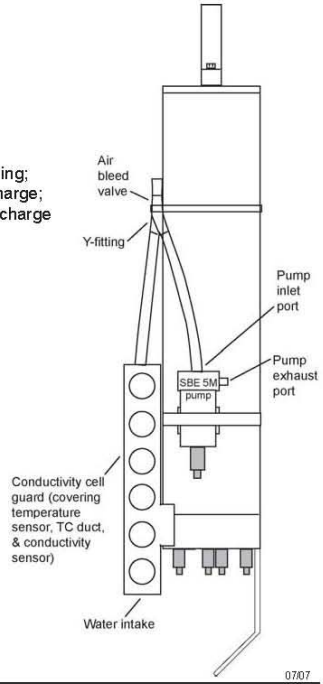
Sampling	65 mA	
Pump	SBE 5M: 100 mA	Optional SBE 5T or 5P: 150 mA
Communications	60 mA	
Quiescent	30 µA	

Auxiliary Voltage Sensors

Auxiliary power out	up to 500 mA at 10.5 - 11 VDC
A/D resolution	14 bits
Input range	0 - 5 VDC

Housing Materials, Depth Rating, Weight in air*, Weight in water*
Acetal Copolymer *Plastic* housing, 600 meter (1950 feet), 7.3 kg (16 lbs), 2.3 kg (5 lbs)
3AL-2.5V *Titanium* housing, 7000 meter (22,900 feet), 13.7 kg (30 lbs), 8.6 kg (19 lbs)
*Weights listed are without pump; pump adds (in air) 0.3 to 0.7 kg (0.6 to 1.5 lbs), depending on pump model selected. See pump brochures for details.

Optional Cage
1016 mm x 241 mm x 279 mm (40 in. x 9.5 in. x 11 in.), 6.3 kg (14 lbs)



Sea-Bird Electronics, Inc.
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Telephone: (425) 643-9866
Fax: (425) 643-9954

LETTER OF APPROVAL

Data Acquisition and Processing Report

H12048

This report is respectfully submitted.

Field operations contributing to the accomplishment of this survey were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report has been closely reviewed and is considered complete and adequate as per the Statement of Work.

John Baker

Chief of Party

C&C Technologies

January 2010