

Klein 5900 MULTI-BEAM SIDE SCAN SONAR

Technical Description



Revision 6.0



11 Klein Drive, Salem, NH 03079-1249, U.S.A.

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Klein 5900 Data Example



1. INTRODUCTION

Klein Marine Systems, Inc. (Klein) has over fifty years of experience with the development and manufacture of high-performance side scan sonar systems. Our side scan sonar systems are respected as the standard of excellence in the industry and are deployed by governments, navies, port authorities, surveyors, oil companies and academic institutions worldwide.

Klein's sonar systems have been used to locate the HMS Titanic, wreckage of the US Space Shuttle, downed aircraft including TWA Flight 800, Swiss Air Flight 111, John F. Kennedy Jr.'s plane and Egypt Air 990, a myriad of underwater antiquities like the Atocha, the Lusitania, the Edinburgh, the DeBraak, the Breadalbane, the Hamilton and Scourge, the Lake George Radeau (oldest warship in the U.S.), Sir John Franklin's HMS Erebus and countless others as well as performing the day to day work of Hydrographic Surveys. Klein employs an experienced staff of technical personnel, familiar with the ocean environment and committed to providing outstanding products and service.

Klein is the pioneer in Commercial Off the Shelf (COTS) Single- and Multibeam Side Scan Sonar technology. Unlike single beam side scan sonar systems whose along-track resolution degrades with increasing range, Klein 5900 Dynamically Focused Multibeam Side Scan Systems deliver constant along-track resolution, with 100% bottom coverage, at tow speeds that are two to three times higher than possible with single beam systems. The superior high-resolution, high-speed performance of the Series 5900 systems has made the product line extremely successful with many of the worlds navies and government organizations where it has become the system of choice used for hydrographic, Q-route surveys and detection of mine like objects (MLO's).

Since the introduction of the Klein 5900 systems as an upgrade to the Klein 5000 systems in 2010, over 20 systems have been deployed worldwide and most remain in service today. Some of the Government organizations using the Klein 5900 include:

- US Navy
- US Naval Oceanographic Office (NAVO)
- Royal Canadian Navy
- Royal Dutch Navy
- Latvian Naval Forces

2. Klein 5900 OVERVIEW

The Klein 5900 represents Klein's next generation multi-function sonar platform and includes the following key features:

- High Resolution Multibeam Side Scan Sonar
- Swath Bathymetric Sonar
- Nadir Augmented Imaging
- Optional Gap-Filler Sonar
- Integrated towbody sensor & subsystems
- Synchronized data processing
- High speed operation and full bottom coverage
- Remote controlled operation

2.1. HIGH RESOLUTION MULTIBEAM SIDE SCAN SONAR

The high resolution multibeam side scan sonar (MBSS) on the Klein 5900 improves on the performance of its predecessor Klein 5000, by employing advanced signal processing techniques and superior acoustic design to improve the overall along track target resolution by more than 100%. The Klein 5900 uses more than twice the number of acoustic channels available on the Klein 5000 series sonar along with an increase in frequency and acoustic aperture length to produce a much higher resolution along-track image. The along-track resolution of the Klein 5900 is 6.2 cm at 50 m range, 9.3 cm at 75 m range and 15 cm at 120 m range with a 0.07° beamwidth. The across track resolution of the Klein 5900 is constant for all operating ranges at 3.1 cm. Optimal range is 120 m per side and capable of 150 m per side

The Klein 5900 sonar is capable of producing sonar imagery similar in quality to that produced by military multibeam side scan sonar systems, which include the AQS-14 (Northrop Grumman, US) and the AQS-20 (Raytheon, US).

2.2. SWATH BATHYMETRIC SONAR

Integrated into the Klein 5900 sonar architecture is an Interferometric Swath Bathymetric Sonar (ISBS). This sonar uses advanced signal processing to produce simultaneous estimates of the seabed topography out to the full swath extent of the MBSS sonar, typically 10-12 times the overall altitude of the towfish per side. This data is co-registered with the resulting side scan backscatter imagery and can be used to position seabed targets more accurately. This added seabed topographic measurement capability is extremely advantageous when performing missions involving shallow water and rapid area assessment.

2.3. GAP-FILLER SONAR

The Klein 5900 Sonar System comes with an optional Gap-Filler Sonar (GFS) used to provide high resolution acoustic imagery in the vicinity of the side scan sonar “nadir gap.” All side scan sonar systems are incapable of adequately imaging the region directly beneath the sonar towbody. This resulting “nadir gap” region, which can be relatively large depending on the towbody altitude, can only be covered by executing a sonar survey which encompasses 100% overlap on reciprocal adjacent survey lines. This requirement can more than double the survey time necessary to achieve full bottom coverage. The GFS on the Klein 5900 operates synchronous with the MBSS and covers a sector directly below equal in width to 2 times the altitude, and ahead of the towbody path, resulting in full coverage over the entire sonar swath.

2.4. INTEGRATED TOWBODY SENSORS & SUBSYSTEMS

The Klein 5900 continues to support a complement of advanced third-party sensors and subsystems to produce a fully integrated set of sonar/sensor data to aid in mission-specific post processing applications. These sensors include water temperature, towbody depth, sound velocity and attitude.

The Klein 5900 also incorporates a precision acoustic altimeter which is used to accurately measure the distance of the towbody above the seafloor. This information is not only critical for the safe operation of the towbody during a survey, but it is also used to provide single-point depth measurements beneath the tow vehicle track.

The Klein 5900 supports several ancillary sensors such as precision magnetometers and ultra-short base line (USBL) acoustic responders for more accurate towbody positioning.

2.5. SYNCHRONIZED DATA PROCESSING

The 5900 system uses a combination of high-speed processing electronics and integrated hardware to accurately synchronize and time-stamp all sonar/sensor data with a time reference standard (1PPS via GPS). This is critical to ensure precise timing between sonar and sensor data to allow for accurate post processing.

2.6. HIGH SPEED OPERATION AND FULL BOTTOM COVERAGE

Similar to other products in the Klein 5000 sonar family, the Klein 5900 is designed to provide high resolution imagery over its full operating speed envelop while maintaining 100% bottom coverage. The Klein 5900 can operate at 14 Knots tow speed, while providing a sonar range of 120m (swath width of 240m) with 100% bottom coverage.

2.7. REMOTE CONTROLLED OPERATION

The Klein 5900 is designed for use by autonomous or semi-autonomous vessels allowing real time data collection and transmission from mine hunting missions without placing personnel in danger. The remote-controlled operation allows the Klein 5900 to gather data and transmit it securely while hosting other surveillance sensors. The Klein 5900 can be deployed from a variety of vessels while reduced data streams are transmitted to observation platform or other locations.

3. KLEIN 5900 SYSTEM BREAKDOWN

The Klein 5900 has a modular design for maximum flexibility in configuration and performance.

3.1. SYSTEM COMPONENTS

The following section provides a brief description of the Klein 5900 system components. Figure 1 and Figure 2 provide block diagrams of the towfish and topside electronics respectively.

3.1.1. SUBSEA COMPONENTS

Subsystem	Description
Multibeam Side Scan Sonar (MBSS)	Provides high resolution dynamically focused multibeam image data for multiple along track swaths each ping cycle for all range scales.
Swath Bathymetric Sonar (SBS)	This option provides swath bottom topography co-located with the MBSS data as a system option.
Gap Filler Sonar (GFS)	This option provides sector image data over a central swath equal in width to twice the altitude of the tow fish.
Klein 5900 Sonar Engine	Core electronics engine for the Klein 5900 tow fish; includes all data acquisition and control electronics, data telemetry, power conditioning, and transmitter electronics. Provides separate serial ports for external sensors including integrated sound velocity, temperature, pressure, attitude sensor, optional Responder, and optional Magnetometer. Decodes serial commands on downlink and routes them to the proper devices. Also provides external sensors with DC power.
Power Subsystem	Handles power distribution to all circuit cards in the subsea electronics. Custom ultra-low noise synchronous switching DC power supplies.

3.1.2. SUBSEA SENSOR COMPONENTS

Equipment	Description
Attitude Sensor	Provides roll, pitch and yaw angular rates, and heave, surge and sway accelerations of the tow fish.
Acoustic Altimeter	Measures altitude directly beneath the tow fish.
Interface for Optional Responder	Power and single ended TTL level trigger interface are provided for an optional responder
Sound Velocity, Pressure and Temp Sensor	Measures sound velocity, vehicle depth and water temperature.
Interface for Optional Magnetometer	Supports the power and RS-232 communication interfaces.

3.1.3. TOPSIDE ELECTRONICS COMPONENTS

Subsystem	Description
Topside Interface Unit (TIU)	TIU provides data telemetry interface and acts as data interface to the PCU. The TIU provides input/output for NMEA 0183 sentence formats from GPS, Magnetometer and Acoustic Positioning System. The TIU also provides trigger inputs and outputs for Acoustic Positioning System, external sensors and 1PPS input.
High Voltage Power Supply (HVPS)	Provides 300VDC to the TIU.
Processing Unit (PCU)	The PCU functions as a data server by receiving the raw sonar and sensor data along with GPS, time and date information from the TIU. The PCU also executes beamformer and interferometric bathymetry processing of the sonar data, time tags and formats the processed data for output to the Sonar Workstation
Ethernet Switch	8 Port Gigabit Ethernet Switch including 4 PoE Ports.
Sonar Workstation	Industrial PC used to host SonarPro data acquisition software. Includes monitor, keyboard, mouse and speaker for audio alarms.
GNSS Antenna	Optional or customer furnished – GNSS with 1 PPS time synchronization
Fiber Optic Interface (FOI)	Optional Fiber Optic Interface provides longer cable lengths operation via fiber-optic cable with Klein custom converter to copper in underwater cable termination
Towcable / Deck Cable / Slip Ring /	Towcable provides mechanical connection, power and data telemetry interface to the tow fish (via the deck and towcable). The electrical requirements for the Klein 5900 telemetry system require the use of a coaxial or F/O slip ring.

3.2. SYSTEM BLOCK DIAGRAM

3.2.1. SUBSEA BLOCK DIAGRAM

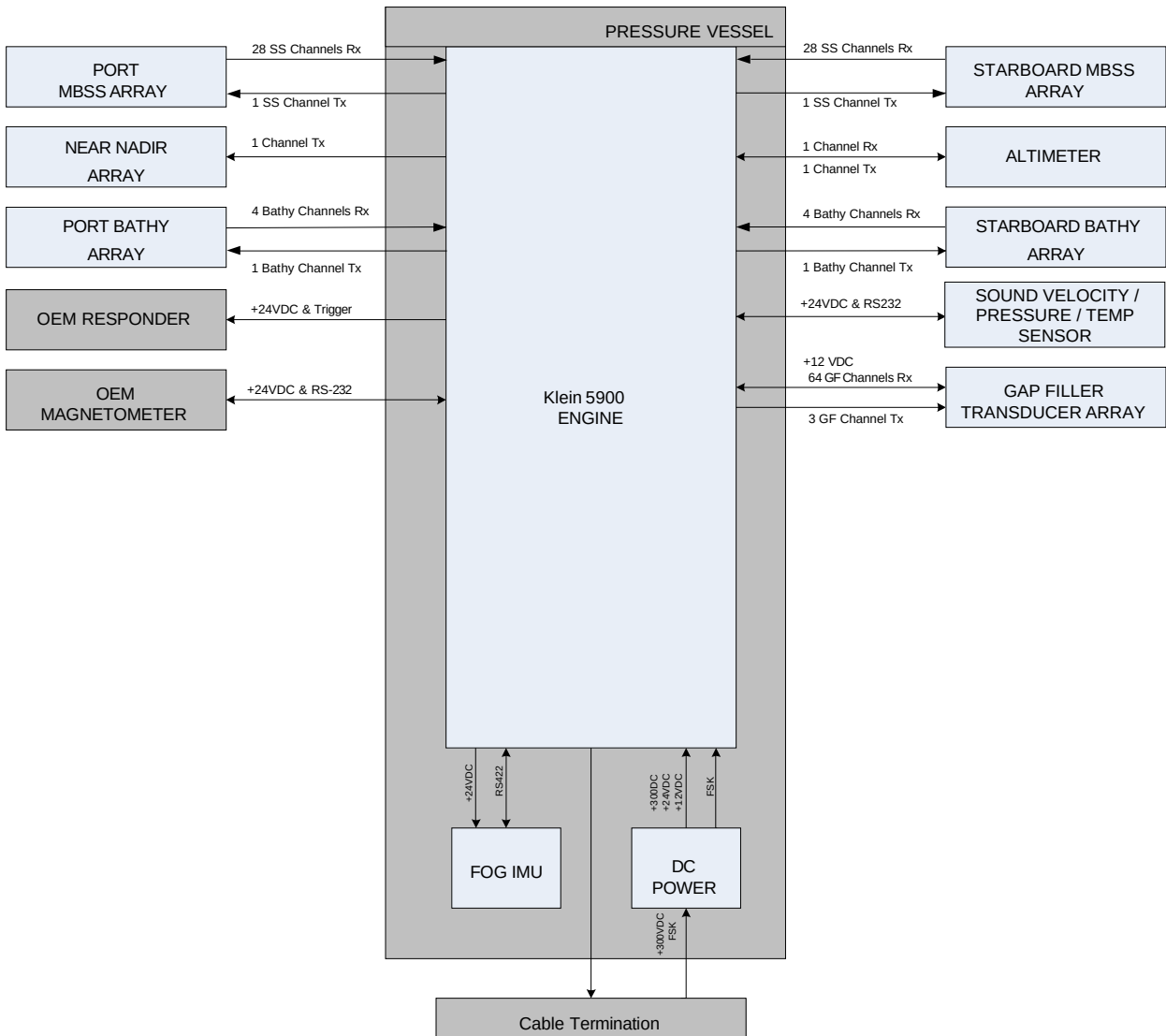


FIGURE 1 – SUBSEA BLOCK DIAGRAM

3.2.2. TOPSIDE ELECTRONICS BLOCK DIAGRAM

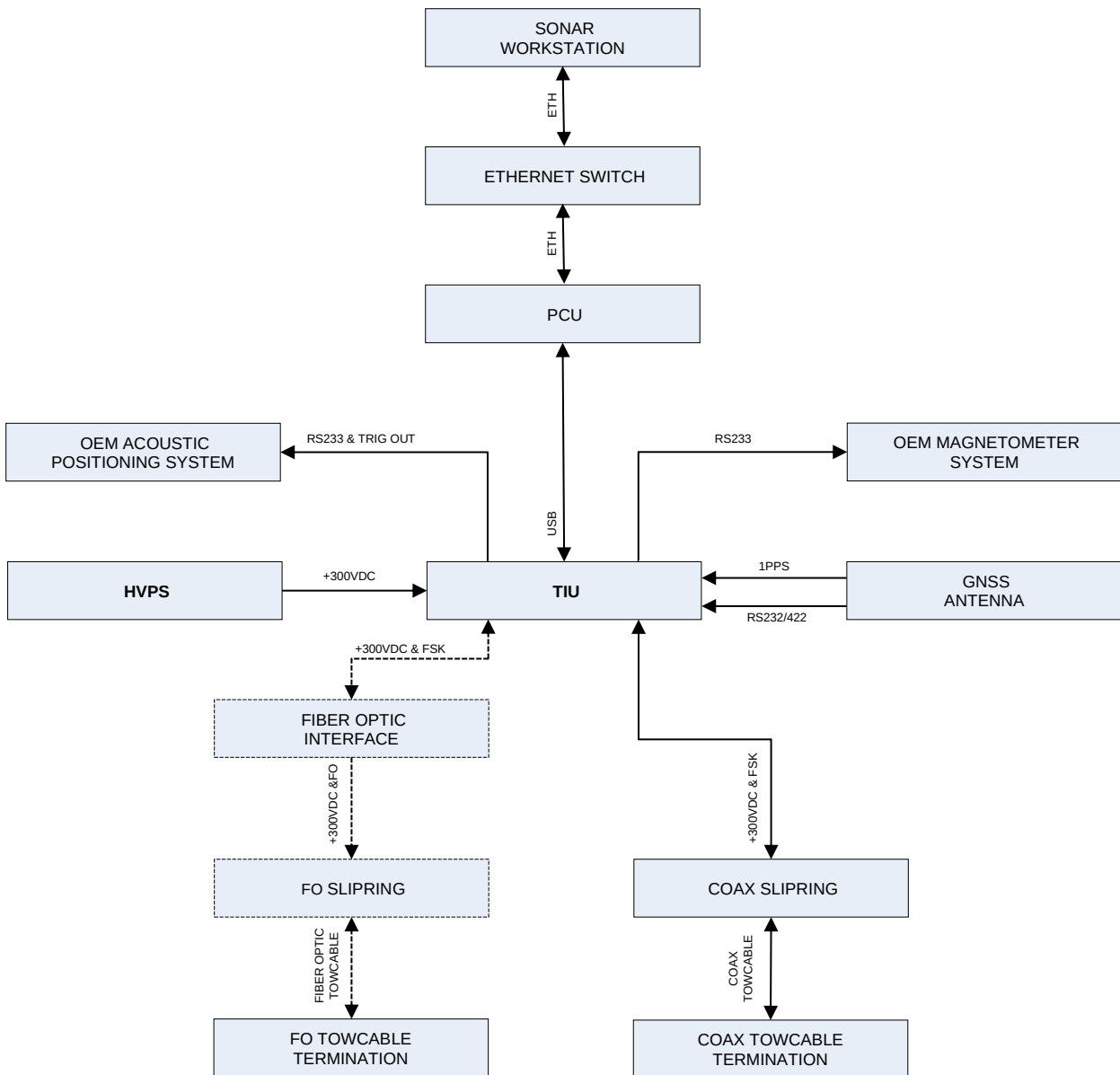


FIGURE 2 – TOPSIDE ELECTRONICS DIAGRAM

4. PERFORMANCE SPECIFICATIONS

4.1. GENERAL PERFORMANCE REQUIREMENTS

Operating Speed:	2-12 knots
Towfish height above seafloor:	10-15% of sonar range
Not to Exceed Operating depth:	750 m
Operating water temperature:	-2° to +35° C
Humidity:	20 – 100% (non-condensing)
Towcable:	Double armored 0.68" coaxial limited to 750 m. Fiber optic option available for extended cable lengths

4.2. MULTIBEAM SIDE SCAN SONAR SPECIFICATIONS

Maximum Operating Range	150 meters per side (300m swath)
Centre Frequency:	600 kHz
Number of beams:	Multiple beams per side sufficient to ensure 100% bottom coverage for all range scales.
Along-track resolution (constant)	6.2 cm at 50 m range setting (constant) 9.3 cm at 75 m range scale 15 cm at 120 m range scale [0.07° beamwidth]
Across Track Resolution:	3.2 cm
Along track coverage:	100% for all speeds
Transmit signal characteristics:	2 - 8 msec CHIRP
Maximum Range:	150 m nominal

4.3. INTERFEROMETRIC BATHYMETRIC SONAR SPECIFICATIONS

Frequency (fc):	450 kHz
Number of beams:	single beam (one per side)
Along track resolution:	0.5° beamwidth
Transmit signal characteristics:	2 - 8 msec CHIRP
Maximum Range:	120 m effective

4.4. GAP FILLER SONAR SPECIFICATIONS

Centre Frequency:	750 kHz
Across track coverage:	2 times altitude
Target imaging angle	30° grazing angle (from horizontal), orientation forward looking
Transmit Vertical Beam Width	15°
Transmit Horizontal Beam Width:	3 successive pulses, each 20° wide; offset $\pm 18^\circ$ & 0°
Transmit signal characteristic	4 msec CHIRP

5. PHYSICAL CHARACTERISTICS

When configured for towing, a typical 5900 system consists of a Towfish, Towcable, Topside Electronics Components located on the towing vessel. The physical characteristics of the towfish are provided in Figure 3.

5.1. SUBSEA - TOWFISH

Weight:	In air: 238 kg (525 lbs) In water: 179 kg (394 lbs)
Length:	Without Gapfiller: 2.36 m (93 inches) With Gapfiller: 2.80 m
Diameter	20 cm (8.0 inches)



FIGURE 3 – 5900 TOWFISH (SHOWN W/O GFS)

5.2. TOPSIDE - ELECTRONICS CONSOLE

The Topside Electronic Components are typically installed in an equipment console configured to support the system components. Figure 4 provides an example of a typical topside.

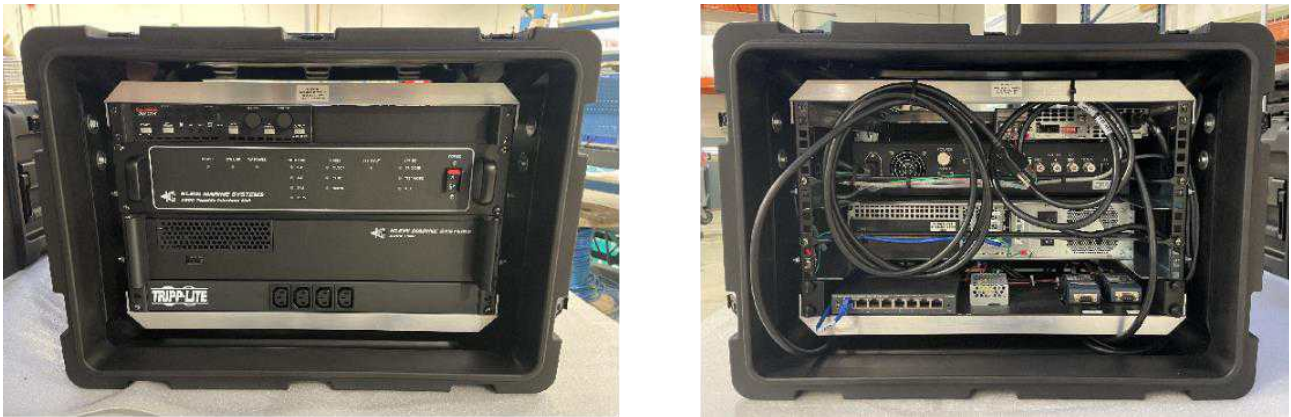


FIGURE 4 – TYPICAL TOPSIDE ELECTRONICS CONSOLE

6. GENERAL LAUNCH AND RECOVERY

The launch and recovery procedure described below is for informational use with the Klein 5900 on a vessel without a Launch and Recovery System (LARS). The general procedure is to launch the 5900 towfish with the ship at bare steerageway, increase speed and pay out the towcable. Recovery is the reverse of launch. Once the crew is familiar with these procedures they will become optimal for whatever winch or crane configuration used.

There should be a minimum number of personnel required for the deployment and recovery of the Klein 5900 (some of these positions may be combined):

- Safety Officer
- Winch Operator
- Crane/A-Frame Operator
- Line handlers (2)

6.1. DEPLOYMENT

Before launching the towfish, the vessel should be positioned with following seas in order to provide the most stable platform environment and safest working conditions on the aft-deck. For towfish launch, 2 knots is the preferred speed.

Line handlers will attach handling lines to each side of the towfish to control the sway of the towfish while it is in the air. The towfish handling lines will be attached to fixed points on the deck or superstructure in such a way that allow movement of personnel without obstruction. The towfish swing should be controlled by on-deck personnel during launch.

Safety briefings should be completed. When ready to launch the operator will lift the towfish body off deck and lower the towfish into the water. When the towfish body is on the surface and free of the vessel, the cable counter need to be set to zero. The winch operator will release additional towcable until the towfish is aft of the vessel. Increase vessel speed to 5 kts while lowering the towfish to operating depth.

6.2. RECOVERY

The recovery procedure is the reverse of launching. After operations are complete and all safety briefs and deck checks have been completed, the vessel will slow to bare steerage way. The winch operator will begin to reel in the towfish at a slow setting, after 1 minute will switch to high-speed retrieval until the towfish is in sight. The towfish is lifted and swung on board. During the sway of the towfish handling lines are attached, towfish swing is minimized and the towfish is lowered on deck and strapped down to its cradle.

7. ENVIRONMENTAL CHARACTERISTICS

7.1. MAGNETIC SIGNATURE

The Klein 5900 Sonar System components are constructed of type 316 stainless steel (surgical steel) for ruggedness and operations in a magnetically sensitive environment.

7.2. VIBRATION & SHOCK

The proposed system has been manufactured to Best Commercial Standards and Practices for operation in an offshore environment. Similar equipment has experienced vibration and a shock level normally experienced in offshore operations and has not exhibited performance degradation or damage. Such operational installations have included both large and small vessels and have provided a vibration environment similar to that specified by MIL-STD-167 (Environmental Vibration). The equipment has not specifically been tested to MIL-STD-167 or other military standards.

7.3. HUMIDITY

The Klein 5900 Sonar System has been designed to operate in an offshore ocean environment with humidity ranging from 20 to 100 percent, non-condensing. The Klein 5900 equipment has not been tested to military standards for humidity.

8. LOGISTICS

8.1. MAINTENANCE

The equipment has been designed to permit troubleshooting and field repair to a line replaceable unit (LRU) replacement level, so that operators can isolate problems and return the sonar to service by replacement of a faulty circuit board or other sub-assembly, such as a power supply. In the sonar system, key electronic sub-assemblies are fitted with plug-in sockets for ease in the isolation of any malfunction and simplicity for field maintenance by inexperienced personnel, should maintenance be required. Materials or components are utilized in the sonar system design, where appropriate or necessary, to insure longevity and ease in field maintenance. Special tools are included for maintenance or repair of the sonar system.

8.2. MAINTENANCE SUPPORT

Field maintenance programs, including training and spares can be provided by Klein to assist the customer in establishing a field maintenance program. Depot level maintenance support can be provided through the establishment of a factory depot level facility at Klein with a spares exchange pool for rapid turn-around of parts. Alternatively, Klein can assist the customer in setting up Depot Level maintenance facility, as desired.

8.3. TRAINING

Klein can provide training for personnel in the operation and maintenance of equipment at Klein Marine's facility, or at a customer site. The training will cover operation, maintenance, and repair. The training will consist of classroom and at-sea portion.

8.4. SPARES

It is Klein's goal to provide spare parts support for a period of ten (10) years, however, due to the commercial nature of the System hardware, some electronic components may be made obsolete by the original equipment manufacturer (OEM). In such an event, the continued supply of spare parts may be beyond the control of Klein.

To address the issue of forced component obsolescence, Klein has a policy of creating new designs which are downward retrofittable, where possible, to older sonar systems, so that a continuing source of spare parts will be available for older sonar equipment. This policy has been effective in the past with Klein being able to provide support for equipment that has been in service for over 15 years.

8.5. DOCUMENTATION

Commercial quality technical manuals written in English will be supplied with the various components of the proposed system. These manuals are sufficient for the operation, maintenance, and field repair of the proposed system.

8.6. QUALITY ASSURANCE

Klein maintains a Quality Assurance program applicable to all equipment manufactured by Klein to ensure functionality of the sonar equipment to performance specifications.

8.7. FACTORY ACCEPTANCE TEST (FAT)

All Klein sonar systems receive a Factory Acceptance Test (FAT) at Klein, Inc.'s, Salem, New Hampshire, USA, facility prior to shipment. The FAT includes functional testing of each system component and functional testing of the total system in the factory and a final seatest. These factory acceptance tests are intended to establish that the equipment supplied by Klein functions to Klein's standards.