SENTINEL

Marine Base Station Magnetometer

Operation Manual

Revision 4.3

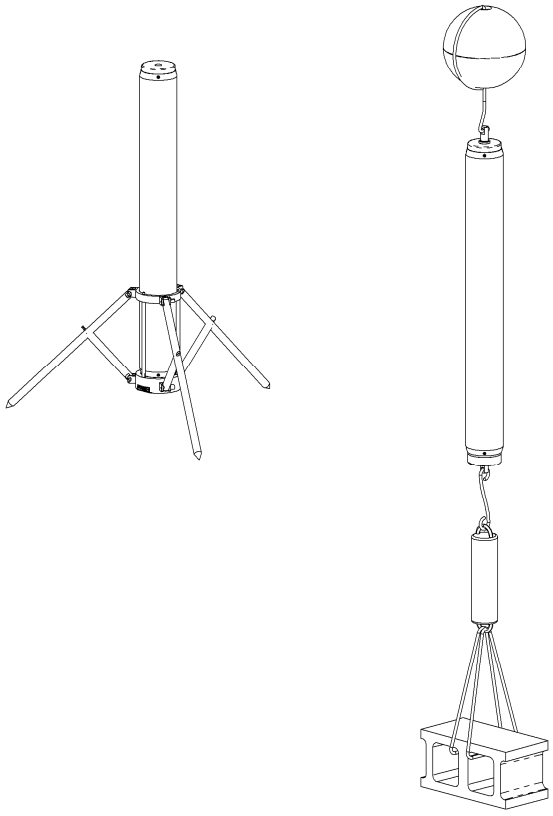

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Table of Contents

1 Introduction

The Sentinel is a high-performance base station magnetometer system that is designed to be used in the harshest underwater and land environments. A standard Sentinel system consists of the following components:

- The main magnetometer unit, consisting of an omnidirectional Overhauser magnetometer sensor, driving electronics with the ability to store one million readings, and a high capacity battery pack. The unit is packaged in a pressurized fibreglass cylinder, coated with tough polyurethane armour.
- An aluminum bulkhead at the base of the unit that is equipped with a micro-circular Subconn connector and a status LED window. The base is also equipped with an eyelet attachment that allows it to be tethered to an acoustic release system for underwater use.
- A 'dummy plug' that connects to the Subconn connector on the nose of the Sentinel and acts as a switch when deploying the unit without the tripod assembly.
- A white plastic eyelet that screws into the tail of the magnetometer. This part allows for the attachment of a syntactic buoy for underwater deployment, or may be used to suspend the unit from above when used on land.
- A battery charger.
- An interface cable that connects to a standard PC RS232 port, and also allows connection of the battery charger at the same time.
- BaseLINK software for Windows 95/98/NT/2000/XP/Vista/7.

A land-deployment Sentinel system is also equipped with a collapsible aluminum tripod base to allow the system to be used on land.

The magnetometer sensor is located at the tail end of the magnetometer tube, while the battery pack provides ballast at the nose end of the tube (the end with the micro-circular Subconn connector). Configuration, control and data access is all via RS232 through this connector.

Note that the Sentinel is always 'off' unless mounted in the tripod assembly or unless the supplied dummy plug is installed. When deploying the unit without the tripod, it is very important to remember to install the dummy plug. Otherwise, the unit will not acquire data. This safeguard exists in order to protect the integrity of the brass contacts of the bulkhead connector on the Sentinel housing, which would slowly corrode if exposed to seawater while the unit is powered on. With the unit powered off, the connector will not corrode or be damaged by seawater.

1.1 Understanding the System Components

Marine Magnetics supplies a separate document called our *SeaSPY Technical Application Guide* that describes in depth how an Overhauser magnetometer works and how it can be used for different applications. Marine Magnetics provides this document to anyone free of charge, so please contact us if you do not already have a copy.

1.1.1 Overhauser Total Field Sensor

The main sensor of the system is based on the Overhauser effect principle, a principle that allows the Sentinel to measure at much higher sensitivity and with a tiny fraction of the power of a standard proton sensor.

All Sentinel magnetometers are supplied with an omnidirectional sensor that is completely isotropic with respect to magnetic field direction. The only restriction is **the magnetometer should not be operated while upside down, i.e. with the connector facing straight up**.

The Overhauser sensor measures magnetic flux density, the unit for which is the Tesla (T). Magnetic flux density on the surface of the Earth typically varies between about 18μT to 70μT, depending on location. The flux density at any fixed location on the Earth's surface also varies with time due to diurnal effects, which depend primarily on influence from the solar activity.

One often speaks of a magnetometer as measuring magnetic field, instead of flux density, since the two values are directly related given an environment of constant magnetic permeability (such as air or water). In this light, it is easier to think of all magnetic objects as creating a dipolar magnetic field, either *permanent* or *induced*.

A permanent dipole is created by objects such as permanent magnets. The magnitude of the magnetic field created by such dipoles is independent of which direction they are facing, or of the ambient magnetic field surrounding the object. The Earth behaves as a permanent magnet, as does the Sun. The magnetic fields of the Earth and the Sun are constantly changing and interacting, causing variations in the magnetic flux density at the Earth's surface, which is what your magnetometer measures.

An induced dipole is created by an object that is magnetically permeable, and that is placed in the ambient magnetic field of a permanent dipole. An induced dipole will always be in the same direction as the ambient field, and will either add to it or subtract from it. Materials such as iron and nickel are extremely paramagnetic, meaning that they are permeable and their induced field will add to the ambient field. While all materials exhibit some degree of para- or dia-magnetism, iron, nickel and cobalt are orders of magnitude more paramagnetic than any other pure elements, and are therefore known as ferromagnetic. Alloys of these elements can be ferromagnetic as well.

An object that creates a permanent or induced magnetic field will distort the surrounding magnetic flux density. These distortions will be in the form of a magnetic gradient, i.e. the distortion will decrease in intensity the farther one goes from the object.

Ideal conditions for a base station magnetometer are zero magnetic gradient, especially if the purpose of the deployment is to monitor variations in the Earth's field. A zero gradient usually means there are no magnetic objects nearby. If a permanent or induced dipole comes very close to the sensor, the magnitude of the gradient may exceed the specification of the magnetometer, and it may stop providing noise-free data. Since most man-made building and structural materials contain iron or nickel, it is best to deploy a Sentinel as far from man-made structures and interference as possible. Stainless steel is often misconstrued as being non-magnetic, although most grades are very magnetic, especially if they have been welded.

Do not expect the sensor to produce good results on the deck of a ship, or inside a building.

A standard proton magnetometer sensor uses a strong DC magnetic field to polarize itself before each reading can be taken. An Overhauser sensor, in contrast, uses an AC magnetic field of radio-frequency to polarize. The benefit of this is that a tiny fraction of the polarization power is required, and the AC field may be left active while the sensor is producing a valid output signal. This allows an Overhauser proton magnetometer to measure more frequently than a standard proton magnetometer, and produce results at least two orders of magnitude more precise.

1.1.2 Electronics Module

The Sentinel electronics module is the core of the Sentinel system. It drives the Overhauser sensor, monitors performance, stores the data and reports the data to the host acquisition for optional real-time retrieval. The electronics module has enough memory to store up to one million readings.

Interface to the electronics module is through a 3-wire RS232 connection via the 8-pin Subconn connector located on the Sentinel bulkhead. DC Power to the batteries and LED status lines are also wired to the same 8-pin connector.

The electronics module requires approximately 180mW of power in command mode (waiting for commands), and approximately 1W at full power while sampling the magnetic field. In sleep mode, the module draws only 96µW.

All Sentinel electronics modules are completely interchangeable. The only difference between them is a 16-bit serial number that is stored in non-volatile RAM within the unit. Each electronics module is a hermetically sealed, self-contained unit that is safe to handle even in dirty or wet conditions.

1.1.3 Housing

The Sentinel housing is a pressurized vessel that carries all of the batteries, the sensor and the electronics module. It consists of a filament-wound fiberglass cylinder coated with polyurethane for abrasion and shock resistance. The nose bulkhead includes an eyelet for attaching an anchor, a status LED and an 8-pin Subconn connector for communicating with a PC and for charging the batteries. A second eyelet can be optionally fitted to the tail bulkhead to suspend the Sentinel from a buoy (underwater deployment) or an overhanging structure such as a tree branch (land deployment).

A standard Sentinel housing is rated to a water depth of 1000m (3280ft). Depth ratings to 3000m (9842ft), and 6000m (19685ft) are available.

For a list of O-ring sizes in the housing seals, refer to section 10.2.

1.1.4 Interface Cable

The interface cable connects the Sentinel to a PC and to the Sentinel battery charger. It is used to program the Sentinel for operation and to retrieve magnetometer readings, either real-time or post-survey. It is a gray and black cable with one female 9-pin DSUB connector that plugs into the serial port of your PC, one male 3-pin circular connector that connects to the battery charger, and one female 8-pin micro-circular Subconn connector that connects to the Sentinel.

1.1.5 Battery Pack

The standard Sentinel includes a battery pack consisting of two 12V sealed lead-acid gel batteries connected in series, providing a total capacity of 7Ah. This is enough to

power the Sentinel for 80 hours at 1Hz or 2Hz sample rates or as long as 2500 hours at the slowest sample rate of once per minute.

1.1.6 Battery Charger

The Sentinel battery charger can accept any AC power from 100 to 240VAC, at 50/60Hz, and is therefore capable of operating worldwide. It produces a constant +15VDC to power the Sentinel and charge the internal batteries.

1.1.7 BaseLINK Software

BaseLINK is a Windows application that interfaces with your magnetometer. It offers full control over the magnetometer. It is used to program the magnetometer before operation and to retrieve the data from the magnetometer after completion. It can also display and record real-time data from the magnetometer if the interface cable is connected.

2 Communication

All communication with the magnetometer is over RS232 using 9600 baud, 8 data bits, no parity and one stop bit. No hardware or software handshaking is used. You can communicate with the magnetometer using any RS232 terminal.

The most common hardware used to communicate with the magnetometer is a PC. BaseLINK software that runs under Windows is included with every Sentinel system.

The RS232 link is used to program the magnetometer, and to download data when your mission is complete. The Sentinel is designed to operate unattended, but it can be monitored at any time through its RS232 link. Whenever the Sentinel takes a reading, or performs a self-test, it will report the results automatically over the serial port.

2.1 Sentinel Operating Modes

The following sections describe the Sentinel's two operating modes. Note that when the Sentinel is not in use it goes into sleep mode. When the Sentinel is placed in the tripod or when the dummy plug or RS232 cable is connected, the Sentinel will wake up from sleep mode and respond in one of two ways. If the Sentinel had been preprogrammed to take readings at a set interval, then it will begin doing so from this time. If sampling has not yet been enabled, then the Sentinel will wait for a command. If no commands are issued within 60 seconds, then it will return to sleep mode.

2.1.1 Command Mode

In command mode, the Sentinel can be programmed with any of the commands described in Chapter 5. To sample at a fixed sample rate select one of the sample rates listed in table 5-1. For sample rates slower than 0.2Hz (once every 5 seconds), the Sentinel will enter sleep mode in between samples.

Some commands will not work when the Sentinel is cycling (acquiring data).

2.1.2 Sleep Mode

In sleep mode the Sentinel consumes only 96µW. This allows the system to conserve battery power when not in use or when sampling at slow sample rates.

Once asleep, the Sentinel does not interpret commands. Instead, any byte sent to the Sentinel will wake it up from sleep mode. It will try to take a single reading and return to sleep. To activate command mode a second byte must be sent to interrupt this reading within 3 seconds. The Sentinel will then enter command mode and wait up to 60 seconds for a new command before returning to sleep mode.

2.1.3 External Triggering Using Sleep Mode

When any byte is sent to the Sentinel while it is in sleep mode, it responds by waking up, taking a reading and going back to sleep. This way an external trigger can be used to initiate readings any time.

3 Connecting and Using the Equipment

The main Sentinel housing is a complete self-contained magnetometer, and does not require any other components to operate. The extra hardware that has been included with your system makes it easy to deploy the magnetometer quickly in almost any environment on Earth, both above and below the surface of the sea.

3.1 Step 1: Connecting the Magnetometer

Locate the gray and black interface cable terminated with a Subconn micro-circular connector at the magnetometer end and a 9-pin DSUB connector at the PC end. This cable also has one circular 3-pin connector, which is used for charging the Sentinel. Plug the DSUB connector into your PC's serial communication port and the Subconn connector into the mating connector on the Sentinel bulkhead. You are now ready to program the magnetometer. Connection of the charging unit is not necessary unless the magnetometer batteries have been depleted.

Important: Do not boot up a PC while it is connected to the magnetometer. Windows often tests the COM ports for the presence of mice and other peripherals while it is booting, which the magnetometer may interpret as erroneous commands.

3.2 Step 2: Programming the Magnetometer

To install BaseLINK, insert the installation disk into the PC's CD ROM drive and run the setup.exe file and follow the onscreen instructions. When setup is complete, run BaseLINK by double-clicking its icon.

By default, BaseLINK expects the magnetometer to be connected to the COM 1 serial port on your PC. If this is not the case then select the appropriate COM port. You can check the COM port using Windows Device Manager.

When you first run BaseLINK, the magnetometer will likely be in sleep mode. The Sentinel always goes to sleep if it has not received commands in the last 60 seconds, and if it is not acquiring data faster than once every 10 seconds. Press any key to wake the unit up.

You should now see a wake-up message appear. The Sentinel is now ready to be programmed. For a list of commands, press the **?** key. You can also get a look at the Sentinel's current status by pressing the ` (reverse single quote) key. Another useful command is **d**, which shows you the battery voltage. A voltage of +12.7VDC indicates that the battery is fully charged, while a voltage of +10VDC or lower means that the battery is low.

Press the space bar to see the current system time setting. The Sentinel is programmed to UTC time at Marine Magnetics prior to shipment. If you need to change this, set the time using the **T** command. The Sentinel will send a prompt to enter the date (Julian day, and year) and time (hour, minute, second). When you enter the last digit, the clock will start immediately. The best reference to use for time is a GPS receiver that has held a position lock for at least 10 minutes. BaseLINK will show you the current Julian day at the bottom of its window.

Now program your desired sample rate. Most users will use a sample rate of 1 reading per second. This retains The Sentinel's maximum sensitivity, and will allow continuous operation for approximately 80 hours (just over three days). Users that do not need such frequent data and need more operation time should survey at 1 reading every 10 seconds, which will allow continuous operation for approximately

540 hours (about three weeks). Run time can be extended to more than three months by cycling at one reading per minute.

Important: The Sentinel will wait indefinitely for input, and will **not** go to sleep, or begin acquiring data, if you are setting time (**T** command) or setting tuning (**L** command). To abort either of these prompts, use **ctrl-X**.

After programming the Sentinel, the RS232 cable can be unplugged. The Sentinel will not begin acquiring data until it is placed in its tripod base, or the dummy plug is inserted. If you unplug the connector from the nose of the Sentinel unit, it will power off. When you are ready to re-deploy, simply insert the dummy plug, and the unit will automatically reactivate. Every reading it acquires will automatically be stored in its memory.

3.3 Step 3: Deploying the Sentinel

3.3.1 Deploying the Sentinel on Land

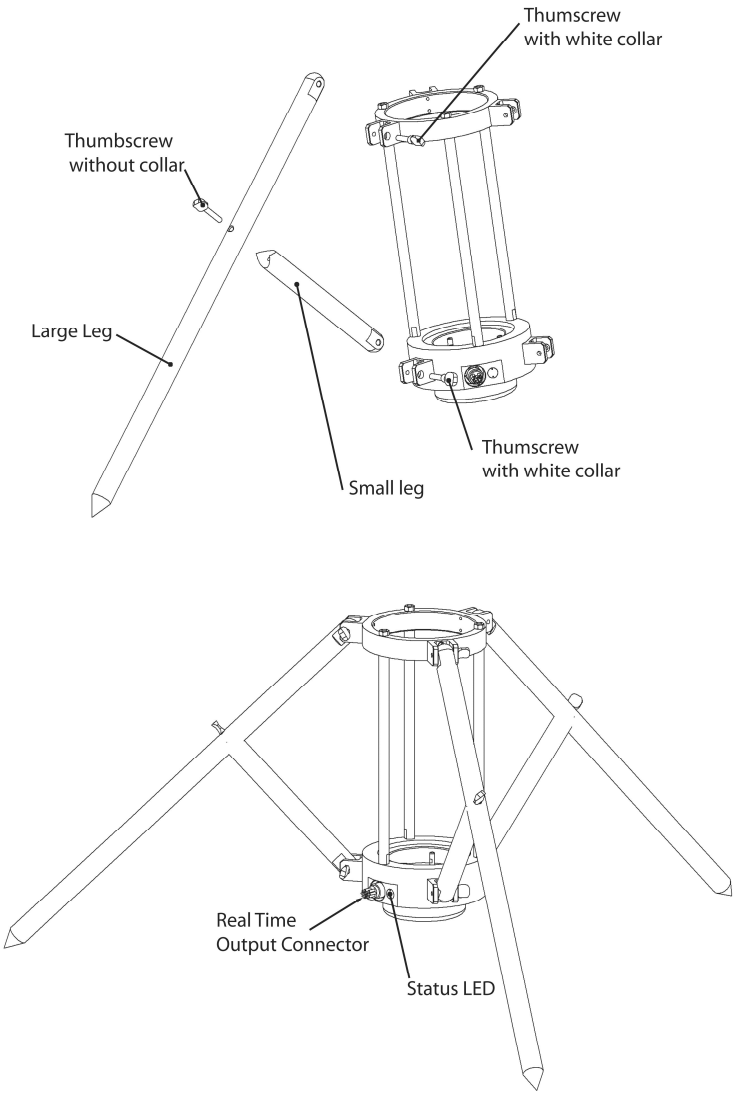

figure 3-1: Setting up the tripod

The aluminum tripod base makes deployment on land very easy. Assemble the base by attaching the six leg segments as shown figure 3-1. Then, just insert the magnetometer tube into the base, and rotate the tube until it snaps into place.

Installing the magnetometer into the base will automatically start the unit, and removing the magnetometer will automatically stop it.

As soon as you install the tube in the tripod, the Sentinel will begin its self-test. You will see the status LED on the base flash on and off for approximately five seconds, followed by a solid green-only light for about one second. If at any time the LED displays solid red for about two seconds, that means that the self-test detected an error. This is probably because the unit was placed in a noisy or high-gradient area. Try moving it away from power lines, cars, buildings or any other possible sources of

ferromagnetic or electromagnetic interference.

You can communicate with the magnetometer without removing it from the base. Just plug the communications interface cable (the one with two cables attached) into the Subconn micro-circular connector on the base, and follow the instructions in section 3.2 above.

While the magnetometer is taking readings, it will automatically store the readings in its internal memory, and also report them over the RS232 link in real time. You can monitor this process by plugging in your PC and running BaseLINK.

Note: When the battery voltage falls below +9.2VDC, the Sentinel will stop acquiring data, and go to sleep to protect the battery pack from over-discharge. You will be able to wake the unit up and communicate with it as usual, but it will not take another magnetometer reading until the battery voltage rises above a threshold level.

3.3.2 Deploying the Sentinel Underwater

Most deployments underwater will require hookup to an acoustic release system and anchor that are available through Marine Magnetic's other suppliers. This setup will require the magnetometer to be buoyant for retrieval at the surface when its mission is complete. Figure 3-2 shows the typical setup for mooring your Sentinel underwater.

1. The magnetometer tube is not buoyant. It weighs about 2kg in fresh water. To make it buoyant, you will need a buoy that can produce enough lift to counteract the weight of the Sentinel and your acoustic release. You can tether your buoy to the tail of the Sentinel's tube **using the detachable white eyelet** that is included with the system.

2. To activate the magnetometer, insert the supplied dummy plug. **It is very important to remember to install the dummy plug. Otherwise, the unit will not acquire data.** Once the plug is installed, the Sentinel will immediately turn on and perform a self-test, which will not succeed on the deck of your vessel. The Sentinel will shut itself down for two minutes and try again, and will keep trying every two minutes until it is far enough from your vessel to start taking good readings.

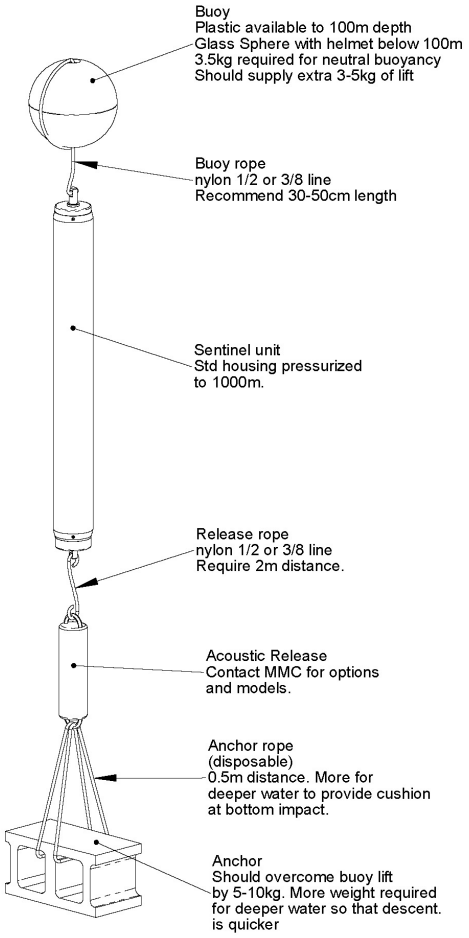

figure 3-2: Typical marine mooring setup

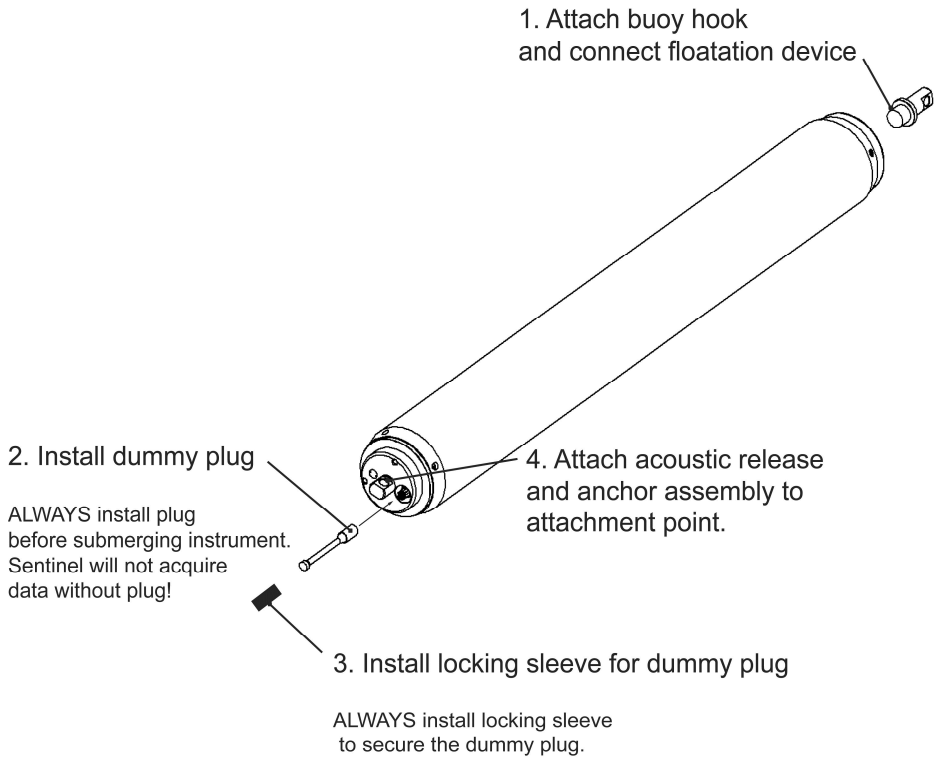

figure 3-3: Preparing for underwater operation

3. Now install the supplied **threaded locking sleeve** that secures the dummy plug**. It is very important that this sleeve be installed over the plug prior to deploying the instrument.** It is also important to remember to remove this sleeve (by rotating it counter-clockwise) before attempting removal of the dummy plug.

4. Finally, connect your acoustic release and anchor to the eyelet on the nose of the tube, and throw the entire assembly overboard. Be sure that the water depth in your area will not exceed the depth rating of the magnetometer tube.

Note: When the battery voltage falls below +9.2VDC, the Sentinel will stop acquiring data, and go to sleep to protect the battery pack. You will be able to wake the unit up and communicate with it as usual, but it will not take another magnetometer reading until the battery voltage rises above a threshold level.

3.3.3 Deploying the Sentinel with the Tripod Base Underwater

The Sentinel's aluminum tripod base is a fully sealed unit and can be deployed underwater if desired. The depth rating of the tripod base is 100m.

Note that the supplied dummy plug and locking sleeve must be installed over the Subconn circular connector on the tripod base for underwater operation. For more information on the tripod base please refer to Section 3.3.

3.4 Step 4: Retrieving the Data

Every reading that the Sentinel takes is stored sequentially in non-volatile memory, along with the reading's date, time and a fault indicator. To find out how many readings are used, use the **ctrl-D** command.

To begin data transfer, send **ctrl-G**. BaseLINK will automatically recognize that a data transfer has begun, and begin saving the data to your hard drive using the file name and directory specified. To abort a data transfer, press the stop transfer button, or use **ctrl-X** if you are not using BaseLINK.

A data transfer will require approximately one hour for every 100,000 records, for a maximum of about 10 hours for full memory.

Records stay in the Sentinel's memory until they are intentionally erased. To erase the memory, use **ctrl-E**. You will be prompted for confirmation. The erase-memory procedure may take several minutes, and cannot be interrupted.

3.5 Step 5: Charging the Battery

To charge the Sentinel, connect the communications cable to the magnetometer as described in Section 3 (it is not required to connect the PC). Now connect the included battery charger to the interface cable using the 3-pin circular connectors. Connect the battery charger to a power supply with 120 to 240VAC at 50/60 Hz.

The battery charger that was supplied with your Sentinel system may be connected to the magnetometer at any time, and for any duration. Charging will take place automatically. When the charging is 80% complete, the yellow light on the charger will change to green. An 80% charge will require approximately five hours from a completely discharged battery, and a full charge will require approximately 10-12 hours.

The battery charger is a 'smart charger' unit that may be left connected to the Sentinel indefinitely without damaging the battery. All magnetometer functions, including data acquisition will operate correctly with or without the charger connected.

Important: Do not connect any power source other than the supplied battery charger to your Sentinel unit, or damage to the battery pack may occur.

The Sentinel contains a reverse voltage protection diode, so that the battery pack cannot be discharged by shorting the power pins on its connector.

The Sentinel also contains an over-discharge protection feature, which protects the battery from damage. It will completely shut itself down when the battery voltage falls below +9.1VDC. This does not affect the data in memory. The Sentinel data is stored in nonvolatile flash memory, and is safe even if the electronics are completely disconnected from power.

4 Application-Specific Sentinel Configurations

A variety of application-specific Sentinel configurations are available. The following sections provide additional information specific to each configuration.

4.1 OEM Sentinel

The Sentinel's electronics module and Overhauser sensor can be provided without the standard pressurized marine housing and tripod base. This is convenient for applications such as mounting onto an ROV or AUV when the unit can be housed and pressurized by the end user.

The electronics module itself is completely water- and air-tight, and it keeps the electronics inside safe from static discharge. Note that this housing is not designed to withstand high water pressure, and should not be submerged to a depth of more than two or three meters.

The Overhauser sensor is individually sealed and shock mounted. Again, this housing is not designed to withstand high water pressure. Also, take note that salt water can corrode the beige conductive paint that coats the housing within the shock mounts. Lengthy exposure to salt water should be avoided.

The Overhauser sensor is supplied with two 2m cables, both terminated with male SMA connectors. One cable is a coaxial RG-58 type, identifiable by a shiny finish on the cable jacket. This cable is responsible for sending RF polarization power to the sensor. The other cable, identifiable by a matte finish on the cable jacket, is a shielded twisted pair that is specially designed to eliminate microphonic effects in the audio range. This cable is responsible for sending the magnetometer signal back to the electronics module.

If the Overhauser sensor and electronics module are packaged separately, the length of cable between the two may be extended to as much as 30m, provided proper cabling is used for the connection. Contact Marine Magnetics for assistance in this area.

Interface to the electronics module is through an 8-pin circular connector on the other end of the electronics module. The pin-out of this connector is shown below in table 4-1. Pin 1 is marked with a dot. Pin 8 is the center pin.

Pin #	Name	Description
1	GLED	Green LED pulse output.
2	SW1	External power switch. Grounded=ON, Floating=OFF. See note.
3	RLED	Red LED pulse output.
4	SW2	External power switch. Grounded=ON, Floating=OFF. See note.
5	RSIN	True-level RS232 input at 9600bps.
6	RSOUT	True-level RS232 output at 9600bps.
7	PWR+	Positive power supply. Range is +9 to +15VDC. When below +9VDC, the Sentinel will interpret a low battery condition, and shut itself down.
8	PWR-	Negative power supply and ground.

table 4-1: Connector pin-out for OEM Sentinel

SW1 and SW2 inputs: The Sentinel's operation is heavily dependent on the state of an external switch. This characteristic was specifically designed so that the Sentinel could be activated or deactivated with a single simple action. When the signals SW1 and SW2 are grounded, the Sentinel will see the external switch as ON. When the signals are floating, the Sentinel will see the external switch as OFF. **It is very important that the signals are not shorted together when floating**. If using a hard switch, it should be DPST, with one end connected to PWR-, and with SW1 and SW2 connected to separate contacts on the other pole. If controlling the unit electronically, SW1 and SW2 should be connected to separate open-drain outputs. Both SW1 and SW2 must have the same logical state at all times. Otherwise, unpredictable operation will result.

GLED and RLED outputs: The LED signals are 5V CMOS-level current-limited outputs that are designed to drive the red and green LEDs on the Sentinel nose bulkhead and tripod as described elsewhere in chapter 3. These outputs can be used to monitor the Sentinel's activity if the unit is being controlled electronically. Every time a reading is taken, a pulse will appear on the GLED signal if the reading was successful. A pulse will appear on both the GLED and RLED signals if the reading was taken under less than ideal conditions, such as in the presence of a high gradient. A pulse will appear on only the RLED signal if a reading was attempted but failed.

The SW and LED signals can be a convenient way of controlling and monitoring the unit if you do not have an RS232 link available.

4.2 Pod Sentinel

The Sentinel's electronics module and Overhauser sensor can also be provided with individual pressurized marine housings for applications where they will be mounted externally on a platform and will be subjected to water pressure. Two coax cables are provided for connecting the electronics pod to the sensor pod. Attach the cable

with the yellow markings (signal cable) to the connectors with the matching yellow markings and the other cable (RF cable) to the remaining connectors.

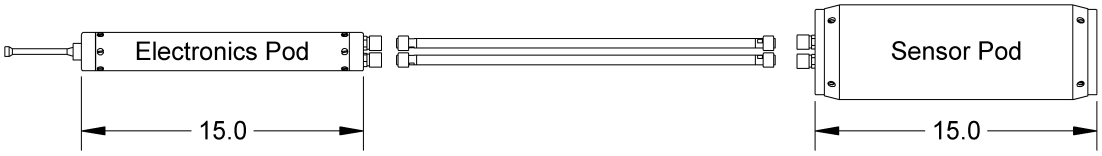

figure 4-1: Pod Sentinel Setup

4.3 Sentinel – No Battery

The Sentinel is also available without internal batteries. This configuration of the Sentinel has a shorter housing and must be connected to an external +9 to +15VDC power source to operate. **Do not exceed the +15VDC maximum rating or damage to the internal electronics will result.**

This Sentinel unit is designed to be constantly connected to an external power source, and powered down with the **S** command. When in command mode (as above) the unit will timeout after one minute of inactivity and place itself in sleep mode. When in sleep mode, the unit consumes only a few microwatts of power, but the onboard clock keeps real time.

If the unit is set to auto-sampling, the correct way to stop sampling is to set the sample rate to 'off' via the COM port. Power should only be disconnected when absolutely necessary because the clock state will be lost.

All other operation is identical to that of the standard Sentinel.

5 Commands

This section describes all of the commands that can be sent to the Sentinel over the RS232 link. If the Sentinel is in sleep mode then it can be woken up by sending any command. This command will not be interpreted as a command. Instead it will take a reading and shut itself down immediately. You can abort the reading by sending another byte before the reading completes (about 3 sec). This will cause the Sentinel to enter command mode. Once in command mode, the following commands are accessible. For more details on the different operating modes refer to section 2.1.

Some commands will not work when the Sentinel is cycling (acquiring data).

Command	Keystroke	Description
Input time manually	T	The magnetometer will respond with a prompt to enter eleven digits that represent a date and a time. There is no carriage return necessary. As soon as the last digit is received, time will start from the entered value. The first three digits are Julian day, followed by two digits for year, and six digits for time in HHMMSS format. Note that this command can be executed while the magnetometer is cycling (taking readings). **While the unit is waiting for input, it cannot go to sleep. To abort this command, press ctrl-X.**
Get time	SPC or t	Requests current magnetometer date and time, which is displayed with a resolution of 0.1 seconds in a 24-hour cycle. Magnetometer time is used for determination of cycle timing, i.e. units with the same time value cycling at the same interval will take readings at exactly the same time, regardless of when cycling was initiated. In addition, a unit cycling at a slower interval will be synchronized with one at a faster interval for appropriate readings. For example, a unit cycling at 5000ms will be synchronized with a unit cycling at 1000ms every five seconds.
Take a single reading	f or F	The magnetometer will immediately respond with an acknowledgement, and start the reading procedure, which will take three seconds. If the tuning value is 0 (zero) when the reading is started, tuning initialization will automatically be performed. On conclusion, the magnetometer will transmit the data obtained from the reading.
Initialize tuning	I	This command will cause the Sentinel to search for the value of the ambient field. The Sentinel will do this automatically when it is commanded to take a reading if its tuning value is set to 0 (init).
Self-test now	P	Will initiate a five second self-test procedure, identical to when the Sentinel is switched on while configured to auto-cycle. The results of the self-test will be output over the serial port, and the LED will flash accordingly on the unit or the tripod, if used.
Enable/Disable Self-test on startup	P	When the Sentinel is configured to auto-cycle, and is installed in its base or has the plug installed, it will automatically perform a self-test before continuing to acquire data. This toggle command will disable the automatic self test feature. You can check the status of the auto-self-test feature in the status list (` command).

1 reading per minute Cycle Rate	7	Puts the magnetometer in a mode that measures magnetic field readings at a rate of once per minute. The magnetometer will continue in this mode until ordered to enter a different mode. After every reading, the magnetic field data will be transmitted automatically. To save power, the magnetometer will go to sleep when in this mode if no command is received for sixty seconds. It will automatically wake up when it is time to take a reading, and then shut itself down again immediately when the reading is complete.
0.1 Hz Cycle Rate	6	Same as above, but will take one reading every ten seconds.
0.2 Hz Cycle Rate	5	The magnetometer will take one reading every five seconds. It will not go to sleep when in this mode, unless RS232 cable, dummy plug, or tripod is removed.
0.3 Hz Cycle Rate	4	Same as above, but will take one reading every three seconds.
1 Hz Cycle Rate	3	Same as above, but will take one reading every second.
2 Hz Cycle Rate	2	Same as above, but will take one reading every half second.
Stop Cycling	0	This command will terminate all cycling. The magnetometer will complete a reading if one is in progress at the time of the command, and return to idle mode (awaiting further commands).
Input tuning manually	l or L	When this command is sent, the unit will prompt for the entry of a new two-digit tuning value in µT. The magnetometer will calculate the actual tuning step number that the user can increment or decrement using the next two commands. To set the unit in a state where it will auto-initialize itself when it takes its next reading, enter 00. **While the unit is waiting for input, it cannot go to sleep. To abort this command, press ctrl-X.**
Increment tuning	. or >	This adjusts the magnetometer tuning in the smallest possible step. The number of that step is reported as a response to the command, and also the corresponding magnetic field value in µT. If auto tuning is not selected, the default tuning value is 0 (zero), which will cause a tuning initialization when the first reading is attempted. If auto tuning is disabled, the default power-on tuning value will be whatever the setting was when the unit was powered off.
Decrement tuning	, or <	Same as above, but opposite.
Sensor information	d or D	Retrieves extra sensor information. The first number is signal strength (for advanced diagnostics only), the battery voltage, and the magnetometer state. A voltage of +12.7VDC indicates a fully charged battery, and a voltage of +10VDC or less indicates a low battery.
Memory status	ctrl-D	Displays how many records are stored in memory, and the percentage used. The maximum number of readings is 1048576 (2^{20}).
Erase memory	ctrl-E	Erases all records stored in memory. You will receive a prompt to confirm. **While the unit is waiting for confirmation, it cannot go to sleep. To abort this command, press n.**
Transfer memory	ctrl-G	Transfers all records in memory. The approximate transfer time is one hour for every 100,000 records. BaseLINK will automatically detect when a transfer begins, will log the records to a file, and will calculate time remaining. **To abort data transfer, press ctrl-X.**
Menu	?	Gives a brief description of the most important commands.

Status	` (reverse quote)	Gives a description of magnetometer status, including serial number, sample rate, and memory free.
Retransmit last reading	G	The last reading that was taken will be retransmitted in the real-time format described later in the manual.
Auto tuning off	Y	By default, an optimal tuning value is calculated at the end of every reading with 100 or more signal periods. Very large and fast changes in magnetic field may cause the unit to mistune. This command may be used to disable auto tuning.
Auto tuning on	X	Use this command to re-enable auto-tuning.
Toggle long deflect	k or K	Long deflect is a technique used in Overhauser magnetometers to boost signal strength in low fields. SeaSPY will automatically switch to long deflect in fields below about 42μT. Although long deflect provides better signal strength, it also shortens measurement time, and it may be beneficial under certain circumstances to disable it. It is recommended to keep this function enabled.
Toggle RF	r or R	This command may be used to turn the RF polarization circuit on or off manually
Connect/disconnect sensor	e or E	This command connects the sensor to the magnetometer's amplifier chain. When off (normal standby), the amplifiers are isolated from the sensor. Use the D command to check the signal level from the sensor when it is connected.
Sleep mode	S	This command will force the Sentinel into sleep mode. When in sleep mode, the unit consumes only a few microwatts of power, but the onboard clock keeps real time. Use this command to shutdown a unit that is constantly connected to an external power source (e.g. Sentinel OEM or Sentinel – No Battery configurations).
Get unit serial number	!	The unit will report its serial number.
Get firmware checksum	%	Get firmware checksum. The firmware checksum can be used to identify your firmware version when calling Marine Magnetics for technical support. The response will be an eight-digit hex number.

table 5-1: Normal operating commands

6 Data Format

The Sentinel will transmit data in real time as it is collected, and also after the mission is complete in the form of a data transfer. The data format for these two different modes is described herein.

6.1 Real Time Data

Real time data contains more diagnostic information than stored data. The format is as follows.

*YY.JJJ/*HH:MM:SS.S*_F:*FFFFFF.FFF*_S:*SSS*_*TTT*ms_Q:*QQ*_*WWWW CR LF*

The first character of each line is always * (ASCII code 42). This leading character is supplied for automated data collection systems that require periodic synchronization with the data stream. Each letter shown in italics stands for a digit of a particular record in the reading.

Letter	Description
Y	Year (time of reading).
J	Julian day (time of reading).
H	Hour (time of reading).
M	Minute (time of reading).
S	Second (time of reading).
F	Magnetic field (nT).
S	Signal strength of reading. This is a raw number generated by the magnetometer that gives (in part) a good indication of the quality of the final total field measurement. Anything over 70 is considered an acceptable signal, and anything over 130 is considered excellent.
T	Measurement time. Ideally, this should be the magnetometer's cycling time minus 32ms, with a maximum of 968ms. If you see a G message, indicating that measurement was prematurely terminated due to a high gradient condition, this value will tell you how severe the gradient is.
Q	Signal quality. This is a two-digit number between 00 to 99. The left digit is a good indication of signal strength, and the right digit indicates how much information was available for measurement.
W	Warning Messages.
CR	Carriage return (ASCII code 13).
LF	Line feed (ASCII code 10).

table 6-1: Real time data output format description

There are five different warning messages that can be displayed in real time data, four of which are not mutually exclusive. The warning messages may be summarized as follows.

Letter	Meaning
W	Weak signal. This message is displayed if the signal strength for the reading is below a low threshold value
G	Gradient condition. In high magnetic gradients, the precession signal produced by the sensor decays more quickly. This message occurs if the measurement time was prematurely terminated due to a quickly decaying signal. The strength of the gradient can be estimated by observing the measurement time. Take note that sensitivity will decrease as the measurement time decreases.
P	Poor reading. This message is displayed if too few zero crossings are taken, for whatever reason. Expect this message under conditions of extremely high magnetic gradient.
M	Instrument mistuned. The magnetometer may decide to display this message under extremely poor signal conditions, which is characteristic of poor tuning setting. When this message occurs, the instrument will attempt to retune itself by executing an auto-tuning procedure, if that feature is enabled.
NS	No signal. This message is never displayed in conjunction with any other messages. It occurs when the magnetometer determines that signal conditions are so poor that there is very likely no sensor connected to the instrument. Since running the unit with no sensor attached for an extended period of time abuses the polarization circuitry, the magnetometer will cease cycling if this message occurs.

table 6-2: Real time data warning messages

6.2 Stored Data

To maximize memory usage, all of the diagnostic information that is stored with each record is limited to two warning messages, which are triggered only if the reading was not of optimal quality. The stored data format is as follows:

`YY.JJJ/HH:MM:SS.S_FFFFFF.FF_WW CR LF`

Note that magnetic field is only stored to a resolution of 0.01nT.

Letter	Meaning
S	Weak signal. This message is displayed if the signal strength for the reading is below a low threshold value.
G	Gradient condition. In high magnetic gradients, the precession signal produced by the sensor decays more quickly. This message occurs if the measurement time was prematurely terminated due to a quickly decaying signal. This message indicates that the measurement time was less than optimal.

table 6-3: Stored data warning messages

7 Inside the Sentinel Tube

7.1 Standard Sentinel

The Sentinel is designed for quick and easy operation, and you will not normally need to open the Sentinel tube. If you suspect something has become damaged, it may become necessary to access the internal components. This section describes how to access the internal components and what these components do.

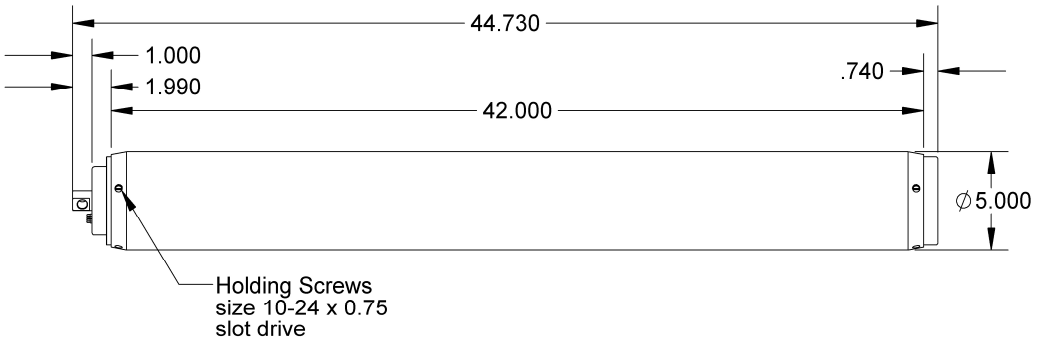

figure 7-1: Standard 1000m Sentinel dimensions

To open the Sentinel, remove the holding screws connecting the nose bulkhead to the tube, as indicated in figure 7-1. All of the internal components are fastened to a rack that is bolted to the nose bulkhead. Once the screws have been removed, pull out the bulkhead and attached internal assembly.

Do not leave the Sentinel internals installed halfway into the housing. If you need to access the internal assembly, remove it completely from the tube until you are ready to reassemble the Sentinel.

Figure 7-2 clearly shows all elements in the internal structure. The electronics module and Overhauser sensor are individually replaceable.

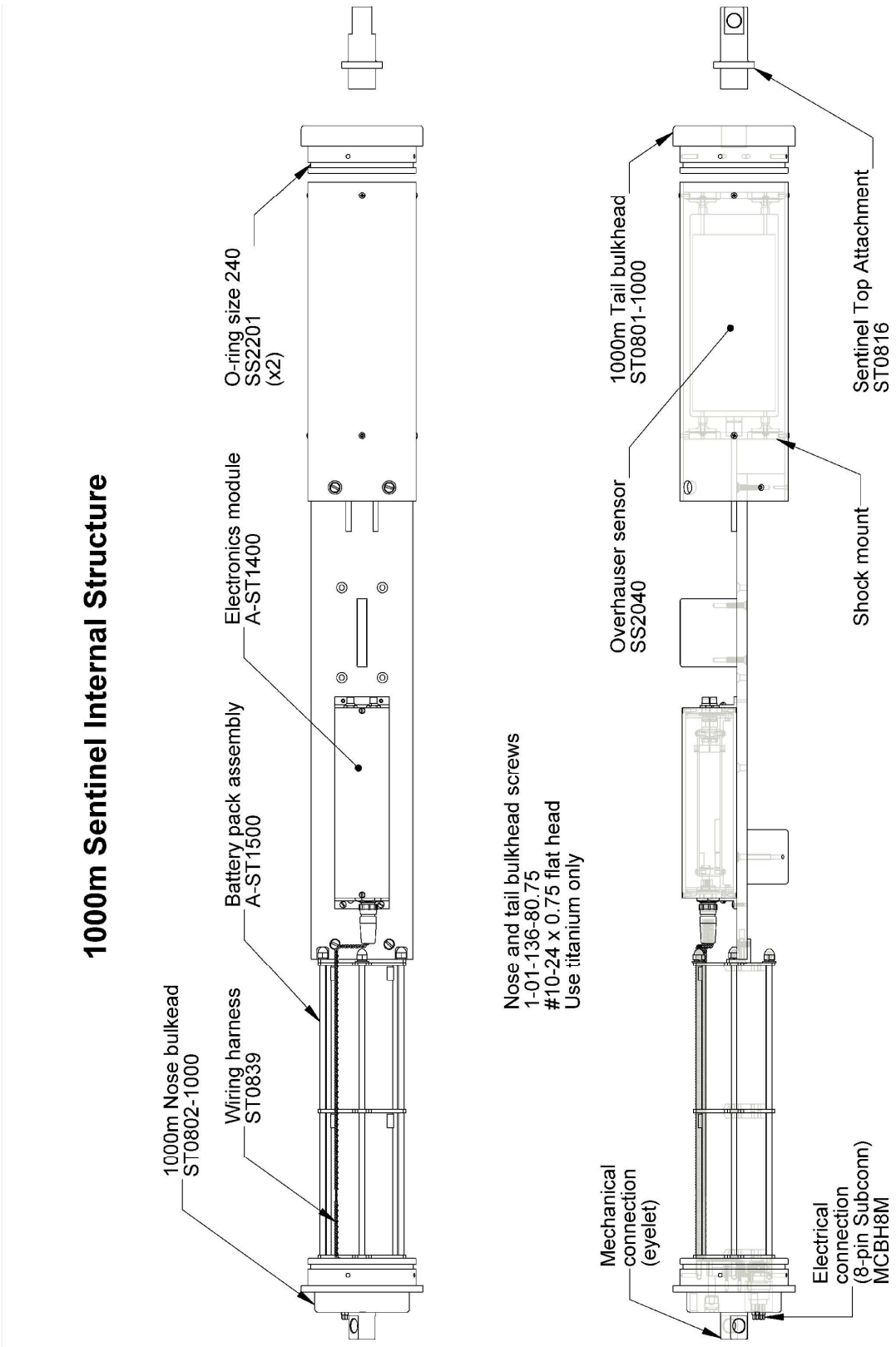

figure 7-2: SeaSPY internal structure

8 Troubleshooting

8.1 Sentinel Test Procedure

If the Sentinel is communicating properly, then the following procedure will verify that the magnetometer is operating correctly and is ready for operation.

1) Check the clock

Issue the **t** or **SPC** command twice to check the clock. Verify that the time has advanced from one line to the next.

2) Scan the sensors

Issue the **d** or **D** command to check the state of the Sentinel. The Sentinel will respond with the following status string.

S:008 B:+12.6V Sw ON

The output voltage should be close to +13VDC for a fully charged battery pack. The switch (Sw) will be active (ON) if the Sentinel is properly installed in its tripod, or if the plug or RS232 cable is connected. The switch should only be OFF if the OEM Sentinel is being used with a physical switch and that switch is off or not connected. If the switch is shown as being OFF when using the standard Sentinel, then the cables or plug might be damaged. Contact Marine Magnetics directly for support.

3) Check the status of the internal memory

Issue the **ctrl-D** command to check how many readings are currently stored in memory.

Mem usage: 0000002 Readings (0%)

4) Download or erase stored data

Issue the **ctrl-G** command to download the memory, and **ctrl-E** to erase the stored readings.

5) Prepare for an environment test

In order to perform the environment test, the magnetometer needs to be far from any magnetic material. If you are testing on land then ensure that the magnetometer is far from any buildings or other ferrous material.

6) Perform an environment test

Issue the **P** command to perform an environment test. If it passes, you should see a message similar to the following.

Initiating Self-diagnostic
Amp test: 234 – Passed
Noise Test: 000 0288 – Passed
Noise Test: 001 0309 – Passed
Noise Test: 002 0304 – Passed
Noise Test: 004 0273 – Passed
Noise Test: 008 0267 – Passed
Noise Test: 016 0342 – Passed
Noise Test: 032 0363 – Passed
Noise Test: 064 0312 – Passed
Noise Test: 128 0346 – Passed
Checking gradient – Passed

If it fails one of the noise tests, try the test again, as there may be some ambient noise interfering with the sensor. If it continuously fails the test, move the Sentinel to a different location and try the test again, as there is too much interference in its current location.
During this test the LED on the nose bulkhead (or the Tripod if used) will flash orange. If the test is successful, it will turn green for a short period, if the test fails, the LED will turn red.

7) Start Sampling

Start cycling at 1Hz by issuing the **3** command and take 5 to 10 sample readings. Each reading should be similar to the following.

**06.327/15:16:47.0 F:055294.465 S:192 0960ms Q:99*

Notes:

- When the Sentinel takes an acceptable reading the LED will flash green, if there is a gradient or the Sentinel cannot take a proper reading, the LED will flash red.
- The value of the F: field may differ significantly when tested at your location.
- The value for S: should be between 130 and 200 for good quality readings.
- The value for the ms reading should be 960 when F: is greater than 42000 and it should be 460 when F: is less than 42000.
- The value of Q: should always be 99 if the Sentinel is taking proper readings.

8) Check that the readings were recorded properly into memory

Issue the **ctrl-D** command to check how many readings are stored in memory.

Mem usage: 0000002 Readings (0%)

Note:

The Sentinel will not record readings into memory until they fall within normal values for the range of the earth's magnetic field that the Sentinel is designed to measure, 20uT – 120uT.

9) Download the recorded data and check that it matches the live data.

Issue the **ctrl-D** command to check how many readings were stored into the memory. Set your file name in the download panel of Baselink and issue the **ctrl-G** command to download the memory.

If the Sentinel passes all of these tests then it is functioning properly and is ready for operation.

8.2 Troubleshooting Specific Issues

The following table (table 11-1) addresses specific issues that may occur. For more details or other issues please contact Marine Magnetics directly.

Symptom	Possible causes	Solution
LED is off **OR** **No response from the Sentinel** **OR** **Communication Issues**	• Insufficient battery power • Sentinel not sampling • Error in the equipment setup	• Make sure all cables are properly connected • Verify that the Sentinel is properly installed in the tripod or the dummy plug or test cable is connected • If communication is functioning, then issue the **d** command to check the battery voltage and internal switch state • If the Sentinel is not communicating or if the battery voltage is below +9.2VDC, apply the charger to revive the battery pack from an under-voltage condition • Follow the steps from section 3.2 to program the magnetometer sample rate • Ensure that the baud rate and communication protocol of the terminal software are set correctly
LED is red	• The Sentinel failed a self-test	• Try moving it away from power lines, cars, buildings, or any other possible sources of ferromagnetic or electromagnetic interference
Poor magnetic field readings	• External noise on the sensor • Power supply amplifiers are adding noise to the system	• Move the magnetometer to a different location and run the environment test again • Avoid interferences such as radio waves, train tracks, on-board generator

table 8-1: Troubleshooting specific issues

9 Specifications

Note: These specifications are preliminary, and may not be exact. For exact specifications please contact Marine Magnetics.

Parameter	Specification
Magnetometer cylinder weight (1000m)	15kg
Magnetometer cylinder size (1000m)	113.5cm x 12.7cm dia
Magnetometer cylinder (1000m) depth rating	1000m, 100bar
Magnetometer cylinder weight (3000m)	21.2kg
Magnetometer cylinder size (3000m)	113.6cm x 13.3cm dia
Magnetometer cylinder (3000m) depth rating	3000m, 300bar
Magnetometer cylinder weight (6000m)	29.6kg
Magnetometer cylinder size (6000m)	114.3cm x 14.6cm dia
Magnetometer cylinder (6000m) depth rating	6000m, 600bar
OEM Sentinel – Electronics Module weight	0.23kg
OEM Sentinel – Electronics Module size	18cm x 5cm dia
OEM Sentinel – Overhauser Sensor weight	1.8kg
OEM Sentinel – Overhauser Sensor size	30cm x 10cm dia
OEM Sentinel depth rating	Splash-proof
Sentinel Pod – Electronics Pod weight	0.9kg
Sentinel Pod – Electronics Pod size	38cm x 5cm dia
Sentinel Pod – Sensor Pod weight	5.2kg
Sentinel Pod – Sensor Pod size	38cm x 12.7cm dia
Sentinel Pod depth rating	1000m, 100bar
Sentinel – No Battery weight (1000m)	11.8kg
Sentinel – No Battery size (1000m)	91cm x 12.7cm dia
Sentinel – No Battery (1000m) depth rating	1000m, 100bar
Sentinel – No Battery weight (3000m)	16.2kg
Sentinel – No Battery size (3000m)	91cm x 13.3cm dia
Sentinel – No Battery (3000m) depth rating	3000m, 300bar
Docking base weight	5kg
Maximum incline angle for deployment in tripod	40 degrees

Operating temperature	-25C to +50C
Storage temperature	-60C to +60C
Communication	Full duplex, 3-wire RS232. 9600bps, 8 data bits, no parity, 1 stop bit.
Data transfer speed	approximately 30 records per second, or 100,000 records per hour
Battery pack	Gel cell +12VDC, 7Ah
Battery charge time	5 hours 80% charge. 10 hours full charge.
Maximum power consumption, while battery charging	25W
Power consumption – asleep	96μW
Power consumption – command mode	180mW
Average Power consumption – sampling 1Hz, 2Hz	960mW, 48 hours run time on full battery
Average Power consumption – sampling 0.3Hz	700mW, 80 hours run time
Average Power consumption – sampling 0.2Hz	490mW, 100 hours run time
Average Power consumption – sampling 0.1Hz	150mW, 300 hours run time
Average Power consumption – sampling once per minute	25mW, more than 1500 hours run time – may vary depending on self-discharge rate of battery.

table 9-1: Specifications

10 Maintenance

A Sentinel base station is designed to withstand years of use in harsh marine environmental conditions. If some simple procedures are observed when deploying and storing the instrumentation, your Sentinel system will continue to deliver high quality performance with no need for service at the Marine Magnetics facility.

10.1 Deployment and Storage Tips

- When deploying the system underwater, ensure that the Subconn connector has a plug installed in order to prevent corrosion of the pins.
- For 6000m deep tow Sentinel systems, use a tow speed and cable length combination that keeps the Sentinel submerged at least 1m below the surface, and as far below waves and swell as possible if the water is rough. Other than this, there is no restriction on tow speed.
- Do not, under any circumstances, exceed the maximum rated operating depth of the Sentinel.
- Rinse the Sentinel and tripod with fresh water after removal from salt water. Surface corrosion will only significantly take place after exposure to atmospheric oxygen in the presence of salt water. Rinsing with fresh water will help prevent this corrosion.
- Do not store the Sentinel in direct sunlight, and keep it away from very hot environments. The operating and storage temperature range for a Sentinel is -40°C to +60°C, but an unsheltered Sentinel in a sunlit area can easily exceed +60°C. Keeping the Sentinel stored in moderate temperatures will prolong the lifetime of the seals and the internal electronics.
- During transit to and from the work site, store the *Sentinel* in its transit case, or if stored on deck, the *Sentinel* should be laid flat on the decking.

10.2 O-Ring Sizes

All O-rings used in the Sentinel are made from 70-durometer nitrile-rubber. All sizes are ASTM. O-rings will not need replacement unless the Sentinel itself is disassembled and the O-ring receives mechanical damage.

When replacing O-rings, ensure that the new O-rings are well greased and free from dust and dirt particles. Also ensure that a coating of grease exists on the mating surface, and that it is free from scratches or gouges.

Size	Quantity	Location
030	2	Electronics module housing
240	2	1000m and 6000m Sentinel nose and tail bulkhead (70D)
240	4	3000m Sentinel nose and tail bulkhead (radial-70D)
247	2	6000m Sentinel nose and tail bulkhead (facial-70D)

table 10-1: Sentinel O-ring sizes

11 How to Reach Us

If you encounter a problem using your Sentinel system, you should contact the distributor that you received the product from. You can also contact Marine Magnetics directly at the address mentioned below. If you have access to the Internet, our World Wide Web page offers support in the form of documents and file utilities, as well as information on product updates.

Marine Magnetics

135 SPY Court
Markham, ON L3R 5H6
Tel: 1 905 479-9727 fax: 1 905 479-9484
Email: support@marinemagnetics.com
URL: www.marinemagnetics.com

12 Warranty

All of the equipment manufactured by Marine Magnetics, with the exception of consumable items, is warranted against defects in materials and workmanship for a period of twenty-four months from the date of shipment. This warranty is not transferable.

During the warranty period, if any defects become evident under normal use, the buyer must notify Marine Magnetics of the defect and describe the symptoms in writing. Within thirty days of receiving said notification, Marine Magnetics will take action to remedy the defect or problem by choosing one or more of the following courses of action:

1. Replace the defective item(s)
2. Request the buyer to return the defective item(s) to Marine Magnetics for repair.

During the warranty period, replacement or repairs to items as described in 1 and 2 will be made free of charge. However, Marine Magnetics' liability in such cases will not extend to transportation charges for any item to or from the buyer, or to any lost time or to other costs that the buyer may incur.

If the buyer requests a technician on-site to complete the repair(s), the buyer will pay for all of the lodging, food and local transportation costs while the technician is affecting the repair(s).

During the warranty period, the *Sentinel* should not be opened or repaired in the field, unless instructed to do so by Marine Magnetics technical support staff. **Opening the *Sentinel* without Marine Magnetics technical support approval will render the warranty null and void.**

12.1 Indemnity

The Customer agrees to indemnify and save Marine Magnetics harmless from and against all loss, damage and expense whatsoever resulting from any personal injury or damages to property directly or indirectly caused by the Equipment or any part thereof during the term applicable to such Equipment, including the operation and handling of the Equipment.

12.2 Disclaimer

Marine Magnetics makes no representation or warranties and there are no conditions with respect to the merchantability, the suitability or durability of the Equipment or any part thereof for the purposes or uses of the Customer, unless the Customer notifies Marine Magnetics in writing of any defects in the Equipment or part thereof on delivery of such Equipment. All such Equipment or part thereof shall be deemed conclusively to have been delivered to the Customer in good and efficient working order and repair, and the Customer shall be deemed conclusively to have accepted delivery thereof on the date of delivery.