

SeaTag-LOG™

A Miniature Archival Geo-Locating Datalogger

Operator's Manual



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1.Introduction



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SeaTag-LOG™ is one of the several tags that make up Desert Star System's new line of animal tags and micro-observation stations developed for NOAA under the Small Business Innovative Research (SBIR) program.

SeaTag-LOG™ is designed specifically as a geo-positioning tag for migratory marine animals, providing both robust data and a low cost to support high-volume tagging programs. It is intended to fill the gap between plastic ID tags that are inexpensive but yield limited information, and the bulk of commercial archival tags that may be too costly to provide a sufficient sized 'N'.

Yet, beyond just cost optimization, LOG offers numerous innovative features. These include geo magnetic sensing to tighten latitude estimations and extend the operational envelop to the deep ocean or the poles where light based geo-positioning is not practical or sometimes even possible. And new sensory capabilities support tasks such as activity level sensing.

Its primary reliance on energy harvesting instead LOG a battery makes this tag multi-use, supporting both extended and repeated deployments and making LOG 'a smart piece of plastics and electronics' that can be used over and over again.

Finally, the application software is GNU open-sourced and we offer a developer's kit for researchers to develop new algorithms and capabilities! The positioning algorithms are published for anyone to view. In doing so we anticipate that scientists will review and improve the implemented algorithms or add new capabilities; and in return share their discoveries with the tagging community.



Figure 1: SeaTag-LOG Miniature Archival Tag

Location

- SeaTag-LOG™ replaces typical light based sunrise/sunset sensing with magnetic measurements to determine location. LOG senses the total magnetic field strength, a property that has a well established gradient in the north-south direction in most parts of the world. That compares to light based latitude measurements of most tags, which are less reliable because day length changes little with latitude in equatorial regions or throughout the world around the time of the spring and fall equinoxes. Magnetic sensing is a mostly robust and instantaneous method. Exceptions are local magnetic field disturbances and a few areas of the oceans where the gradient is low, it does not allow for large latitude errors.
- For applications where light is not available, such as tagging deep ocean animals, magnetic sensing provides limited position sensing by itself. For example, for animals known to migrate along a north-south running coast, magnetics is sufficient to establish a point along the coast. In the open ocean, magnetic sensing can constrain the animal's location to the region of a measured intensity level.
- The use of a wrap-around solar panel rather than a small light sensor averages or smooths the senses light level independent of the orientation of the tag. This can improve longitude sensing accuracy.

Sensors

The three axis magnetometer of LOG in particular can potentially be used for several applications beyond just position sensing. See the next chapter for details.

Power

SeaTag-LOG collects solar energy when available, then stores it in a 'super capacitor'. The standard version has no battery. Tens of minutes in bright sunlight support nearly a week of operation plus additional reserve for clock maintenance. LOG can be re-used at will. A battery assisted version is available for deep-ocean, no light, or dark water work. This version will draw on the battery when stored solar power is exhausted. The battery supports about two years of operation in darkness. But, following its depletion, the tag will continue to operate on stored solar power.

Connectors

SeaTag-LOG™ has no external connectors. To communicate with the docking station (the device used to configure and retrieve data from the tag), the tag uses a built-in radio antenna. The docking station uses powerful LEDs to send commands to the tag using the tags solar panel as the receive antenna.

2. The SeaTag-LOG Sensors

The SeaTag- LOG™ several sensors:

- **3-Axis Magnetometer:** Used primarily to measure the total strength of the earth magnetic field as an indicator of latitude. Resolution and noise level around 15 nT (approx. 0.03% of earth magnetic field). While field strength sensing is currently the only software supported function (as per V1.06 of the tag firmware), several other uses can be imagined:
 - The activity level of the animal could be determined by solving for the change in orientation over time, i.e. body turn rate expressed in degrees per second. This is possible because the sensor can detect the orientation of the tag relative to the earth magnetic field at any moment in time. By taking two measurements in rapid succession during each wake-up interval, and average activity level for a day could be established, or daily periods of activity could be determined.
 - For animals that dive in a distinct body orientation, typically head down, the sensor could be used to identify periods of diving or level swimming. As the orientation of the magnetic field relative to the horizon is location specific, this parameter would be back-computed after the animal location is first established and magnetic field inclination for that location is then applied.
 - The sensor could be used to establish horizontal body orientation of the animal, i.e. direction of swim.

- **Temperature Sensor:** The temperature sensor is used to compensate the internal clock and measure water temperature. The accuracy is 0.1 deg C, with a recorded resolution of 0.01 deg C.
- **Solar Cell:** The wrap around solar cell is used for a variety of tasks. Regarding sensing, it serves as the light intensity sensor for sunrise/sunset detection. The large-surface design smoothes out the light level (as compared to a small area sensor), thus making light readings mostly insensitive to tag orientation.

3. Operating Procedure

The operating procedure of a SeaTag-LOG™ deployment consists of these fundamental steps once drivers and software have been installed:

1. Charge the capacitors of the SeaTag™ devices by placing the devices in bright light for an hour.
2. Configure each device, setting the data acquisition schedule and tag identifying information. This also sets the tag's clock and/or erase LOG's log to make room for new data.
3. Conduct an internal test and place tags outside where they can see sunlight and operate them for one complete day and look at the results.
4. Tag the animals.
5. Recover the tag and retrieve the log data. Then process the data to obtain positions from recorded light and magnetometer readings.
6. Finally export the data as either a basic text file or a Google Earth (kml) file.



Figure 2: SeaTag-LOG™ system setup with ST-DOCK docking station connected to a small netbook PC via a USB cable. The SeaTag™ application for Windows is used to configure the tag and retrieve data logs.

Step 1: Capacitor Charging

The standard SeaTag™ (part number Tag-LOGs) does not contain a battery but instead is powered by stored solar energy only. Before configuration operations can proceed, the capacitor must be charged to at least 2.3V. This is done by exposure to bright light. Charge time depends on the initial state of the capacitor, but one hour of direct sunlight exposure is sufficient even if the capacitor was previously completely depleted (such as after multiple weeks in darkness). As an alternative, the tag can be subjected to artificial light. A method that works quite well is to place the tag inside the coil of a highefficiency bulb while blowing a desk fan on the bulb to keep the bulb cool.



Figure 3: Several SeaTag-LOG™ are charged inside the coil of a General Electric Helical 42W bulb, one of the larger and more powerful models. Even though this is a high-efficiency bulb, a fan is mandatory to keep the bulb cool and avoid overheating the tag. Charge time depends on energy already stored in the capacitor. Just ten minutes is often sufficient. But, one hour may be needed if the capacitor was previously completely depleted. The GE bulb is available at hardware stores such as Home Depot.

Step 2: Tag Connection & Configuration

Once charged, the tags are ready for configuration. **It is important to make sure your computers current time is as accurate as possible before configuring the tag because the tag will match this time (see Appendix C).** If you configure a tag with the wrong time then the noon time, longitude, and latitude of the tag will be inaccurate. See Appendix C if you have Windows Vista and would like to make sure your clock is set via the internet to ensure its accuracy.

Insert the tag into the docking station (part # Tag-Dock) and start the SeaDock software on the PC. The tag is inserted with the tip (rounded end) first and all the way, so that the tip comes to rest in the rounded indentation at the bottom of the chamber. Note the high-intensity LED along the sides and the small antenna near the bottom indentation. SeaTag uses light for transmission of data from the dock to

the tag and RF (radio waves) for transmission of data from the tag to the dock. A few pieces of advice for the dock operation:

Advice for Reliable Dock Operation

- The clear sides of the top cover provide a visual feedback of data transmission between the dock and the tag. But, external light can also filter in under bright conditions and interfere with data transfer. During the connection process or heartbeat monitoring you will notice this if the heartbeat indicates an INVALID light level instead of OFF. In that case place a cover or your hand over the dock. INVALID could also be a notice that the tag's capacitor voltage is too low (*note the voltage in the heartbeat data*).
- For reliable data transfer, make sure the tag is seated all the way in the dock. If you are having trouble to connect, rotate the tag a bit.
- A connection will only be established if the tag capacitor voltage, as reported in the heartbeat, is at least 2.3V.



Figure 4: The tag inserts into the dock rounded end first.

The SeaTag™ dock connects to the PC by USB cable. While the dock electronics are powered by USB power, the high-intensity LED requires the use of the external power adapter. After making

these connections, start the SeaTag™ software and select the COM port of the SeaTag™ dock. The COM ports on the list can be identified by placing the mouse over them.

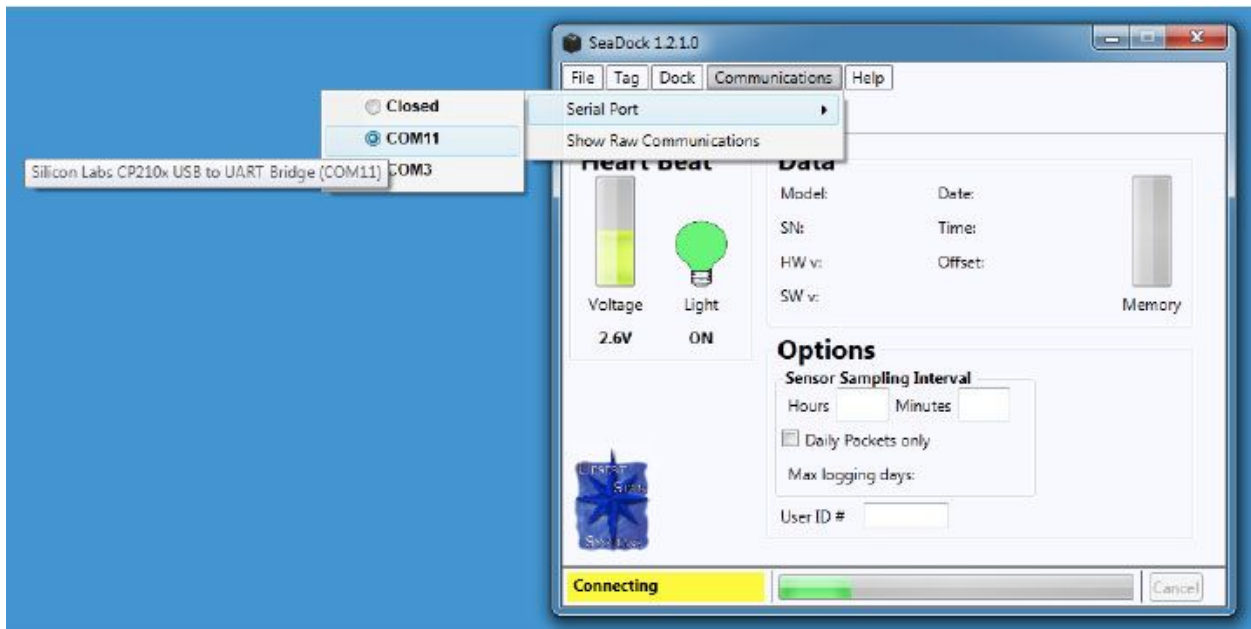


Figure 5: The SeaTag software main screen detecting a dat. A mouse-over identifies COM11 as the ‘Silicon Labs’ COM port to connect to (‘Pololu’ is also possible). The tag’s reported voltage of 2.6V is sufficient to connect.

The dock will now be in **Detecting mode**, listening for the heartbeat of any inserted tag while the chamber light will stay off. When a heart beat shows up the software will automatically switch to **Connecting** mode. Assuming the tag voltage is at 2.3V or higher, this will start the connection cycle in which the dock switches the chamber light ON and OFF in response to the heartbeat received from the tag. Once the tag detects two successive ON/OFF cycles (i.e. after about one minute) it will link to the dock. The status bar in the lower left corner will now read **Connected**. To make sure you start with fresh memory, hit the **Erase Logs** button under the **Tag** menu at the top of the screen now.

Configuring the Tag

Following connection, observe the “Options” box at the bottom of the window.

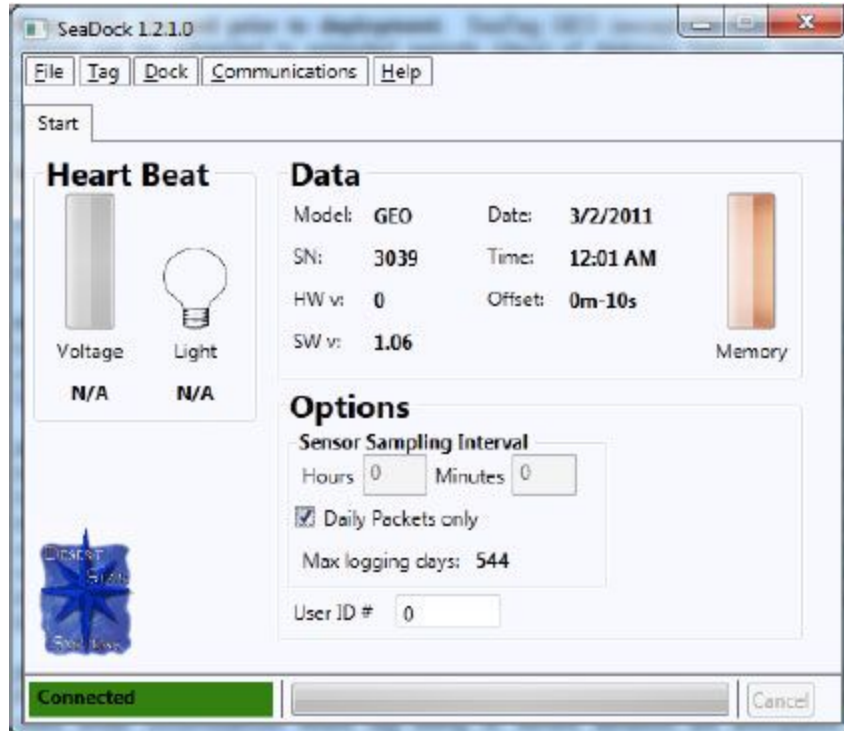


Figure 6: The options are set up for daily packets only, i.e. the acquisition of data, processing and storage of one packet each day containing averages sensor data and noon timing for position computation. Note the indicators showing that the log will be exhausted in 544 days, and the clock is set correctly with an offset of ten seconds between PC time and tag time. The memory bar is also full because this tag has not had its logs erased since running a sensor sampling test.

The sample screen shows the configuration for acquiring daily packets with position related information and averaged sensor data only. This is the standard setting, and will make the tags memory will last longest. In this case the deployment length is indicated as 544 days. If you want to collect a full set of sensors data in regular intervals, uncheck the 'Daily Packets Only' mark and enter the acquisition interval in minutes. But, be careful to watch the 'Max. log days' to make sure you have enough memory to support your intended deployment duration. The minimum sensor sampling time with the default software is every 4 minutes to ensure low power consumption.

Finally, you can set the User ID to provide an experiment or other identification for the tag. The available range is zero to 65535.

To save your settings click **Write Config** under the **Tag** menu at the top of the screen. The information and current time will now be written into the tag and also read back for verification. Following this readback, verify the clock data. This data is retrieved from the tag and compared to your PC time. Make sure the date & time (always stated in UTC / GMT) is correct. The clock offset

should be no more than several seconds. This initial offset is not drift, but processing delay between the tag and the PC application.

This concludes the configuration and you can now remove the tag from the docking station.

Step 3: Animal Tagging

A list of things to consider:

1. **Evaluate the solar energy harvesting potential:** SeaTag-LOG, except the battery assisted version Tag-LOGb, does not have a battery and relies on stored solar power only to sustain operations. However, the energy harvesting potential is strongly dependent on your operating environment and the animal's dive characteristics. Appendix B of this document recommends tests to be conducted on-site in preparation for your tag deployment. You may also wish to review Appendix A, which explains the fundamentals of LOG's power system.
2. **Keep LOG charged prior to deployment:** SeaTag-LOG (except the battery assist version) should not be subjected to extended periods (days) of darkness between configuration and deployment to assure that the clock will keep running. It's also a good idea to start a deployment with the LOG near fully charged. Put it in the sun on the day of the deployment, or charge under a bright light (see Step 1).
3. **Minimize obstructions of the solar panel:** Design the tag attachment method in such a way as to minimize blockages of the solar panel. See the figure below. In particular, make sure that you never obstruct any one of the five series-switched cells of the panel completely. Each of these sets of cells generates 0.6V, so if one is obstructed all around (such as by a band or a ring) then the required charge voltage can no longer be developed.
4. **Keep away from ferrous metals:** LOG uses small intensity changes in the earth magnetic field to compute latitude. Thus, use non-metallic hardware to attach the tag. If metal use is mandatory, use non-ferrous types. Stainless steel actually does have a weak but still significant field. Brass is better. We have not seen any measureable magnetic in common aluminum alloys.
5. **Attachment points:** LOG has attachment holes drilled through its tip. You can use or drill out this hole. The tag is potted in clear epoxy, and you can drill other holes or make modifications as long as none of these modifications penetrate the electronics or remove the protective layers from the solar panel. For example, a hole could be safely drilled into the base of the tag to provide a second attachment point. Rings or bands placed around the tag are best kept in the areas of the metal solar panel electrodes (to avoid obstructions of the panel itself). When mounting against the body of an animal, face the small gap in the wrap-around solar panel towards the animal's body as this area does not harvest solar energy.
6. **Abrasion, Cuts & Bites:** The outer perimeter and surface of LOG consists of three layers. Please review for suitability for your application. Our tests have not found any

problems, but if used under circumstances where tag biting or severe abrasion are anticipated, additional protective layers could be applied.

1. The ID label is on the very outside. This has an identifying function only (we will ship the tags with contact or other information per your instructions) and is not considered a protective layer. You can remove or replace the label if needed.
2. Next, the tag is wrapped in a tough, clear PVC shrink tube. You can see or feel the edges of that tube near both ends of the tag. This is the first protection against abrasion or cuts. The PVC tubing could be doubled up for severe conditions.
3. Below the shrink tube is the epoxy body of the tag, including a thin layer that forms over the solar panel. By itself, this thin layer of epoxy however has only limited strength and can tear (although we have also subjected it to about five months exposure in a water filled vibrator tank where it rubbed against fine grid sandpaper, without noticeable damage).
4. The solar panel is covered with a tough plastic film, constituting the final layer of protection.

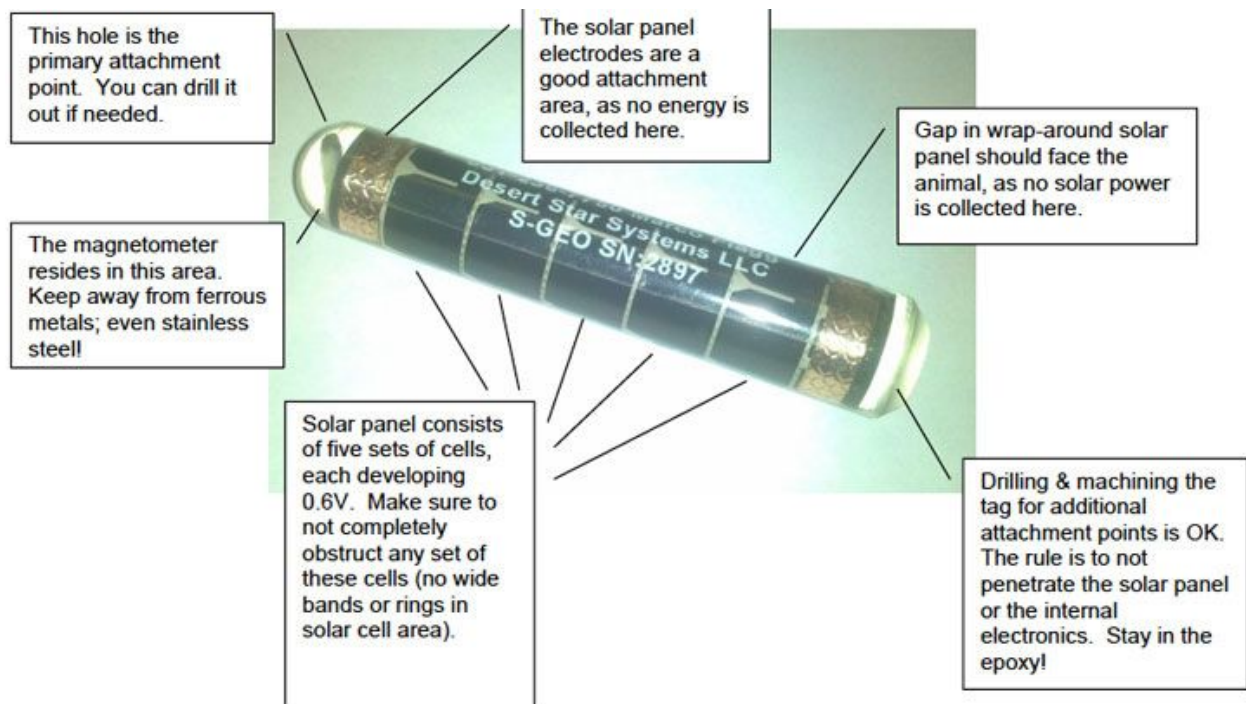


Figure 7: SeaTag-LOG™ Mechanical Characteristics & Features

Step 4: Recover the tag and retrieve and process the data log

Following the recovery of the tag, it is time to download the data log. Connect as described in step #2, and then hit the **Download Logs** button. The data will be downloaded as a comma delimited

text file, suitable for import into Excel or any analysis program. The following is a print-out of a short log.

Desert Star Systems LLC SeaTag Log File

Tag Serial number: 1001

Tag User Identification number: 0

Tag Model: LOG

Log downloaded on(UTC): 2/21/2010 2:11 AM

Tag clock offset (in seconds): -6.5625

——Beginning of log (Import the following as a comma delimited file into Excel or similar)——

PACKET_type, sensor packet date/time, temperature (deg C), capacitor voltage (mV), solar panel voltage (mV), mag_x (nT), mag_y (nT), mag_z (nT), mag_magnitude (nT), status byte, noon date/time, day length (hh:mm:ss), average temperature (deg C), average capacitor voltage (mV),

average solar panel voltage (mV), average magnetic field amplitude (nT)

PACKET_SENSORS,2/18/2010 6:34 AM,10.317,2542,2,15730,-45370,1550,48040,,,,,

PACKET_SENSORS,2/18/2010 8:38 AM,9.951,2534,2,15880,-45450,2010,48180,,,,,

PACKET_DAILY,,,,,,,,,0,2/18/2010 6:59 AM,00:00:00,10.46,2545,2,48080

PACKET_SENSORS,2/18/2010 12:45 PM,9.86,2519,2,15880,-45230,1940,47970,,,,,

PACKET_SENSORS,2/18/2010 2:49 PM,9.585,2510,20,15510,-45520,900,48090,,,,,

PACKET_SENSORS,2/18/2010 4:52 PM,9.585,2499,975,15060,-45590,-250,48010,,,,,

PACKET_SENSORS,2/18/2010 6:56 PM,11.405,2496,1722,14690,-45660,-1030,47970,,,,,

PACKET_SENSORS,2/18/2010 9:00 PM,12.932,2487,2118,17230,-44140,8570,48150,,,,,

PACKET_SENSORS,2/18/2010 11:04 PM,12.395,2478,928,17760,-44290,6230,48120,,,,,

PACKET_SENSORS,2/19/2010 1:07 AM,11.676,2469,111,17080,-44720,5120,48140,,,,,

PACKET_SENSORS,2/19/2010 3:11 AM,11.586,2460,2,17680,-44290,7590,48280,,,,,

PACKET_DAILY,,,,,,,,,0,2/18/2010 8:15 PM,11:01:05,10.94,2498,623,48080

PACKET_SENSORS,2/19/2010 5:15 AM,11.586,2452,2,16260,-45370,2530,48260,,,,,

PACKET_SENSORS,2/19/2010 7:18 AM,11.134,2446,2,16180,-45300,2530,48160,,,,,

PACKET_SENSORS,2/19/2010 9:22 AM,10.953,2437,2,14990,-45810,-1030,48210,,,,,

PACKET_SENSORS,2/19/2010 11:26 AM,10.863,2428,2,15880,-45450,1420,48160,,,,,\

Note The identifying information, then the data header identifying the various data fields and then the data itself. Note also that the data contains both the daily packets for geo-positioning (PACKET_DAILY) and sensor packets (PACKET_SENSORS), in this case one every two hours. The log is set up such that each datum independent of its origin from a sensors or daily packet will wind up in its own column with the data type specified in the header. This simplifies subsequent processing in a spreadsheet or analysis software and is the reason that numerous ,,,, precede the daily packet sensor data.

Measurement	Units of Measurement
Time	Time & Date of this packet (UTC)
Temperature	Degrees Celsius
Capacitor Voltage	mV
Solar Panel Voltage (light intensity)	mV
Mag_x	Magnetometer Unit, x axis, nano Tesla
Mag_y	Magnetometer Unit, y axis, nano Tesla

Mag_z	Magnetometer Unit, z axis, nano Tesla
Mag_amplitude	Magnetometer Unit, total field strength, nano Tesla

Figure 8: Sensor Packet Units of Measurement

Measurement	Units of Measurement
Status	0: Normal end-of-day 1: Time-out package. Issued when no sunrise/sunset has been detected in 30 hours.
Noontime	The noon time in UTC (coordinated universal time)
Day length	The length of the day. hh:mm:ss
Average temperature	The average temperature for the day. Degrees C
Average capacitor voltage	mV
Average solar panel voltage (average light intensity)	mV
Average mag amplitude	The average magnetic field strength for the day

Figure 9: Daily Packet Units of Measurement

Computation of Latitude and Longitude, and Export to Google Earth & other processing software

For geo-positioning, the file can now be run through the **SeaTrack** software, which converts noontime and magnetometer readings to longitude and latitude. **SeaTrack** outputs a comma delimited file similar to the log itself, but also containing latitude and longitude values. It generates a separate .KML file with which the data can be viewed directly in Google Earth.

4.SeaTag™ Docking Station Software Reference

The SeaTag™ docking station software (SeaDock) is used to configure a tag, retrieve data logs and related management functions. It requires the use of the SeaTag™ docking station, which must be connected to the PC via a USB cable. This chapter provides a reference for the various software functions. See chapter three for a review of the SeaTag™ operations process from tag configuration to data retrieval using this software.

Start Tab

The SeaTag™ software starts with this tab. It is used to establish a connection with a tag, monitor a tag's heartbeat and retrieve data logs.

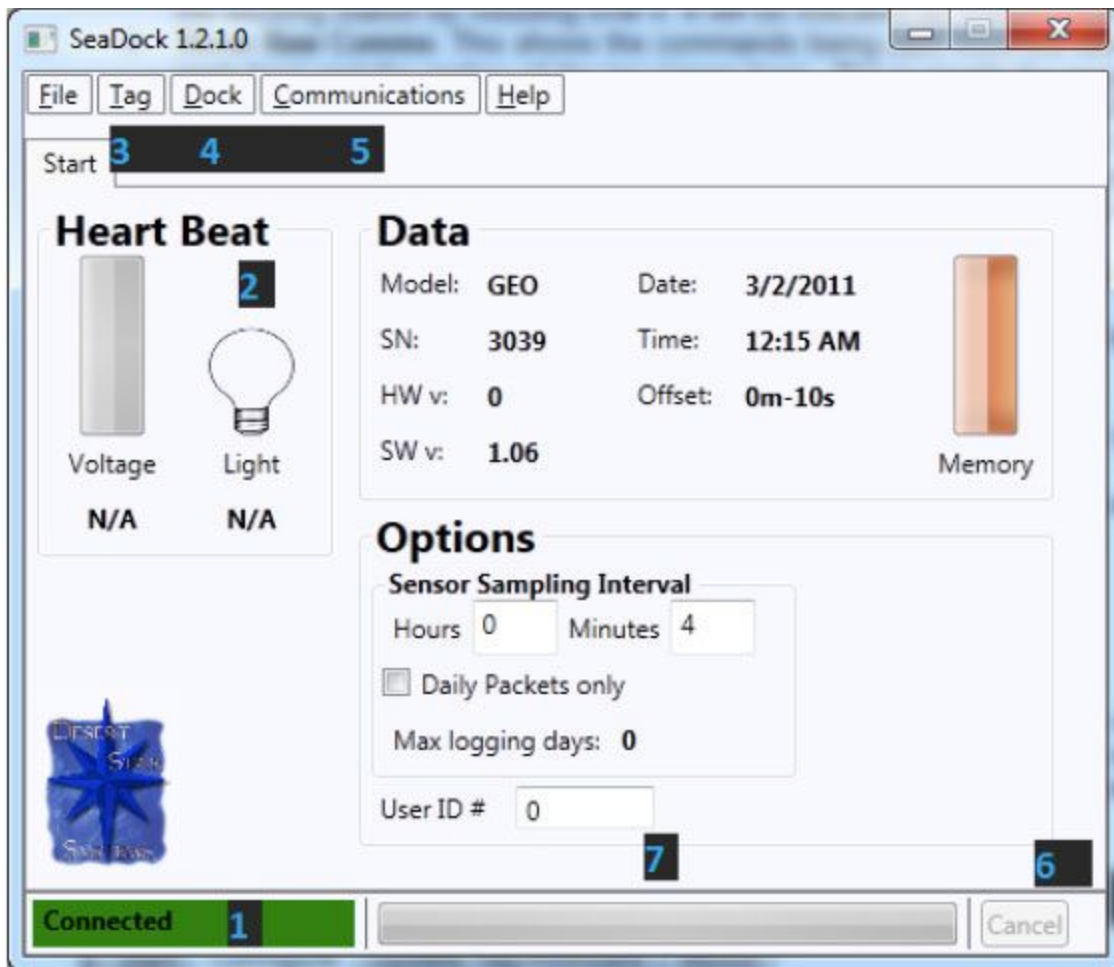


Figure 10: Start Tab

1. **The status bar:** The list of available states for the status bar is as follows: **Disconnected**, **Dock Sleep Mode**, **Detecting**, **Charging**, **Connecting**, **Connected**, **Erasing Tag**, **Downloading**, **Reading Tag**(options), **Writing options**, and **Uploading Firmware**.

2. **Heart Beat Data:** The heart beat will show the tag's capacitor voltage and whether it sees the dock light as on or off. This is useful to establish that the tag is running and its capacitor charged. During the connection phase, you will see the dock light cycle ON and OFF in 16 sec intervals in response to the heartbeat. The heart beat data in turn will show if the tag sees the light as either ON or OFF. If you see an INVALID reading in the heartbeat data, the tag has seen a light level that is too bright for OFF and too dim for ON. That can happen when the dock light is off but ambient light penetrates the dock (put a towel or your hand over it) or if the dock light is on but the tag is really dirty (wipe it clean). The tag sees two successive OFF/ON cycles as the sign that it is in the dock, and it will now establish the connection.
3. **Tag Menu**
 - **Update Firmware:** This will upload new firmware to your tag. *Be warned that this button will erase your tags firmware as its first step.* If you don't have new firmware to put on your tag then you will end up with an empty tag that won't do anything until you upload new firmware to it. The upload firmware button is enabled even if a tag hasn't been detected so that it can work with empty tags.
 - **Download Logs:** This button is used to download the logs from the tag.
 - **Erase Logs:** This button is used to erase the logs from the tag. You will be asked to confirm this action. But, be careful! Once erased, log data is no longer available. So make sure first it's really already been saved to your PC. And, for high-value data, keep the data on the tag as a backup until you have made a separate backup and inspected the data.
 - **Read Settings:** This will read the tags settings including its clock, sampling rate, etc.
 - **Write Settings:** This will save your options to the tag and set its clock to match your PC's time.
4. **Dock Menu**
 - **Wake From Sleep:** This will wake up the dock if it has gone to sleep due to inactivity.
5. **Communications Menu**
 - **Serial Port:** This is the COM port being used by the docking station. If the PC only has one COM port in use, only that COM port will show. If there are more, verify which one is the docking station by mousing over it. It will be indicated as 'Pololu USB-to-serial adapter' or 'Silicon Labs CP210x USB to UART Bridge'.
 - **Show Raw Comms:** This shows the commands being sent from the docking station to the tag (pink box) and the replies of the tag (green box). This is mostly for engineering and debugging purposes. You will find it useful if you are developing new code for SeaTag.
6. **Cancel:** This button is used to cancel a log download that is in progress.
7. **Progress Bar:** Display the progress of a log download or other operations like the reading of a tag configuration.

Configuration

Prior to a deployment, use the options area to set the sampling interval, the type of data being collected and a user ID. Feedback information identifies the tag. The tag's clock setting is displayed and can be used prior to deployment for verification purposes, and a clock offset shows the accumulated drift during a deployment.

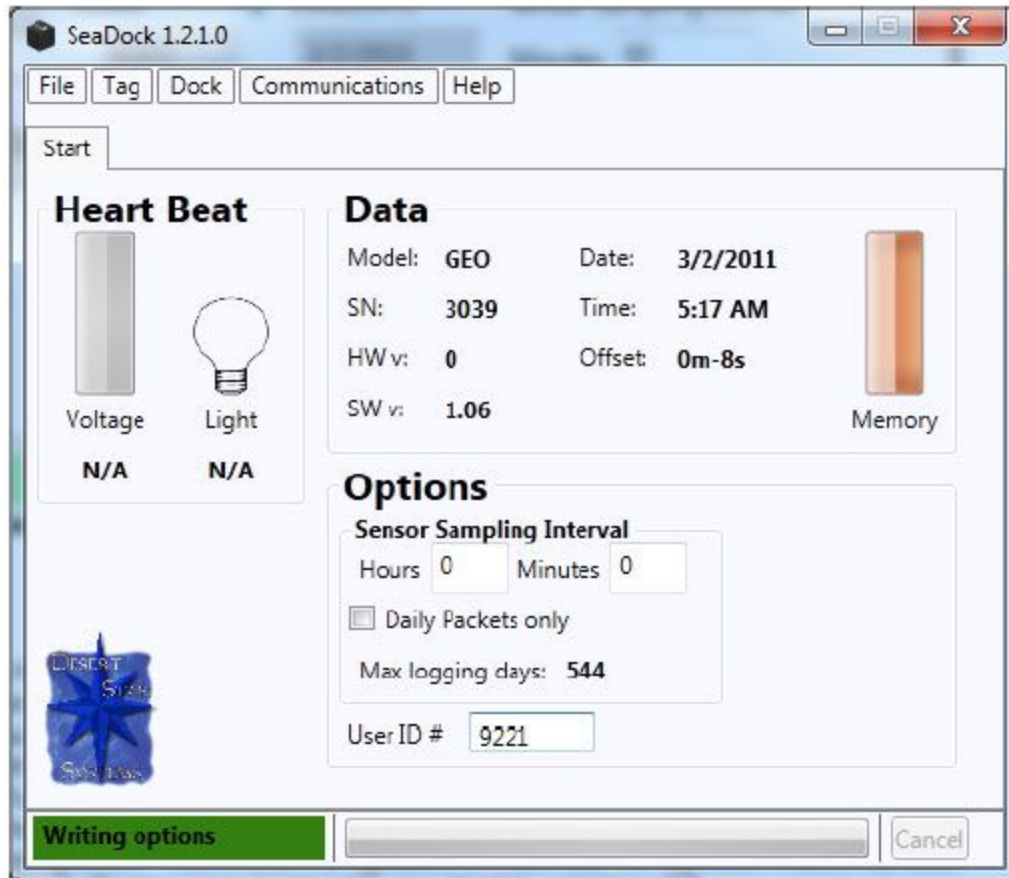


Figure 11: Tag Configuration

1. Tag Info:

- Model: This auto-populates with the model tag being used (ie: SeaTag-LOG)
- SN: This is the factory assigned serial number of the device
- HW Version: This auto-populates with the version of the hardware for the tag
- SW Version: This auto-populates with the version of the firmware on the tag
- Date/Time: These show the time and date according to the tag. It is updated when you read the configuration and also automatically during the read-back cycle after writing a new configuration. View it after configuration to make sure the tag clock indeed has been set. Use it after tag recovery to make sure the time remains valid.

- Clock Offset: This shows the difference in your computers time compared to the tags time. It is updated when you read the configuration and also automatically during the read-back cycle after writing a new configuration. Following tag recovery after a deployment, this number is an indication of clock drift during the deployment. This number will also appear in the header of the data log and can be used to adjust time in post processing for greater longitude sensing accuracy.
- User ID#: You can set this field with a number between 0 and 65535. Use it to identify the tagging experiment or otherwise organize your data.

2. **Sampling Interval:**

- Minutes: The tag will read all of the sensor data at each interval. For example, in the above figure, the tag will read all sensor data every 60 minutes and store the data to the tag. The tag automatically reads and records sensor data on a default time schedule (daily packets). Reading and recording all sensor data on a custom defined sampling interval is generally used when short term deployments are anticipated or when testing new algorithms (see Developer's Kit).
- Daily Packet Only: Check this box if you want to only log daily packets and get the longest deployment duration.

Dock Sleep Mode

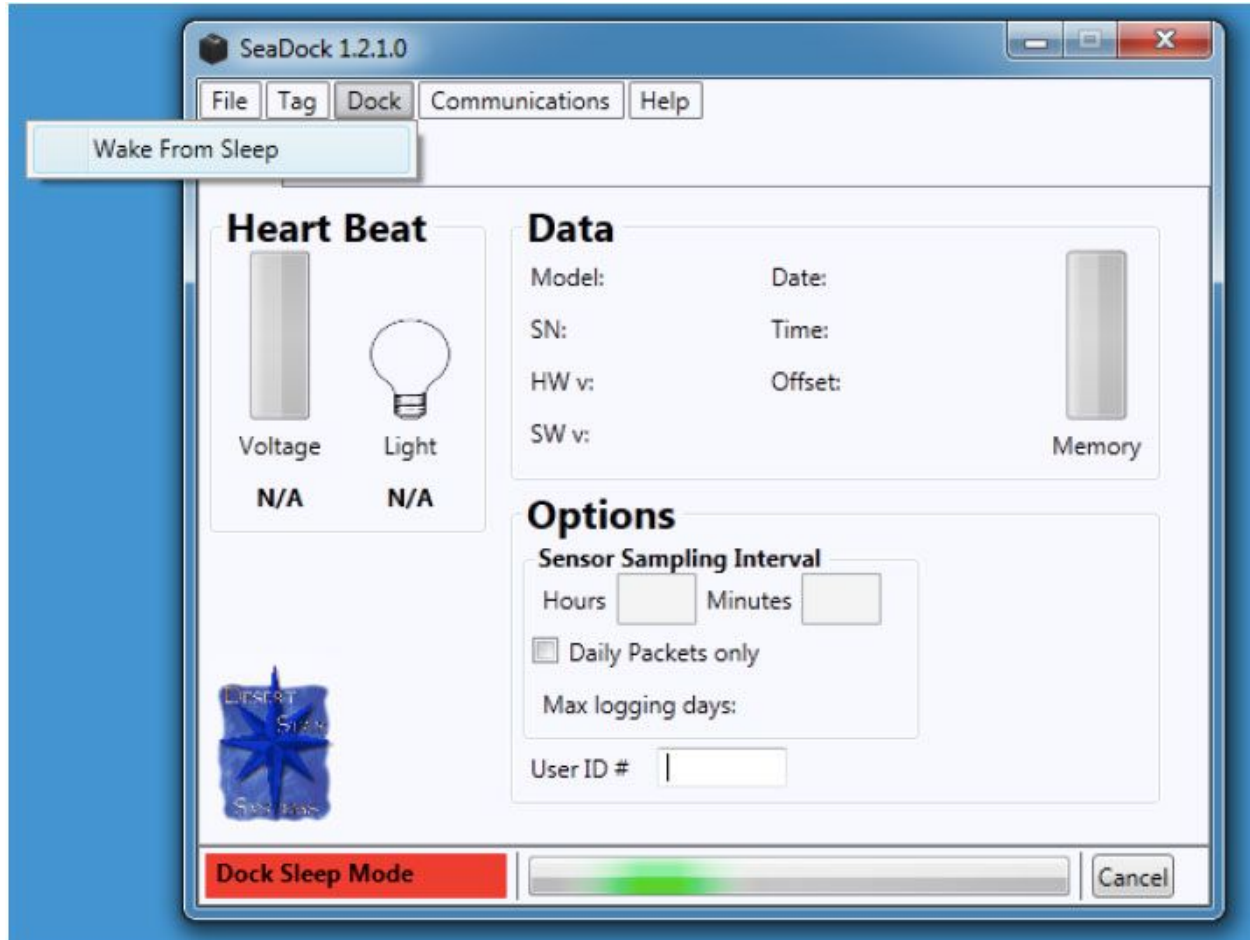


Figure 12: Waking up a dock after 10 minutes of inactivity.

To conserve energy the dock will go to sleep after a lack of activity for 10 minutes. To wake it up from this mode click **Wake From Sleep** under the **Dock** menu at the top of the screen.

5.SeaTag™ Position Processing Software Reference

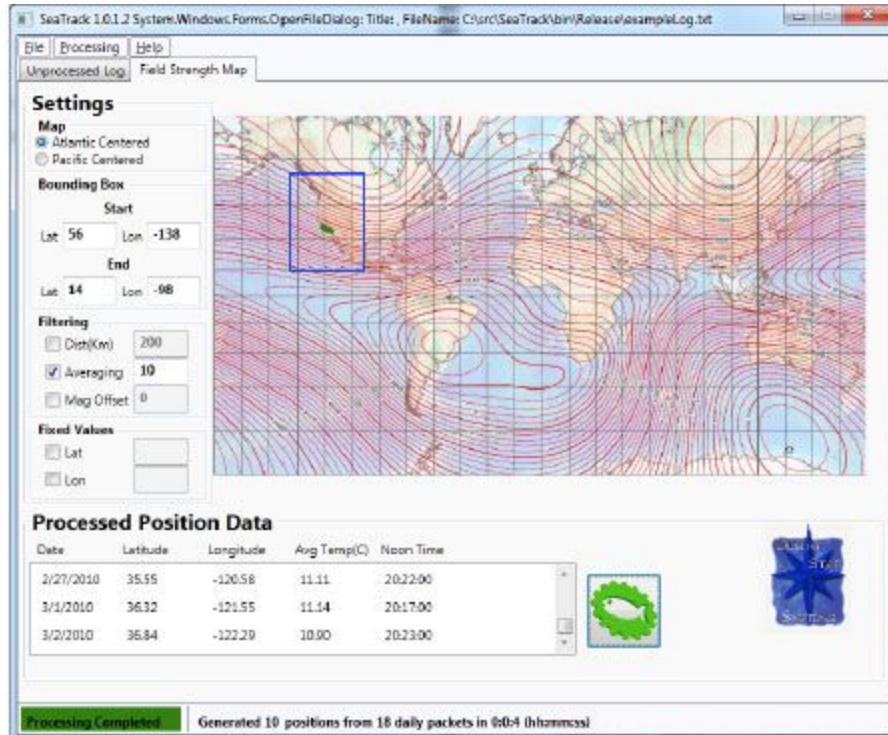


Figure 13: SeaTrack position plotting screen

SeaTrack is used to process the data downloaded from tags. The program takes in raw log data and generates both kml position files for use in Google Earth as well as comma delimited text files. It generates these positions by using two key algorithms. First the longitude is computed by using the noon time for a given position. Then we search up and down along the computed longitude for a closest match to the predicted magnetic field strength for that day using the world magnetic model. [\(link\)](#) Other filtering is available including a bounding box, applying a running average, maximum distance per day filtering, and fixed latitude or longitude.

Loading a Log

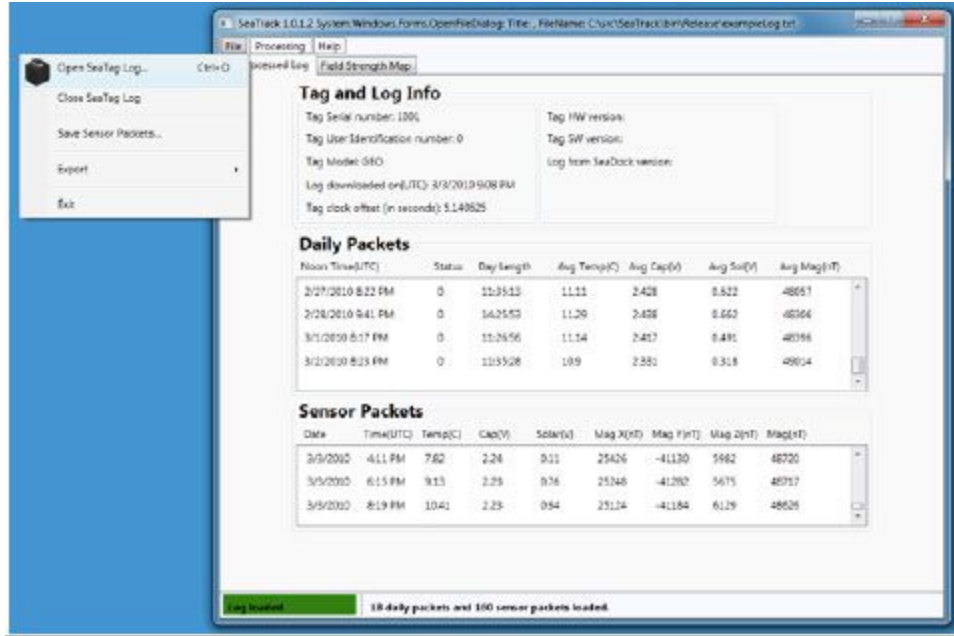


Figure 14: Loading a log

The first step is to load up a log by pressing **Ctrl+O** or clicking **Open SeaTag Log** in the main **File** menu. Daily packets and sensor packets will be loaded and displayed along with the tags information.

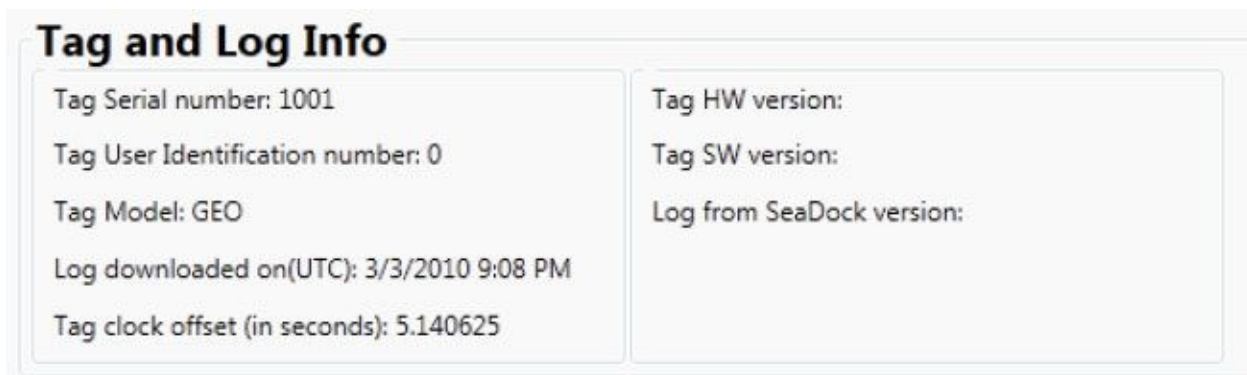


Figure 15: Header with extra information stored in the log

The header shows the factory configured serial number of the tag, the user ID code set in SeaDock, the date the log was downloaded on along with the clock offset at time of download, and version information for various system components.

Daily Packets

Noon Time(UTC)	Status	Day Length	Avg Temp(C)	Avg Cap(V)	Avg Sol(V)	Avg Mag(nT)
2/27/2010 8:22 PM	0	11:35:13	11.11	2.428	0.622	48057
2/28/2010 9:41 PM	0	14:25:53	11.29	2.438	0.662	48306
3/1/2010 8:17 PM	0	11:26:56	11.14	2.417	0.491	48396
3/2/2010 8:23 PM	0	11:35:28	10.9	2.331	0.318	49014

Figure 16: Loading a log

The daily packet display shows what all of the daily packets that were found in the log. These packets consist of a Noon Time (used for longitude calculation), a status byte used for debugging information and future expansion, the length of the day, and sensor information including the average magnetic field strength for the day(used for latitude calculation).

Sensor Packets

Date	Time(UTC)	Temp(C)	Cap(V)	Solar(V)	Mag X(nT)	Mag Y(nT)	Mag Z(nT)	Mag(nT)
3/3/2010	4:11 PM	7.82	2.24	0.11	25426	-41130	5982	48720
3/3/2010	6:15 PM	9.13	2.23	0.76	25248	-41282	5675	48717
3/3/2010	8:19 PM	10.41	2.23	0.94	25124	-41184	6129	48626

Figure 17: Loading a log (continued)

The tag above was configured to log sensor packets every two hours. Logging raw sensor packets diminishes your maximum deployment length because the tag fills up. This kind of logging can be used for debugging, testing, and novel applications however. For example a tag might be configured to log a sensor packet once an hour and detect magnetic field strength changes as vehicles enter or leave a parking lot.

Processing a Log

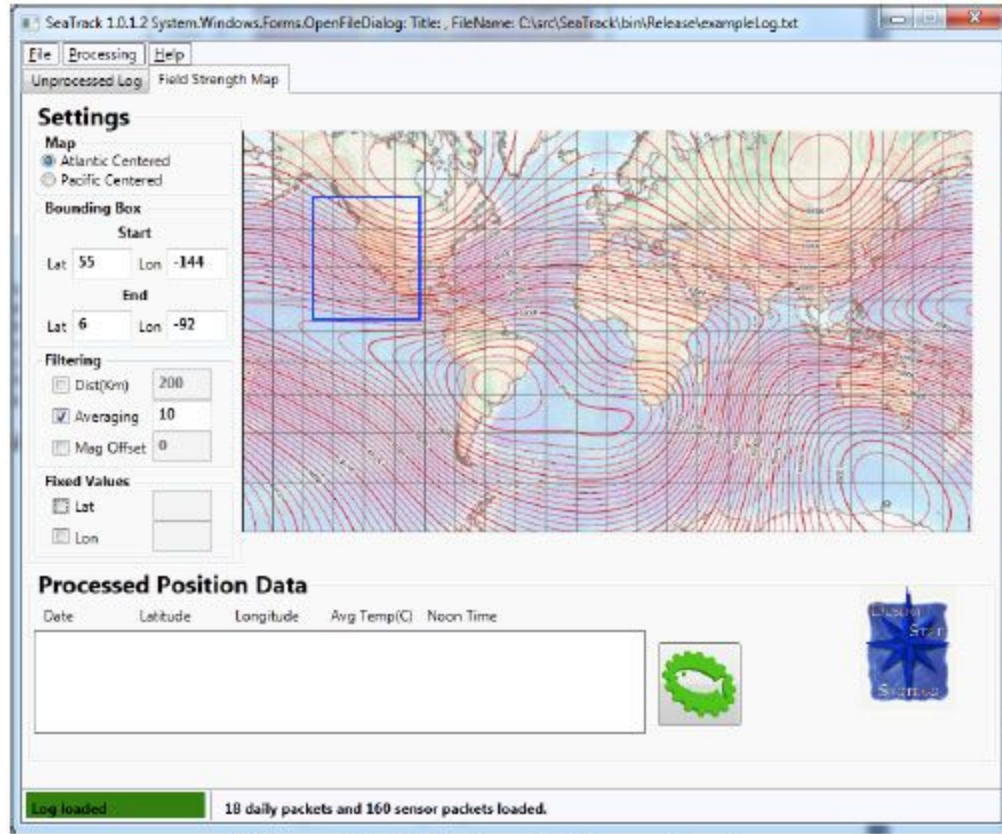


Figure 18: Defining the bounding box

After loading a log with daily packets in it you'll need to switch to the Field Strength Map tab to convert them into positions. After switching to this screen you can begin by selecting an Atlantic or Pacific centered map at the top of the settings sidebar depending on roaming area of your target.

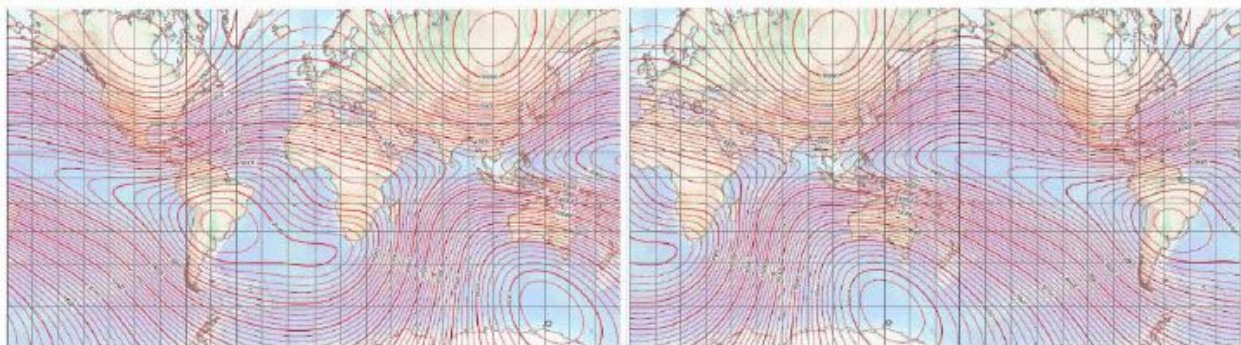


Figure 19: Atlantic(left) and Pacific(right) centered maps (based on [link](#)).

With the map style defined the next step is to draw a bounding box around the approximate search area for your target. To do this left click and drag the bounding box starting at the top left corner. If

you don't like your bounding box you can right click to clear it or just start drawing it again which will automatically clear it for you. Alternatively you can type in the bounding box properties in the “Bounding Box” are on the left side of the screen. Press tab after entering each value to move on to the next one until the box is fully defined after which point it will appear on the map.

Bounding Box

Start

Lat Lon

End

Lat Lon

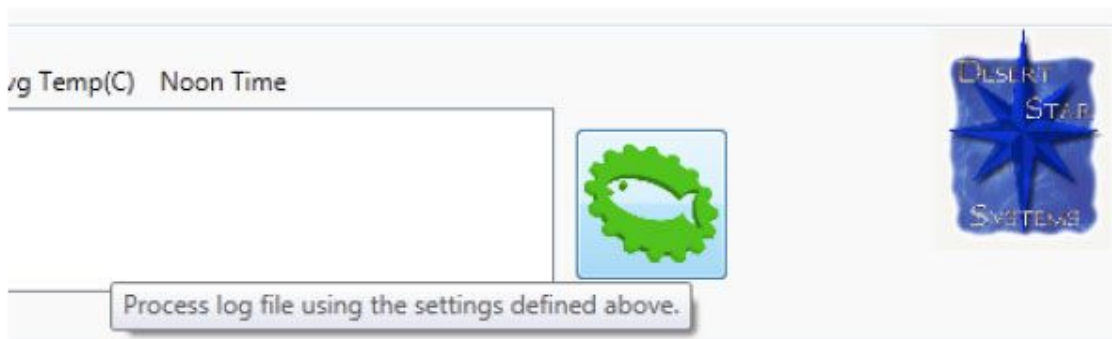


Figure 20: Beginning processing by clicking the gear fish

Clicking the picture of the gear fish at the bottom of the window will start the log processing and generate positions using the default 10 day averaging, no distance filtering, and no magnetic offset. If you know your animal can't travel more than a certain distance per day, or that the magnetic sensor in your unit needs an additional offset, then feel free to enable these options in the Filtering section of the Settings. If you decide you want to cancel the processing and change the settings after it has begun you can click the gear fish again, or redraw the bounding box.

Exporting Positions

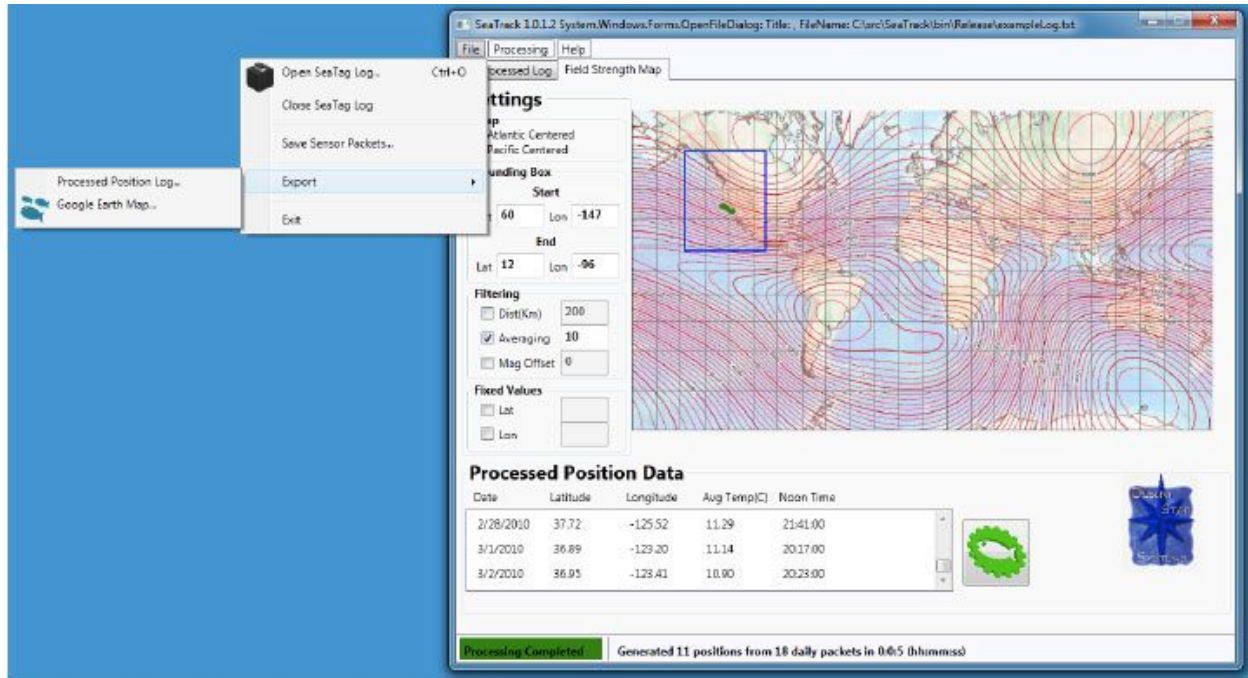


Figure 21: Exporting position files

You have two options for position data export. SeaTrack will export text and KML(Google Earth) files. Alternatively you can also save your unprocessed sensor packets if you decide you want to split them off from your daily packets.

6. Technical Specifications

Size:	77mm L x 13mm D
Weight:	<u>Tag-LOGs:</u>
	14.1g in air
	4g in fresh water
	<u>Tag-LOGb:</u>
	16.4g in air

	6.3g in fresh water
Power Supply:	<u>Tag-LOGs:</u>
	3V Solar Cell charging a 3V 4F Aerogel Capacitor.
	Approx. 6 days of operation for a full solar charge plus 11 days reserve to clock loss
	Approx. 12 minutes charge time in full, direct sunlight
	<u>Tag-LOGb:</u>
	Battery assisted version. Same as LOGs, but includes lithium battery backup for extended periods of darkness. Supports operation for 2.5 years in darkness. After battery depletion, tag will behave like a standard battery-less tag.
Sensors:	Three-axis precision magnetometer, 15 nT resolution (approx. 0.03% of earth field)
	Solar power panel doubling as large-surface light sensor
	Temperature sensor, 0.1 deg C accuracy
	Precision calibrated clock, < 10 ppm
Processor:	Texas Instrument MSP430F2274
Memory:	Processor internal FLASH memory sufficient for approx. 18 months of daily packets
Data Transmission:	To Tag: Through light sent to the solar panel
	From Tag: Through RF using internal antenna

Op. Temp. Range:	-50 deg C to +85 deg C
Depth Rating:	Tested to 2000m (3000psi) and worked fine, further testing available upon request

Appendix A

F Yj JYk 'cZ9bYf[m< Ufj Yghjbl 'UbX'CdYfUjcbg'k Jh 'h YGYUHJ !@; 'GtcfYX'Gc`Uf'Dck Yf` GngHYa`

SeaTag-LOG relies on stored solar power instead of a battery to support operations. Unlike a typical battery operated tag with a lifetime limited by battery exhaustion, LOG can operate without any time limit, potentially for many years and spanning multiple deployment cycles. LOG can be thought of as a 'smart' tool or just a block of plastics and electronics that can be stored and used over and over again until worn out by factors such as mechanical attack, abrasion, fouling or perhaps aging due to UV exposure.

Yet, whereas a battery-powered tag functions without interruption until its battery is dead, LOG operations are subject to available light. As LOG uses stored solar power, light need not be there continuously. In fact LOG can survive and even operate for days or a few weeks in complete darkness, then re-charge in a matter of hours or even tens of minutes of sunlight exposure. But, considering a long deployment, the tag's level of activity and the continued operation of its clock (a critical function for geo-positioning) is guided by the averaged level of its exposure to light.

For this reason, it is important to understand the LOG power system. Evaluate it in the context of the environment where tagging will take place (cloudiness, water clarity) and the expected behavior of the tagged animal, in particular its time spent at or close enough to the surface for energy harvesting. Then, conduct a few experiments as explained in Appendix B to determine if a LOG powered by just solar will work for your task. If not, consider the use of the battery assisted or hybrid version, part # Tag-LOGb, which will operate for about two years in darkness yet use stored solar power when available.

For applications where stored solar power alone may not be sufficient, we recommend the use of the battery assisted version of SeaTag-LOG (Part # Tag-LOGb). This version includes a battery to augment solar power and will operate for an estimated two years in complete darkness.

The SeaTag-LOG Power System

SeaTag-LOG's power system principally consists of a flexible solar panel in its outer skin which produces energy at a rate depending on light exposure, and a 'super capacitor' that stores the

accumulated energy and delivers it as needed to the electronic circuitry of the tag. Three major parameters describe this system. You can use these parameters to estimate performance for your application:

- The **charge current** of the solar panel defines the rate at which energy is produced. The charge current is measured in microamperes. It is proportional to **illumination** and will reach roughly 7,000 microamperes during full sunlight exposure of 100,000 Lux. The minimum light needed to charge the capacitor is approx. 700 Lux.

Illumination	Charge Current	Charge Time (1.7V to 3.0V)	Equivalent Condition
100,000 Lux	7,000 uA	12 minutes	• Full sunlight at the surface.
10,000 Lux	700 uA	2 hours	• Moderate cloud cover at the surface
			• High-turbidity coastal water at 2.5m, sunny day
			• Medium-turbidity coastal water at 6m
			• Clear coastal / Mid-latitude open water at 22m
			• Extremely pure open water at 90m
1700 Lux	0 uA (Light must be above this minimum to obtain charge energy)	Charging stops	• Very heavy cloud cover at the surface

			<ul style="list-style-type: none"> • High-turbidity coastal water at 4.5m, sunny day
			<ul style="list-style-type: none"> • Medium-turbidity coastal water at 11m
			<ul style="list-style-type: none"> • Clear coastal / Mid-latitude open water at 39m
			<ul style="list-style-type: none"> • Extremely pure open water at 160m

Notes: Equivalent light condition underwater is based on Jerlov (1976) as cited in 'Introduction to Physical Oceanography' by Robert H. Stewart, Texas A&M, 2006, Figure 6.18. Energy harvesting depends on the combination of the solar cell response (the Quantum Efficiency curve) and the wavelength specific transmittance of the water (%/m). We used a single wavelength of 500nm as the reference standard. At 500nm, the solar cell QE is at 80% of its peak value, and the water transmittance is at 66% of peak to 100% of peak depending on the water conditions. The goal is to arrive at 'typical' energy harvesting estimates, but significant variations should be expected.

- Extremely pure open water: Jerlov type I. 97.5% / m transmittance.
- Mid-latitude open water (type III) or clear coastal water (type 1): 90% / m transmittance
- Medium turbidity coastal water (type 5): 70% / m transmittance
- High turbidity coastal water (type 9): 40% / m transmittance

Figure A1: SeaTag-LOG condition dependent energy harvesting and charge time

- The **storage capacity** of the capacitor, measured in microampere hours. It defines how much energy is stored and is subsequently available for periods of darkness. The more energy is stored in the capacitor, the higher the voltage across it will be. SeaTag-LOG has a storage capacity of 888 microampere hours between the level of a full capacitor at 3.0V and the stop-acquisition voltage of 2.2V. It then has a reserve of another 555 microampere hours for clock maintenance/sleep mode until time tracking may be lost at 1.7V.

- The **power consumption** (or discharge current) of SeaTag-LOG for a specific operating mode, measured in microamperes. For example, when conducting normal operations for daily-packet collection including light and magnetic readings every four minutes, SeaTag-LOG consumes approx. 6 microamperes. In clock maintenance mode, which is automatically entered whenever the capacitor voltage drops below 2.2V, power consumption is 2 microampere.

Operating mode	Power consumption	Operating time (see notes)
Geo-positioning only (wake up every 4 minutes for light, magnetic, temperature and voltage measurements. Write a daily packet with geo-positioning data and averaged sensor readings once every 24h)	6 uA	Six days
Geo-positioning plus acquisition & storage of a full raw sensor package every 4 minutes (max. possible power consumption)	15 uA	2 ½ days (note that memory would be full after about 18 hours)
Clock maintenance mode	2 uA	Eleven days

Notes:

- Operating time for clock maintenance mode is for capacitor discharge from 2.2V to 1.7V. When the capacitor voltage is below 2.2V, SeaTag-LOG will automatically enter clock maintenance mode to avoid loss of time tracking.
- Operating time for all other modes is for the discharge of a full capacitor from 3.0V to the stopacquisition voltage of 2.2V.

Figure A2: SeaTag-LOG Power Consumption and Stored Solar Power Operating Time in Darkness

The Battery Assisted Version of SeaTag-LOG

In some applications, sufficient sunlight may not be available to continuously operate SeaTag-LOG without a battery. This may include tagging of animals that rarely venture close to the surface, or do so only at night. It could be operation in turbid waters. Or it might be tagging of marine mammals in the Arctic / Antarctic winter when light levels are very low, or in regions where heavy cloud cover is the norm.

In these cases, the capacitor voltage may drop below 2.2V, causing a stop of data acquisition – and ultimately below 1.7V at which point the SeaTag-LOG clock will stop. While SeaTag-LOG will re-start its clock and then resume data acquisition operations once light is available again, clock synchronization to UTC will be lost. This limits the data that will subsequently be available from SeaTag as described in the box below.

What Happens When The SeaTag Clock Stops Temporarily Due To Low Voltage?

- The clock will start again once light is available and the capacitor is charged above 1.7V.
- Data acquisition will resume once the capacitor voltage reaches 2.2V.
- Correct time & data is no longer available, but time progression continues to be accurately measured.
- Longitude data will no longer be available because the clock has lost synchronization to UTC. However, an animal progression east or west is available from the change of noon time on successive days.
- Magnetic based latitude measurements will resume and will remain valid.
- Temperature measurements will resume and will remain valid.

The risk of clock loss may be acceptable in some applications. For example, when tagging animals that move along the north-south running coasts of the Americas, Australia or the Antarctic Peninsula, the clock-independent magnetic measurements alone can be sufficient to discover their range.

Similar, if an animal is known to move around an island, then the magnetic information along with light based (but no longer UTC synchronized) east-west progression can be used to reconstruct the motion.

For other applications, a battery assisted version of SeaTag-LOG, part # Tag-LOGb is available. SeaTag-LOGb is the same size as Tag-LOGs, but adds a small lithium battery in a space that is otherwise epoxy filled. This non-rechargeable lithium battery, a Sanyo CR 1/3N, has a rated capacity of 160,000 microampere-hours. It will 'pick up the load' whenever the SeaTag-LOG capacitor voltage drops below 2.7V if the battery is fresh or 1.7V if the battery is at the end of its useful life. Thus, in lit conditions, SeaTag-LOG will run on solar power and charge its capacitors. During darkness, the capacitor will deplete and the battery will eventually take over.

Will SeaTag-LOGb become useless once the battery is completely depleted? No! It will now simply act as a purely stored solar powered device, i.e. just like the standard version of SeaTag-LOG does.

Operating mode	Power consumption	Operating time in darkness
Geo-positioning only	6 uA	2.5 years
Geo-positioning plus acquisition & storage of a full raw sensor package every 4 minutes (max. possible power consumption)	15 uA	1 year (note that memory would be full after about 18 hours, so this is for multiple deployments with one tag)
Clock maintenance mode	2 uA	1.7 years

Notes:

- Geo-positioning and geo-positioning plus acquisition operating time is based on a battery capacity assumption of 130,000 micro-ampere hours, after which the battery can no longer maintain a 2.2V system voltage.
- Clock maintenance operating time is based on the final 30,000 micro-ampere capacity of the battery, during which it develops a sufficient voltage to maintain the clock but not to support acquisition operations. During this final stage of battery life, SeaTag-LOGb will require solar power for acquisition operations.

Figure A3: Endurance of the battery assisted SeaTag-LOGb in complete darkness

Storing SeaTag-LOGb Tags

In order to maintain the SeaTag-LOGb battery during storage, we recommend storing the devices in a well lit area. A place with frequent daylight exposure such as a window sill might be best. This will keep the capacitor voltage high, removing the load from the battery. While the battery data sheet does not specify a storage life, lithium batteries are generally considered to have a storage life of around ten years.

Appendix B

Df Y!HU [] b ['Gc `Uf `Dck Yf `HYgh

SeaTag-LOG™ uses stored solar power instead of a battery (see Appendix A for technical details on the power system). When solar power availability exceeds the tags power demand, its storage capacitor will charge. In dim light or darkness, tag demand will exceed solar power and the capacitor

will discharge. For operation, the capacitor voltage must be between its maximum of 2.9V and a minimum of 2.2V. Below 2.2V, the tag will go into a very low-power clock maintenance mode. If the capacitor is depleted to somewhere in the range of 1.6V to 1.7V, the processor will reset and clock synchronization to UTC will be lost. That means longitude information will no longer be directly available even if light levels rise and the tag starts operating again (other data such as magnetometer readings will remain valid).

Without any light, it will take about six days for a fully-charged LOG operating in its standard 'daily-packet' geo-positioning mode to reach the 2.2V operations cut-off point. It will then take approx. another 11 days in clock maintenance mode before clock synchronization is lost at 1.7V or below.

Two Solar Power Test Options

In order to determine if SeaTag-LOG will be able to harvest enough solar energy to support operations, we recommend one of two simple tests.

1. **Capacitor Charge Monitoring Test:** The first option is to expose a tag to an approximation of

the light levels that are expected on a tagged animal. Then, every few days, insert the tag into the docking station to monitor its heart beat. Note if the capacitor voltage is on a rising or a declining trend. If rising or fluctuating near the top limit of 2.9V, the tag is harvesting sufficient energy. If declining to 2.2V and below, energy harvesting is insufficient. This test should be run over a period of several days and spanning typical weather cycles to obtain good data.

1. **Fast Light Level Measurement Test:** A fast test can be done to check if light levels at a certain water depth or in a specific location are sufficient for capacitor charging, without actually observing the charge or discharge process. For this test, SeaTag-LOG is programmed to collect and store a full set of sensor samples at its fastest rate, once every four minutes. The tag is recovered after a short test period of minutes or an hour and the data is reviewed. This test is useful to estimate performance for animals that do not surface, by briefly lowering the tag and evaluating light levels at depths where the animals is expected to be found. The disadvantage is that this test produces just measurements of a few short points in time. It may not capture the impact of weather changes or varying water turbidity, for example.

If you determine that light levels are insufficient for solar powered operations, consider use of the battery assisted version of LOG, part # SeaTag-LOGb. This version will operate on battery power during extended periods of low light, when the capacitor voltage drops too low. In complete darkness, SeaTag- LOGb can operate for about two years. Once the battery is depleted, it behaves like a standard LOG without a battery.

In some cases, dark-condition clock synchronization loss may be tolerable. Review Appendix A for details.

The Capacitor Charge Monitoring Test

This long-term test should be run for anywhere from three days to several weeks. It is powerful in that it can evaluate energy harvesting in the longer term, spanning changes in weather or in the expected activity (length of surface periods) of tagged animals. You will probably come away with a good intuitive 'feel' of what works and what doesn't – and can apply that experimental knowledge to your subsequent tagging operations.

The test essentially consists of placing a tag in a location or in a way where it might experience typical light exposure, then observing the rise or decline of the capacitor voltage over time. The test is useful to evaluate tag performance for animals that spend much time at the surface, and where the surface interval is the main energy harvesting opportunity. This includes penguins and pinnipeds, for example. It should also work well to evaluate performance for tagging reef fish, as a SCUBA diver could place a tag on the reef for a few days.

Step #1: Condition the tag for the solar power test

Start by bringing the capacitor voltage to the mid to high operating range, say somewhere between 2.6V and 2.9V. An hour in bright sunlight or in a light charging station should be sufficient. Then, connect to and configure the tag for its operation. Configuring it for 'daily packets only' provides the data you need, but you can also store a raw sensor package every hour or two to get more data points.

Step #2: Verify the starting capacitor voltage

Insert the tag in the docking station and start the SeaTag software on the PC. **Do not** press the Connect button. Instead, just remain in monitor mode (yellow status field in the lower left corner of the window). The dock light will remain off and the dock will now look for the tag's heartbeat. The tag emits a heartbeat every 16 seconds. Note the capacitor voltage (see screen dump below). If it is below about 2.6V, continue charging the tag.

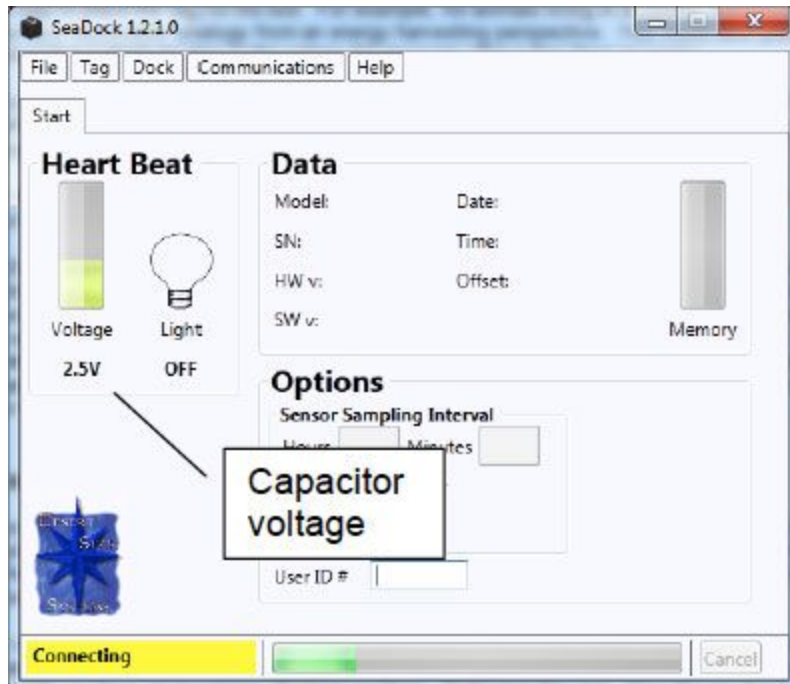


Figure B1: The SeaTag software is in Connecting mode, listening for the tag's heartbeat. The tag emits a heartbeat every 16 seconds. Note the capacitor voltage, such as 2.5V here. Make sure it is stable, i.e. look for the same reading at least twice in a row.

Step #3: Place the tag for observation

This step does require some serious consideration and some improvisation perhaps, to best approximate the light levels seen by a tag on an animal. A few things to consider for evaluating energy harvesting during an animal's surface period are the prevalent light levels on account of weather, the length and frequency of the surface intervals, the light exposure on the part of the animal's body where the tag will sit, and the method by which the tag is attached and the resulting solar blockage.

To form a frame of reference, start by considering the location, say the animal's haul-out spot. If you are studying seals or penguins near McMurdo (Antarctica) during the spring, summer or fall – you are in luck. It is frequently sunny there. Just a few tens of minutes of direct sun exposure will fully charge the tag and support nearly a week of operation, with more in reserve for clock maintenance. Similar, tropical reef or open ocean fish frequently cruising near the surface in tropical or mid latitudes will likely get plenty of sunlight. On the other hand, if you are tagging salmon in murky California waters – or animals along the cloud bound Antarctic Peninsula, watch out. Light levels may be low.

Based on such considerations, you may decide to run just a quick test with a single tag just to verify the 'obviously' plentiful sun exposure. Or, set up for a through test series that looks not only at

available light but also compares the energy harvesting efficiency of a few methods of tagging the animal.

Next, find a good way to place the tag for the test. For example, for animals living in a colony, placing the tag on a rock may be a reasonable analogy from an energy harvesting perspective. You could also place the tag on an animal that is likely to stay in the colony for recovery after a few days or weeks.

In either case, consider the light blockage on account of the tagging method. At least part of the cylindrical tag will be blocked from sunlight in most cases. The test should approximate your tagging method in that aspect. To maximize energy harvesting, consider this:

- Notice the gap in the solar panel of the tag as it is wrapped around the tag's surface. This portion of the surface can't harvest energy, and so it should always face the animal's body.
- The SeaTag-LOG solar panel consists of five sets of cells switched in series, each cell set contributing 0.6V nominal. Looking at the tag, notice the silver divider lines between the cells and count the five sets from the back end to the tip. It is important that none of these five sets of cells is ever obscured completely by tagging hardware. Each set must have at least some of its surface exposed, or else the solar panel cannot develop the 3.0V needed for capacitor charging. Therefore, any obstruction should be minimized and no wide band, ring or similar that might obscure an entire set of cells should ever be placed across the tag.

Step #4A: Evaluate the capacitor level in-situ by heartbeat monitoring

Heartbeat monitoring was already described in step #2. Now you can use it to check the voltage on the capacitor in regular intervals, while your test remains in progress. As in step #2, insert the tag into the dock and start the software. Do not press the Connect button. We want to monitor the heartbeat only and avoid interfering with the solar charge/discharge cycle by leaving the dock light off.

The tag will emit a heartbeat once every 16 seconds (if you don't get it, make sure the tag is fully seated and perhaps rotate it a bit). Notice the voltage reported with each heartbeat. To make sure the reading is accurate, wait until you have received two identical readings. Following this test, place the tag back in its observation spot.

Since the tag electronics other than the LED are operated by USB power from your PC, you don't need the power adapter of the dock for heartbeat monitoring. So, you may carry just your battery operated PC and the dock into the field for in-situ monitoring.

If the tag is not harvesting any energy you will see as decline of about 0.1V per day. If energy harvesting is sufficient, you will see a rising trend or a voltage fluctuation near the top end, such as between 2.6V and 2.9V.

Step #4B: Recover & evaluate the data log

An alternative to heartbeat monitoring is to recover the tag’s log after a few days. Insert the tag into the dock, and establish a connection. Then, use the Download Logs button. Figure Y shows a four day excerpt of the daily packets (PACKET_DAILY), with the average capacitor voltage highlighted. The test started with a voltage of 2812 mV on the first day. Some decline had happened by the second day, but much less than the 100 mV expected if no energy harvesting had occurred. By the third day, the voltage had more than recovered and on the fourth day a slight decline was seen again.

status byte	noon date/time	day length (hh:mm:ss)	average temperature (deg C)	average capacitor voltage (mV)	average solar panel voltage (mV)	average magnetic field amplitude (nT)
0	2/13/2010 20:21	10:56:49	11.44	2812	780	48470
0	2/14/2010 20:25	11:09:37	13.4	2773	1598	48330
0	2/15/2010 20:18	11:09:37	12.35	2896	1277	48510
0	2/16/2010 20:25	11:11:28	15.09	2865	1608	48390

Figure B2: An excerpt of daily packets after a capacitor charge test. The average capacitor voltage fluctuated near the top end of the measurement range for four successive days, indicating that solar energy harvesting was sufficient to sustain ongoing operations.

The Fast Light Level Monitoring Test

Doing a multi-day energy harvesting evaluation may not always be practical. In particular if you are tagging open ocean fish, it’s hard to place a tag at expected diving depths and recover after a few days.

So, rather than monitoring the slow rise or fall of the capacitor voltage, we can also evaluate the voltage on the solar panel at points in time. If the voltage is higher than about 2000 mV (2.0V), light levels are sufficient for capacitor charging. Below that, they aren’t and the tag is running on stored power.

The test procedure is very similar as for the capacitor charge monitoring test. Make sure you have precharged the capacitor, and then configure the tag. But, rather than collecting just daily packets, enable sensor packet collection at a fast rate. For brief tests, use the fastest setting of one packet every four minutes.

For ocean testing, you can now lower the tag to any particular depth of interest, and just leave it there for a few sample periods. By that means, a profile establishing energy harvesting capability as a function of depth can be established. Finally, recover the log.

Figure Z shows a typical excerpt of sensor packets (PACKET_SENSORS) from the log. Notice that this tag happened to be programmed for one data point every two hours, which is for more of a long term study (the memory lasts about 22 days).

This particular tag experienced periods of low light highlighted in red, and others where light levels were sufficient for charging (green).

Note that the solar voltage will never indicate more than about 300mV above the capacitor voltage because once solar voltage exceeds capacitor voltage, energy flows into the capacitor and 'clamps' the solar voltage from rising any further. Also, the maximum limit of the measurement range is 2997mV.

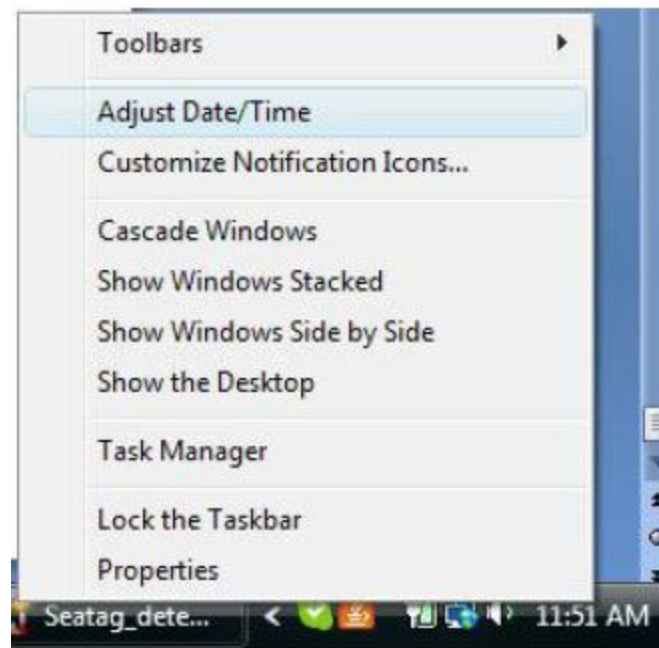
Sensor packet date/time	temperature (deg C)	capacitor voltage (mV)	solar panel voltage (mV)	mag_x (nT)	mag_y (nT)	mag_z (nT)	mag_magnitude (nT)
2/16/2010 13:58	7.916	2835	2	13040	-46390	7010	48690
2/16/2010 16:02	8.197	2824	418	14990	-46100	5450	48780
2/16/2010 18:05	12.036	2821	2047	19710	-44210	-450	48400
2/16/2010 20:09	19.274	2821	2000	20610	-43560	-1880	48220
2/16/2010 22:13	18.224	2806	2255	13790	-45880	6680	48370
2/17/2010 0:16	19.187	2973	2997	10560	-46170	8240	48070
2/17/2010 2:18	13.467	2912	2	6590	-46460	12400	48530

Figure B3: An excerpt of sensor packets shows periods of solar voltage over 2V (green), sufficient for capacitor charging. At other times (red), light levels were insufficient for energy harvesting.

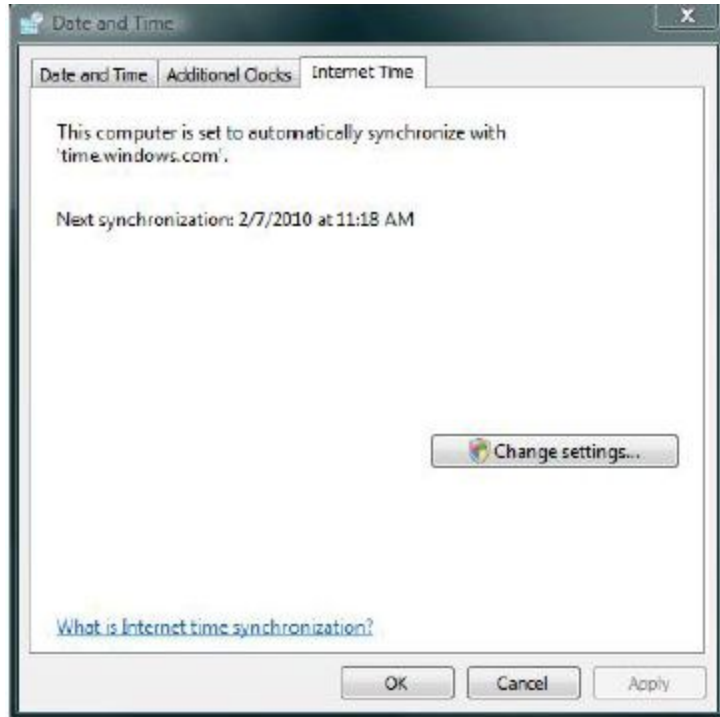
Appendix C

GYHjb['nci f 'Vca di hYf 'lc 'i dXUH'Jlg'WcW'Zca 'H Y=blYfbYhi

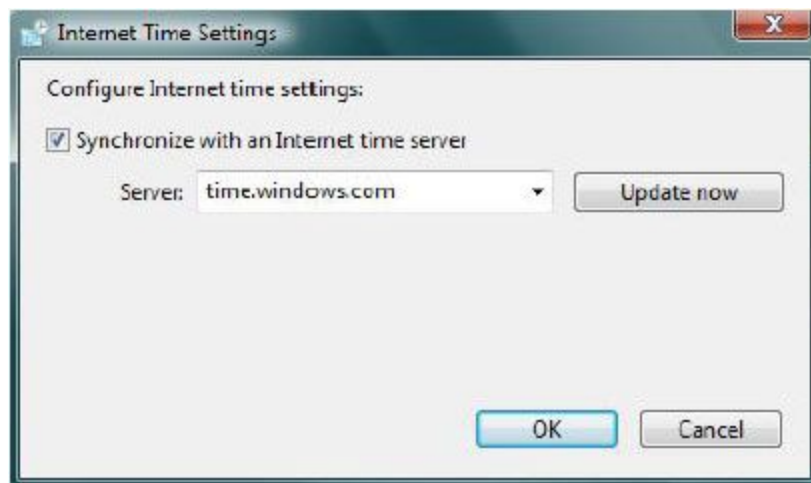
Setting your clock to update from the internet will insure its accuracy and increase the precision of your tags positioning. To make sure it's up to date and that this option is enabled do the following:



- **Step 1:** Right click on the clock at the bottom right hand corner of your screen and select “Adjust Date/Time”



- **Step 2:** Select the tab at the top that says “Internet Time” and click “Change settings...”
- **Step 3:** A window will pop up saying that windows needs your permission to perform this action. Click “OK”.



- **Step 4:** The “Internet Time Settings” window will now appear. Make sure the box “Synchronize with an internet time server” is checked. Click “Update now” to update your clock using the time server that is listed.

That's it. Your clock should be updated and set to auto-update with the internet time server.

Appendix D

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Your SeaTag-LOG™ is a high quality product, which has been designed and manufactured in the United States of America. Like all Desert Star Systems products, it is backed up by a one year limited warranty. To make a warranty claim, call Desert Star Systems to obtain a return authorization number.

The precise legal wording of our warranty can be found on the following pages.

Desert Star Systems Terms of Sale

1. Desert Star System's general terms of sale are specified by the Uniform Commercial Code (UCC), supplemented by the following conditions and the warranty statements. Where Desert Star Systems terms of sale are in conflict with UCC, Desert Star Systems terms apply.
2. At times an advance payment either partially or in full is required for large orders. In these circumstances, no portion of this payment is refundable.
3. On orders with Net 30 terms, a return is acceptable for 30-days following delivery only if a shipped product is non-conforming within Desert Star Systems' specification. In addition a return must first be arranged with Desert Star Systems. Payment constitutes acceptance of product and no return is available thereafter.
4. Desert Star Systems warranty applies (see below). A warranty claim requires that the product is returned to Desert Star Systems. Therefore, warranty is not available for devices deployed or lost at sea unless the device is recovered and returned to Desert Star Systems.
5. In order to support best success with our products, Desert Star Systems provides a number of resources, support and recommended techniques. We emphasize your use of these resources to optimize results with our products:
 1. Desert Star Systems guarantees only minimal specifications, and instead relies on the publication of measured performance data in the knowledge base ([link](#)), application notes and other documents. Please evaluate this data to estimate suitability for your application. Please contact Desert Star Systems for any additional performance data.
 2. Desert Star Systems provides on-site training and support. This is highly recommended to optimize the system performance and shorten the learning curve.
 3. Please evaluate our products through a small initial purchase before following up with a large scale purchase. Please be aware that large scale orders in general require an advance payment in consideration of the discount, and that this advance payment is non-refundable. In addition, be aware of any lead time expectancies when placing a larger quantity order.

4. Operations should follow a ramp-up schedule of lab/pool testing, followed by testing in a controlled ocean environment (harbor testing), and then followed by the full deployment. The goal is to identify any problems or technology limitations at the earliest possible stage, when there is a maximum level of control and an ability to correct such problems.
6. Desert Star Systems return policy and warranty specifically excludes return or warranty claim on account of suitability for purpose. Suitability for purpose is out of Desert Star Systems' control. Please use a product evaluation based on the above recommended resources and techniques to establish suitability for purpose prior to any purchase.

Note: These terms along with any technical specifications, warranty implications, or pricing may change without notice at any time.

WARRANTY STATEMENT

Desert Star Systems ("Seller") warrants hardware products of its manufacture to be free from defects in design, workmanship and material under normal and proper use and service until the tag is deployed on the animal or up to one year following delivery to Buyer (whichever comes first). Seller agrees to repair or replace at the place of manufacture, without charge except shipping charges, all parts of said products which are returned, for Seller's inspection, to its factory within the warranty period, provided such inspection discloses that the defects are as above described and provided also that the equipment has not been altered or repaired other than with Seller's authorization and by its approved procedures, subjected to misuse, improper maintenance, negligence, or accident, damaged or had its serial number or any other part thereof altered, defaced or removed. Software is warranted to conform to Seller's Software Product Description applicable at the time of shipment to the Buyer. Seller's sole responsibility hereunder shall be to remedy any non-conformance of software to the Software Product Description during the one-year period following delivery. THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING THOSE OF MERCHANTABILITY, PERFORMANCE OR FITNESS FOR PURPOSE.

LIABILITY DISCLAIMER

By purchasing or using any Desert Star Systems product, it is agreed and understood that in no event will Desert Star Systems or any of its representatives be held liable for any personal injuries or death or damages to property resulting from its operation, or for any other damages whether direct, indirect, or consequential even if Desert Star Systems has been advised of such actual or potential damages. Desert Star Systems science products are authorized for use only by properly trained scientists and technicians, and are NOT intended for general consumer use. The user must understand that the products are liable to sudden failure, including for example with SeaTag the premature firing of its energetic release mechanism. Marine activities are inherently dangerous. Proper safety procedures demand that the equipment user never rely solely on any single instrument, method or mechanism for his/her safety or the safety of property.

SeaTag Return & Refund Policy

1. SeaTag devices may be returned for replacement or refund only within a 30-day period following delivery, and only for non-conformance with Desert Star Systems specifications, as published for the product in the Operator's or Technical Reference manual. Products must be in factory new condition and without any alterations to qualify for refund or return.
2. Returns for refund are subject to a 20% re-stocking fee.
3. Custom configured or designed versions of SeaTag are excluded from return or refund. These orders will be identified with appropriate language such as 'Customized Product – No Refund or Replacement Available'
4. Volume orders may require a partial up-front payment to qualify for the volume discount. Any such up-front payment will not be refunded in case of an order cancellation or product return.

NOTICE TO U.S. GOVERNMENT BUYERS

The equipment listed in this price schedule has been developed under phases 1 and 2 the Small Business Innovative Research (SBIR) program. Under DoD rules, the dual competition of the SBIR program satisfies the requirements of the Competition in Contracting Act (CICA). Thus, contracts for product delivery or follow-on research may be awarded on a sole-source basis, without the need for further competition. The contracting officer should establish, through consultation with the prospective COTR for the proposed contract as well as the COTR on the SBIR project whether the proposed follow-on R&D or production work meets the statutory criteria for 'SBIR Phase III'. For details please refer to this [link](#).