

LISST-SL2



Operating Manual

Version 1.2

SEQUOIA

2700 Richards Road, Suite 107
Bellevue, WA 98005
USA

Tel: (+1) 425-641-0944

Fax: (+1) 425-643-0595

info@SequoiaSci.com

www.SequoiaSci.com



Waste Electrical and Electronic Equipment

Smaltimento di apparecchiature elettriche ed elettroniche da rottamare

Technical assistance

To obtain technical assistance please contact your local Distributor.

A list can be found on

<http://www.SequoiaSci.com/contact/international.aspx?SectionName=contact>

Alternatively, you may contact Sequoia Scientific, Inc. directly.

Sequoia Scientific, Inc. Contact Information:

Telephone: +1(425) 641-0944

Email: Suport@SequoiaSci.com

Please be sure to include the instrument serial number with any correspondence.

Contents

1.	Introduction	3
	The LISST-SL2 sensor	4
	The Topside Box (TB).....	5
	The B-Reel and Crane.....	6
	How It All Works.....	7
	<i>Operating Principle – Laser Diffraction Optics</i>	7
	<i>Backgrounds</i>	7
	<i>Instrument Stability Parameter</i>	8
	<i>Data Collection</i>	8
	<i>Working Limits of Sediment Concentration</i>	8
	General Precautions	9
	<i>WARNING</i>	9
	<i>Operational Precautions</i>	9
	<i>Shock and Cleaning</i>	9
	<i>Cleaning the Optics</i>	9
	<i>Storage</i>	10
	<i>Battery</i>	10
	<i>Charging Precaution</i>	10
2.	Software	11
	Settings	12
	Communication Port Setup	12
	Background Collection	13
	Data Collection.....	16
	<i>Viewing Real Time Data</i>	18
	<i>Recording Data</i>	21
	<i>Cleaning</i>	22
	<i>Viewing A Data File</i>	23
	<i>Viewing Depth Averaged Data</i>	23
	Warnings	25
3.	Getting Started: Test use in a Laboratory	26
	Capturing a Background	26
	Capturing Sediment Data.....	28
	Compute Averages	28
	Cleaning the Optics.....	28
4.	Field Deployment of the LISST-SL2	29
	Pack List.....	29
	Battery Check.....	29
	Launch and Data Collection.....	30
	Shut Down and Clean	31
5.	Handling, Cleaning, Maintenance and Storage	32
	Handling	32
	Cleaning and Maintenance	32
	Storage.....	32
6.	FAQ's.....	33
7.	Appendix I: Technical Specifications	34
8.	Appendix II: Contents of Ship Package.....	35
9.	Appendix III: Establishing and Troubleshooting Bluetooth Connection	37
10.	Appendix IV: Data files, Formats and Contents.....	39
11.	Appendix V: Particle Size Bins	41

12.	Appendix VI: Clearing a Pump Jam due to Blockage	42
13.	Appendix VII: Cleaning the Laser Optics inside the LISST-SL2	42
14.	Appendix VIII: Purging Air from Pitot Tube and Cleaning Screen.....	42
15.	Appendix IX: Advanced Data Processing for Scientists	44
16.	Appendix X: Mechanical Dimensions (in.[mm])	45
17.	Appendix XI: 5-pin Connector and B-Reel Cable Termination.....	46
18.	Warranty.....	47
19.	MY NOTES	50

1. Introduction

The LISST-SL2 System



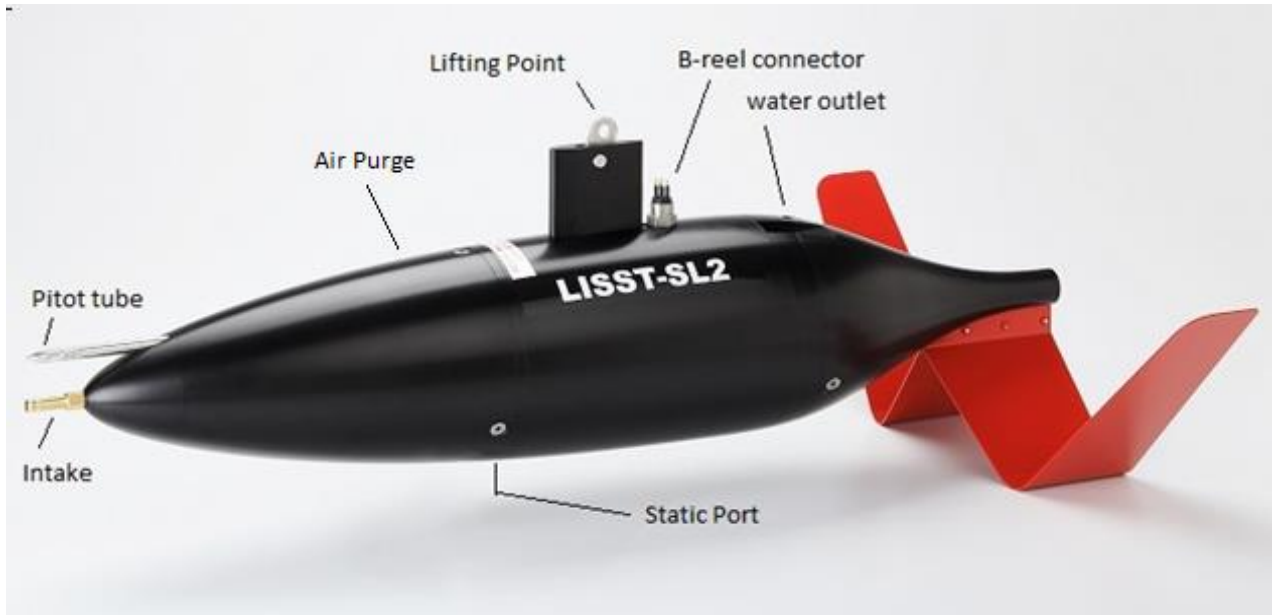
Thank you for purchasing the LISST-SL2 second generation isokinetic sediment grain-size analyzer! It is a sophisticated sediment sensor for use from bridges or boats. It provides all the data you need for computation of river velocity, sediment concentration, particle size distribution, depth, and water temperature. The LISST-SL2 is more advanced, and yet much simpler to use than the original LISST-SL. Technical Specifications are provided in Appendix I.

In the shipment you will find 3 main items which comprise the LISST-SL2 Instrument System: the LISST-SL2 submersible sensor, a Topside Box (TB), and a B-reel if you ordered one. If you did not order a B-reel, you will need to procure one from Rickly Hydrological Company in the US. Also included is Windows software for operating the system and saving data. A full list of shipped items appears in Appendix II.

The main part of the system is the streamlined submersible LISST-SL2 sensor. This is only a sensor; it needs power to operate, and it needs a computer with specific software for control, data display and storage. It must be connected to the TB for power and for relaying commands and data between it and the computer (See Section 1.3). Data are stored directly on a computer (or tablet) that is used for control and real-time data view. Software displays the following in real-time view: Particle Size Distribution (PSD), Suspended Sediment Concentration (SSC), depth, water velocity, and temperature. Also displayed on software is the state of charge of the battery. The system provides low-battery warnings, and also executes an orderly shut-down if the warnings are ignored and battery is fully depleted. Data are not lost with the abrupt shutdown, the datafile is saved on the computer.

At Sequoia Scientific, Inc. we strive to make our instruments rugged, reliable, and simple to operate. If you should have any difficulties, questions, or suggestions, please feel free to contact us: support@SequoiaSci.com . We begin below with a description of the 3 subsystems – the LISST-SL2 sensor, the Topside Box and the B-reel. [The B-reel is not part of our standard package. It can be purchased directly from Rickly Hydrological Company or from us. Sequoia will put a termination on the steel cable at no cost.].

The LISST-SL2 sensor



The LISST-SL2 sensor contains the laser optics, and electronics used to detect light scattered by particles. It also contains sensors to measure depth, temperature, and velocity. It contains a micro-processor controlled pump that draws water in at velocity equal to river velocity (isokinetic operation). Whenever power is applied to the LISST-SL2 from the TB, the dedicated microprocessor reads all sensors and begins transmission of data to the TB.

The LISST-SL2 measures water velocity with a Pitot tube that projects into flow above the main water intake. A highly sensitive differential pressure sensor within the LISST-SL2 measures the ram pressure of water for computing water velocity. This input controls the speed of the pump. Hall effect sensors in the pump provide pump speed to the microprocessor for feedback control. Instrument depth is sensed with a pressure sensor, and water temperature is sensed with thermistors. Two thermistors are used: one for measuring instrument temperature and the other to measure temperature of water flowing through. No water flows through the Pitot tube. Even so, care should be taken to keep it clean. An internal screen keeps sediment grains out. An air purge port was added on units SN 2014 and later. Its purpose is described in Appendix **

A large tail-fin is provided to stabilize the LISST-SL2 sensor and point it into the flow. The downward pointing fin enters water first, immediately spinning the instrument and pointing it into the flow. While in water, the LISST-SL2 will sway a little in the river current. This is because of turbulent eddies in the river, causing the instantaneous flow direction to veer slightly; the

instrument follows this instantaneous direction.

In fast moving rivers, an extra weight may be needed. Sequoia offers lead weights which can be added to the sensor to achieve smooth swimming of the LISST-SL2. Please contact us.

The Topside Box (TB)



The LISST-SL2 needs the TB for power. The TB houses a 12V, 35A-hr lead-acid battery. Electronics in the TB perform multiple functions such as conditioning of battery voltage to 26V for transmission to the LISST-SL2, capture and relay of data between the LISST-SL2 and the user's computer, generation of battery discharge warnings, and system shut down when battery is totally depleted. The TB also stores instrument specific calibration information. The side panel has the power switch (blk), LED lights for power (red), battery condition (grn), and Bluetooth (blu). Connectors for serial link to computer (blk) and for power to B-reel are below the LED's. Do use the dust protection for connectors. The charging connector is under the top cover. Use only a Sequoia provided charger.

IMPORTANT: Since the TB holds instrument-specific calibration information, it cannot be used with different SL2 sensors. The TB may only be used with the SL2 sensor of corresponding serial number.

The B-Reel and Crane



This is an essential part of the system. It has 50m of strong cable wrapped on a barrel and a handle to manually operate it as a winch.

The B-reel serves a dual purpose: it is used to suspend the LISST-SL2 sensor into water, and it also provides electrical connection between the sensor and the TB.

The B-reel cable has a river-side terminal, which splits into a Y. One end of the Y is tied to the lifting point on the LISST-SL2, and the other end is a female submersible connector, which attaches to the LISST-SL2 underwater electrical connector. This connector is made by Sequoia.



The other end of the cable is permanently attached to slip-rings, which are permanently fastened to the rotating barrel of the B-reel. The slip rings connect to 2 terminal posts. A provided cable is used to connect to these terminal posts and to the TB.

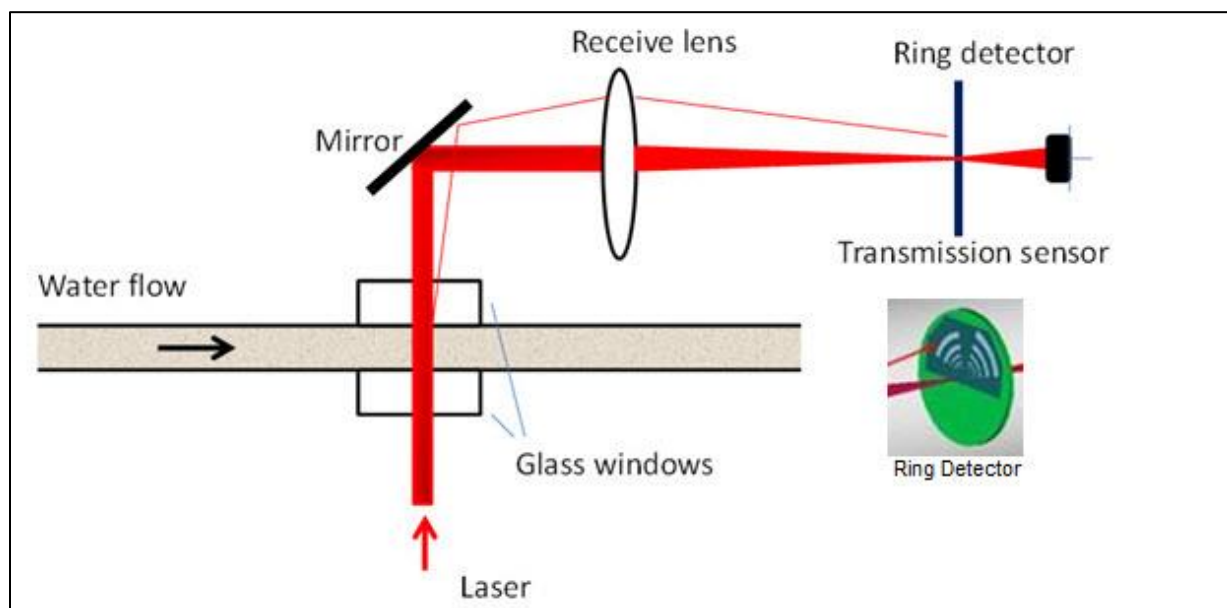
If you ordered the B-reel from Sequoia, the river-end termination is done by us. See Appendix F for connector type and wiring instructions.



Crane

A crane is necessary to suspend the instrument into the river. Sequoia recommends that the user purchase the crane directly. One vendor is Rickly Hydrological Company in the US.

How It All Works



Operating Principle – Laser Diffraction Optics

The measurement of sediment size distribution and concentration in the LISST-SL2 is based on the principle of laser diffraction. Because some of the terminology in this manual refers to principles and components of laser diffraction, a brief explanation is offered.

Water entering the LISST-SL2, passes between a pair of parallel glass windows (see diagram above). A red laser beam crosses these windows. Light scattered by particles in this laser beam is collected by a receive lens, and is sensed by 36 'ring' detectors placed in the focal plane of the receiving lens, each one covering a small, distinct angle sub-range. The 36 measurements are inverted to produce the concentrations of particles in 36 size classes. This is the PSD. Simple sum of these concentrations forms the total concentration, or SSC. *Note that there is no simple relation between any single detector and concentration of particles of a particular size.* All particles produce scattered light on all 36 rings. The inversion amounts to finding a PSD that would produce the same light scattering signals as seen on the 36 detectors. For more details, see <https://www.sequoiasci.com/article/laser-diffraction-principles/>.

Backgrounds

Even when water is pure and without particles in it, the detectors see some light. This light originates from optical components – windows, lenses, beam-splitter etc. These components have micro-scratches in them. When the laser beam passes through, light is scattered by the micro-scratches. This is *background* scattering. When water contains particles, scattering from particles adds to this background. Before inversion to compute the PSD, this background must be subtracted from the total. This makes a high accuracy measurement of the background scattering important. It is emphasized in this manual.

Instrument Stability Parameter

The magnitude of background light from optical surfaces depends solely on the state of the optics. Age can degrade the polish of glass windows by sediment abrasion. Deposit of sediment on windows can also increase the background. But a significant factor that can affect the background level is temperature difference between water and the LISST-SL2 instrument. Temperature differences cause scintillation (light scattering by turbulence). In the software provided with LISST-SL2, automatic provision is made to wait till the temperature differences become low enough to be unimportant. When you launch the software to collect a background (see later chapters), a display shows the progress of this equilibration process. When equilibrium is reached, software automatically saves the background, checks its quality, and either approves for saving or guides the user further to repeat and obtain a good background measurement.

The same automatic procedure is again followed when the LISST-SL2 is inserted in the river. Again, the instrument waits till thermal equilibrium between water and LISST-SL2 is reached. Only then, the data are displayed (see below also).

Data Collection

Once the instrument is lowered into the river, software displays an *Equilibrium parameter* which represents the stability of temperature of the optics. When equilibrium is reached, only then the software begins display of data. The decision about reaching equilibrium is automated. No judgement is required from the operator. Once data are available, user can select to display data in numeric format, as time-series, or as depth profiles. After data collection, averages of various parameters over specified depth ranges can be saved by the software from the homepage, Save Depth Averages button.. See Appendix-III for formats of saved datafiles. See the Chapter on Software on how it works.

Working Limits of Sediment Concentration

Please note that there are limits on both the lower and upper concentrations at which the instrument will make high quality measurements.

At the lower end of concentrations, too few particles in the laser beam can lead to weak scattering signals on ring detectors. Indication of the strength of light scattering signals is provided by the *optical transmission* measured across the test cell. The optical transmission is the ratio of laser power transmitted through the cell, divided by its value in clean particle-free water. This defines the lower concentration limit of operations. Although, with care, you may be able to operate and get meaningful data at transmission as high as 99.5%, the instrument is designed to produce good data at transmissions below about 98%. Optical transmission measurements are saved in processed files. See files and file formats in Appendix III.

At the high end of concentrations, when too much sediment is present in water, multiple scattering of laser light degrades results. Multiple scattering (light once scattered by particles re-scattered by other particles) grows with sediment concentration (decreasing transmission). As a practical matter, we suggest that at transmission below about 30%, multiple scattering degrades accuracy. When transmission drops lower, fine particles are invented in the inversion. You may examine this in a laboratory with a narrow size particle dispersion. These limits are not sharp; they are worth remembering while you interpret your field measurements. Transmission values are saved in the processed datafiles.

For quantitative information on operating limits, please visit <https://www.sequoiasci.com/article/working-limits-particle-concentrations/>. The data at transmissions below 30% are still usable, though with awareness that the error (bias) is growing mainly through the invention of particles at the finest sizes.

General Precautions

WARNING

MAKE SURE THE POWER SWITCH ON THE TOPSIDE BOX IS OFF. TURN ON POWER ONLY AFTER ALL CONNECTIONS ARE MADE. AT END OF WORK, TURN OFF POWER FIRST BEFORE DISCONNECTING LISST-SL2 FROM TB.

Operational Precautions

Slip Ring Cleanliness: Dirty slip-ring on the B-reel increases contact resistance. Excessive contact resistance produces a larger voltage drop between the battery and the LISST_SL2, reducing available life of the battery.

Order of Connections in Use: Always make connections first, before turning on battery power.

Pump: Never operate the pump dry for more than a minute or so.

Shock and Cleaning

The LISST-SL2 instrument is a precision opto-electronic device. **AVOID SHOCK AND VIBRATION.** See also chapter 5. We have provided soft foam supports for resting the instrument. Please use them.

Cleaning the Optics

Over time, sediment will deposit in thin layers on internal glass windows. When this happens, the backgrounds will increase. In general, software corrects for it; it is not a problem until the backgrounds threaten to degrade performance. At some point, the instrument will automatically alert you to clean the optics. Cleaning requires removing the nose section, and reaching to the optics. The procedure is a bit cumbersome. A description of the procedure can be found in Appendix VI.



It is best to get extended use before having to disassemble the instrument for cleaning. The best strategy is to flush the optics with clean water immediately following every use. To help, the software reminds you to clean the optics every time after data collection. Just follow the instructions in software.

Storage

The instrument and Topside Box can be stored over long periods in reasonable temperature environments. Remember to charge the battery overnight before setting off to the field!

Battery

It is recommended that the battery be stored in the charged state. The charging port is under the top lid of the TB. Use only Sequoia provided charger.

Charging Precaution

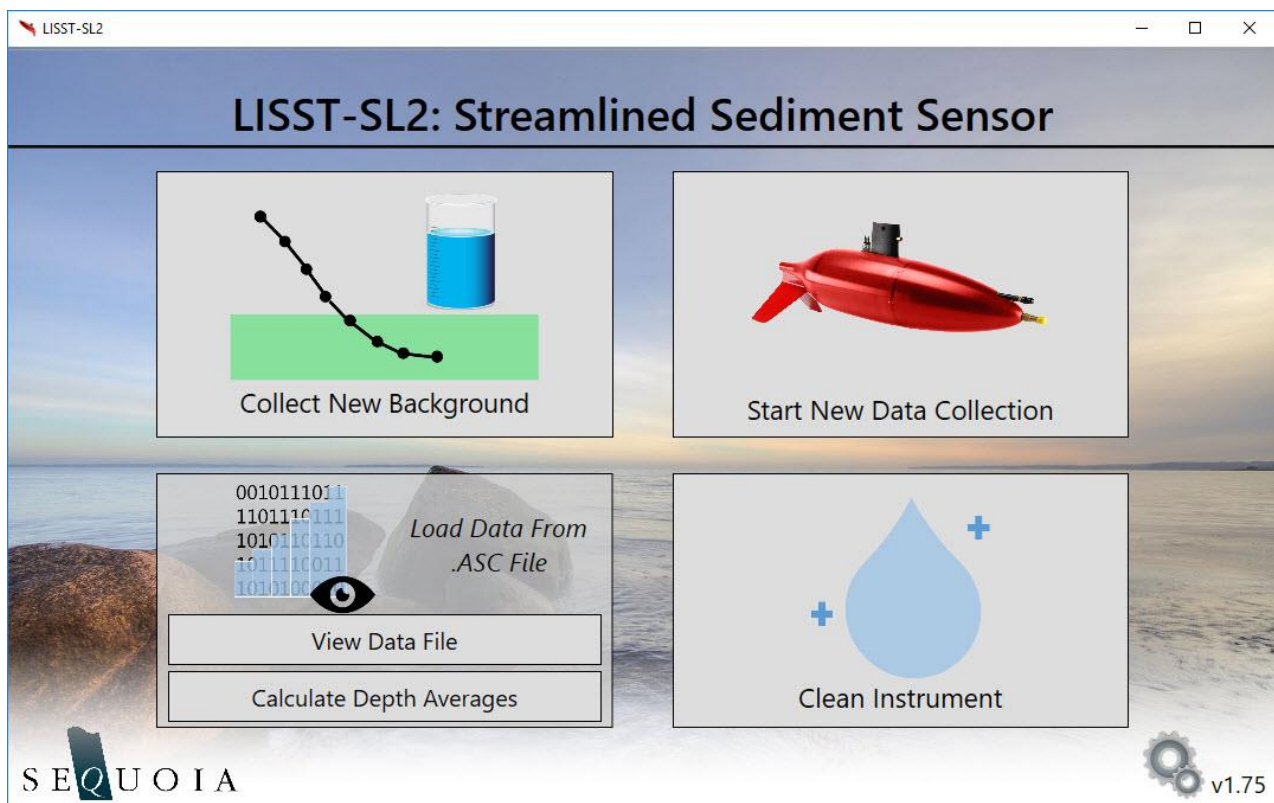
Do not leave TB power turned on while charging the battery. Under some conditions, it can run the pump dry, causing damage.

2. Software

The LISST-SL2 software is a Windows based program used for controlling the instrument, viewing real time data, and processing the data fully. The software is designed to guide the user through the process of background and data collection without having to refer to the user's manual. However, reading through this section will be beneficial for a first-time user. In Section 3, you will perform these operations without reminder of these instructions.

On the home page (or home screen), you have five options:

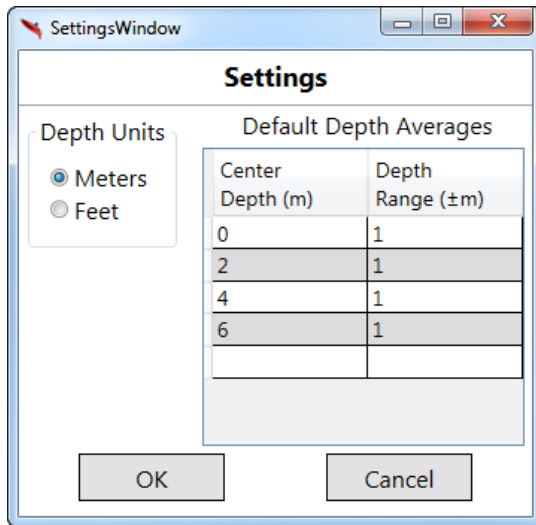
1. Collect New Background
2. Start New Data Collection
3. View Data File
4. Calculate Depth Averages
5. Clean Instrument



Each of these options is covered in the following sections. The home page also provides access to software settings by clicking on the gear icon in the lower right.

These five functions are available upon startup. However, an instrument must be connected to the computer to get functionality for Background, Data Collection or Cleaning.

Settings



These settings are to select the units for data and for specifying the depths and depth-ranges for computing averaged parameters. You can access this box from the gear icon in bottom right of the home page.

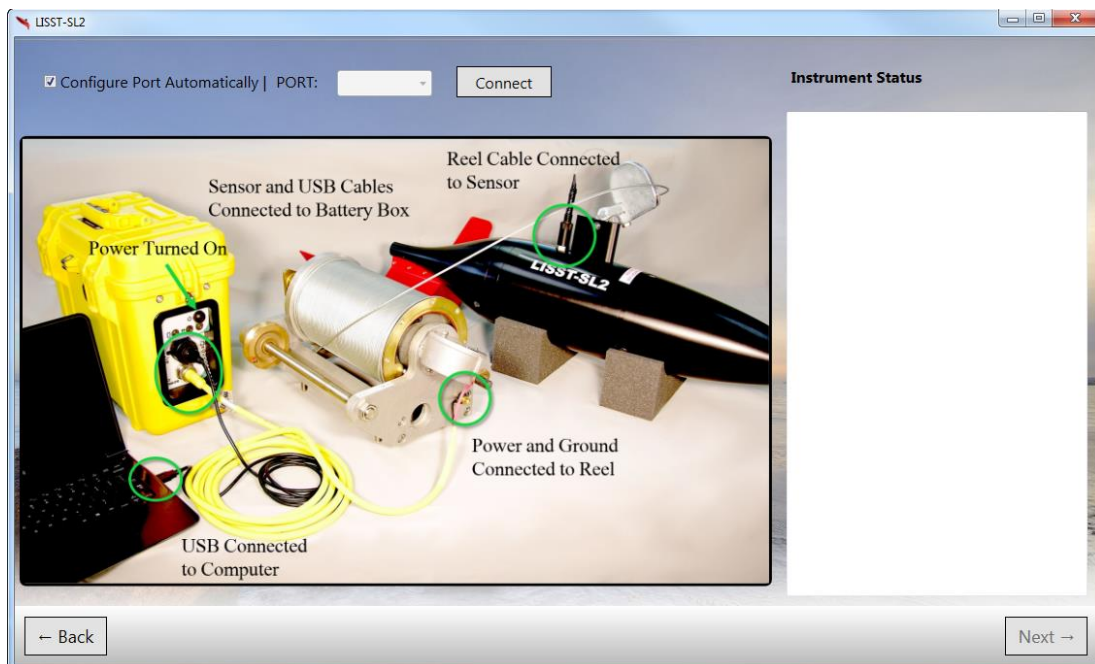
The depth bins for averaging can also be selected elsewhere.

The units are saved in processed data file.

Communication Port Setup

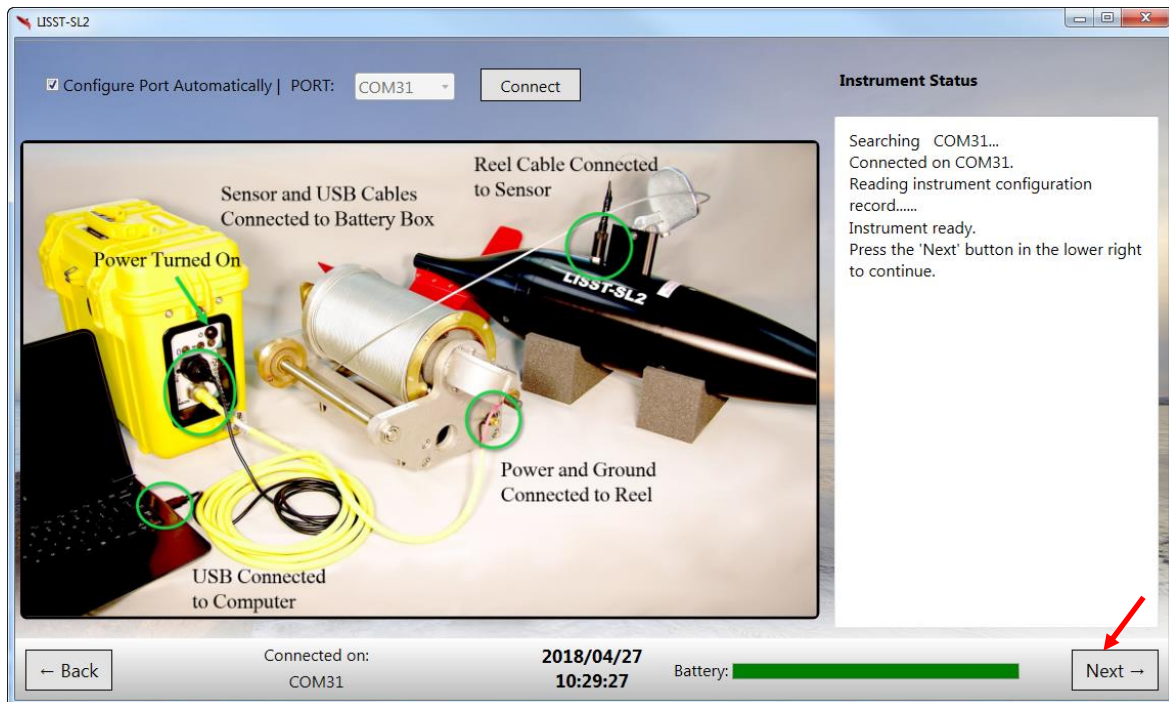
The LISST-SL2 can communicate via a USB cable or Bluetooth connection. To use the Bluetooth connection, the USB cable must be unplugged, and the instrument must be paired with the computer. **It is required you test the Bluetooth setup in the office before heading into the field. You may need an internet connection to configure the Bluetooth serial port the first time you connect.** See appendix III, Establishing and Troubleshooting Bluetooth Connection. The LISST-SL2 software operates the same whether it is using the USB or Bluetooth connection.

When selecting Collect New Background or Start New Data Collection from the homepage, the following page is shown to first setup the communication port. A diagram showing all the required cable connections is shown. 'Configure Port Automatically' is checked by default (top, left).



This feature will automatically locate the LISST-SL2 among the ports on your computer. If you are using Bluetooth, the instrument will still be connected via a virtual serial port. If you need to select the port manually, you may uncheck this and use the dropdown box to select from a list of available ports.

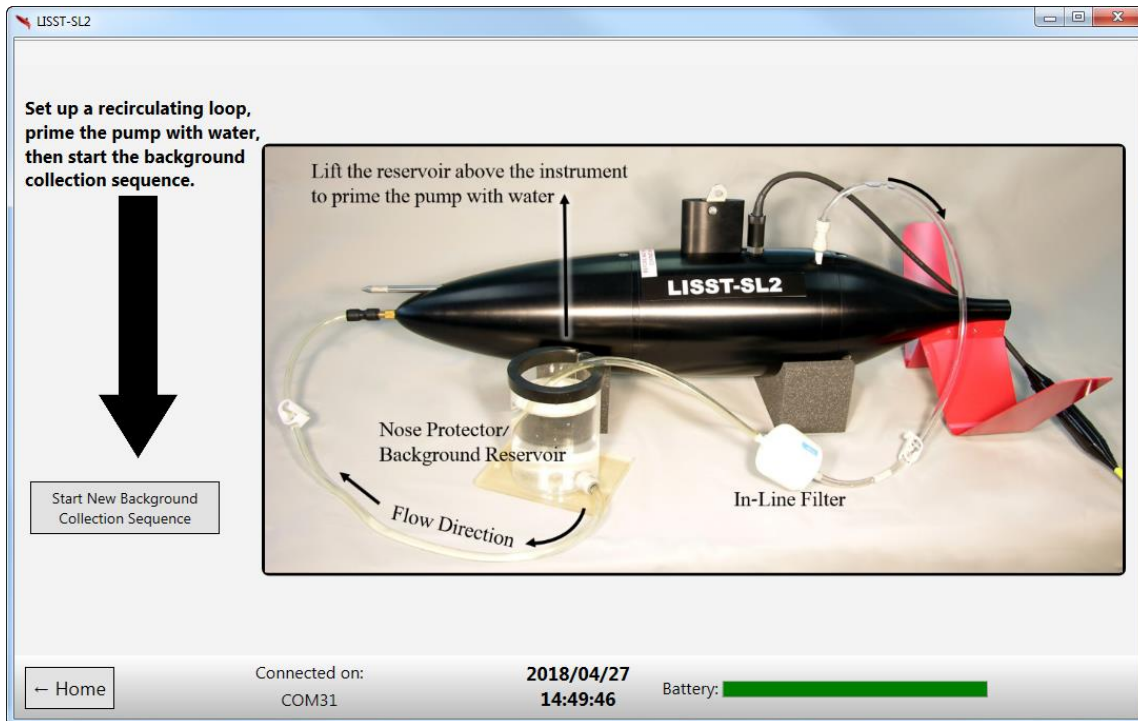
Pressing the connect button will initiate the connection to the instrument. Once the instrument is connected, a status bar will be displayed at the bottom of the screen and the 'Next' button (bottom right) will be enabled. If the connection fails, an explanation of the problem will be displayed in the 'Instrument Status' text box [see a successful connection in figure below].



Background Collection

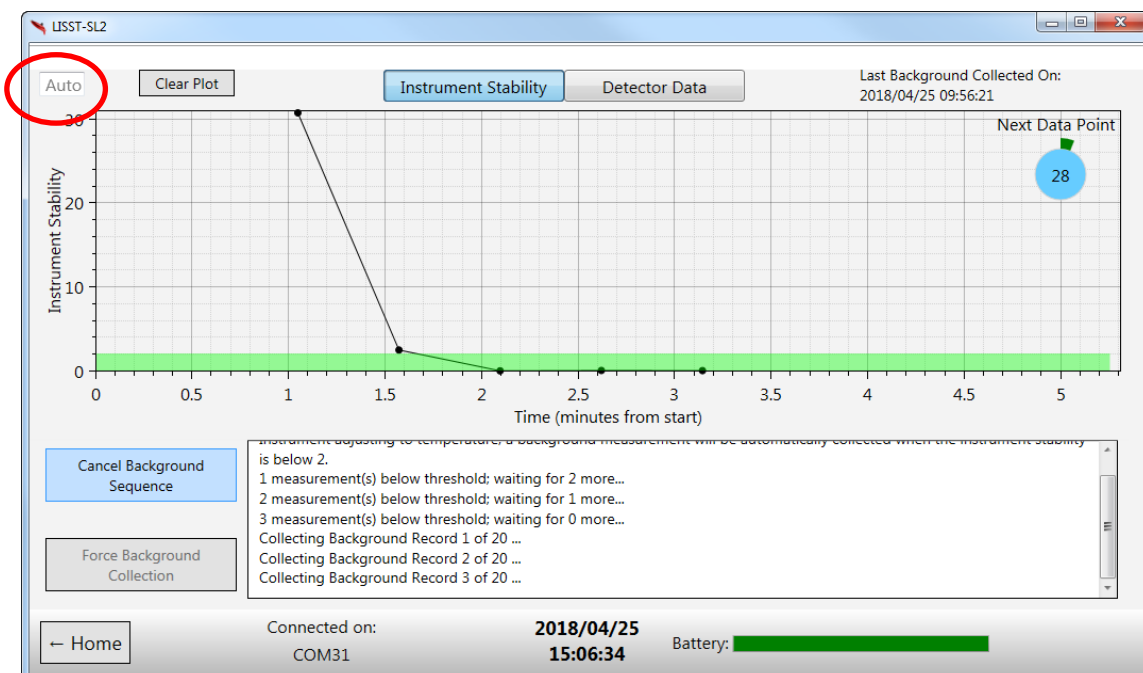
The 'Collect New Background' option is used to collect a clean water background and save it onboard the instrument. This can be done in the field or ahead of time in the lab. After setting up the COM port, you will need to set up a recirculating loop, as shown in the software window (next page).

Fill the clean water reservoir and lift it above the instrument about 1m, keeping the return tube low and open to drain. This will set up a head to prime the pump. After some time when all air has been drained out along with water, lower the reservoir and insert the drain end of tubing into the reservoir. It is best practice to use an in-line filter to eliminate any residual particles or bubbles. Now, press the 'Start New Background Collection Sequence' button.

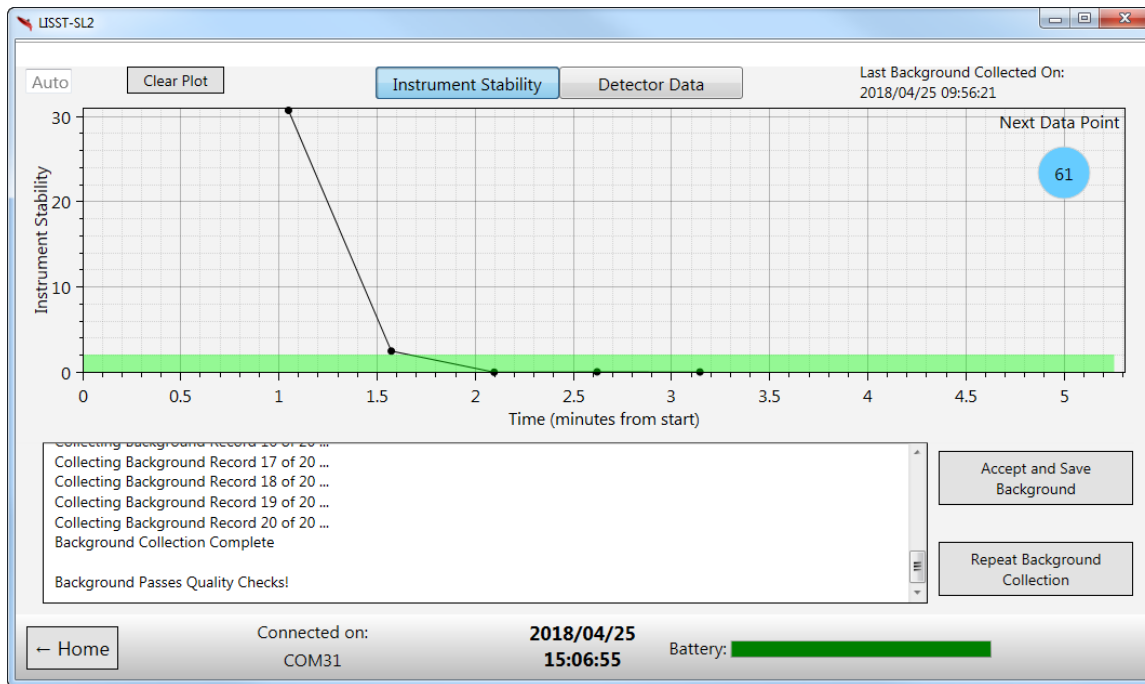


The pump will turn on and the software will begin to analyze the instrument data. The scattering must become stable before a background can be collected. The software will calculate and display an Instrument Stability parameter approximately every 30 seconds (see Next Data Point timer in top right of frame). Once this stability parameter falls below 2.0 (green zone) for three consecutive measurements, the LISST-SL2 has reached equilibrium, and a background will be automatically collected.

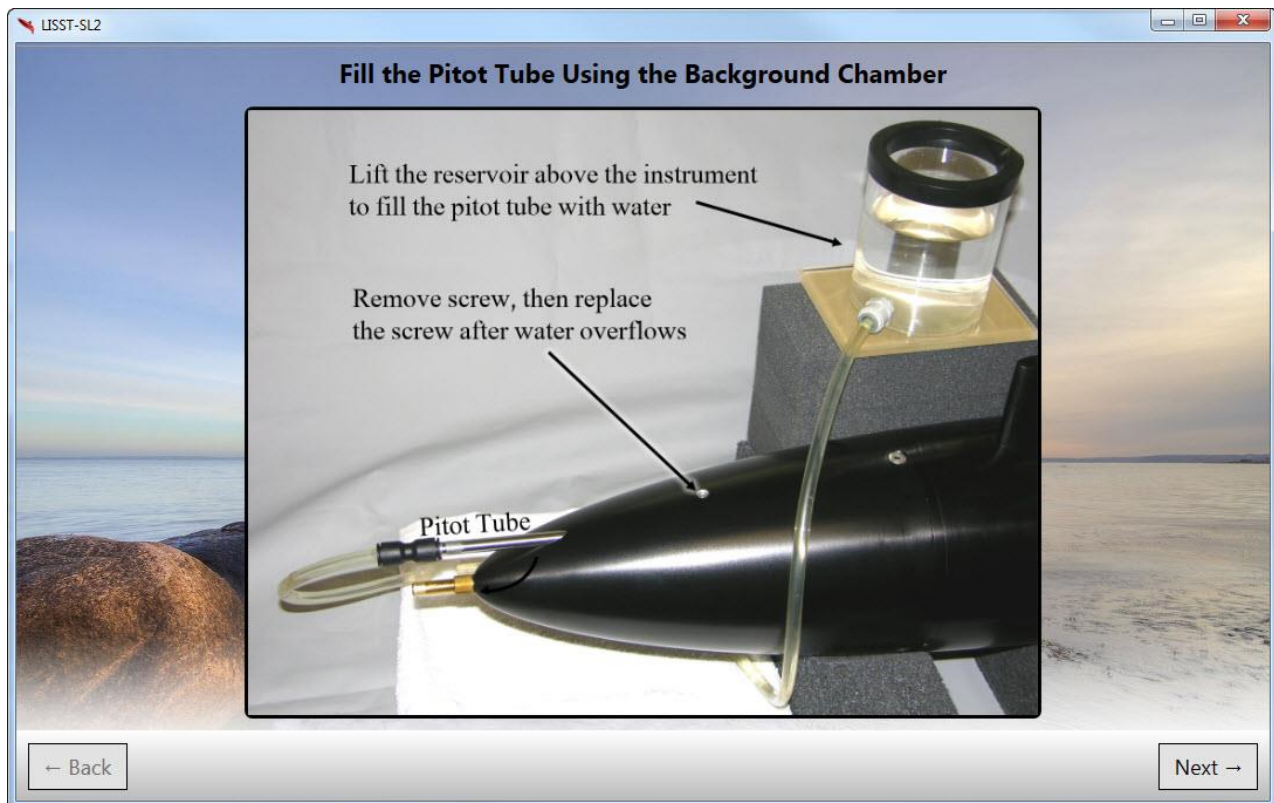
Option to manually set Y-axis scale



After the background is collected, the software will automatically perform quality checks on the new background. If a problem is detected, a description of the problem and a possible solution will be displayed on the screen. Otherwise, 'Background Passes Quality Checks!' will be displayed (below). [The automated quality check on the new Background examines Laser output power and its stability, optics alignment, state of cleanliness of windows, bubbles, and thermal scintillation. If errors are found, helpful solutions are suggested.]



From here you have the option of accepting and saving the Background, or repeating the background collection sequence. If you select 'Accept and Save Background' the newly collected background will be saved onboard the topside box, where it will be available the next time you collect sediment data.

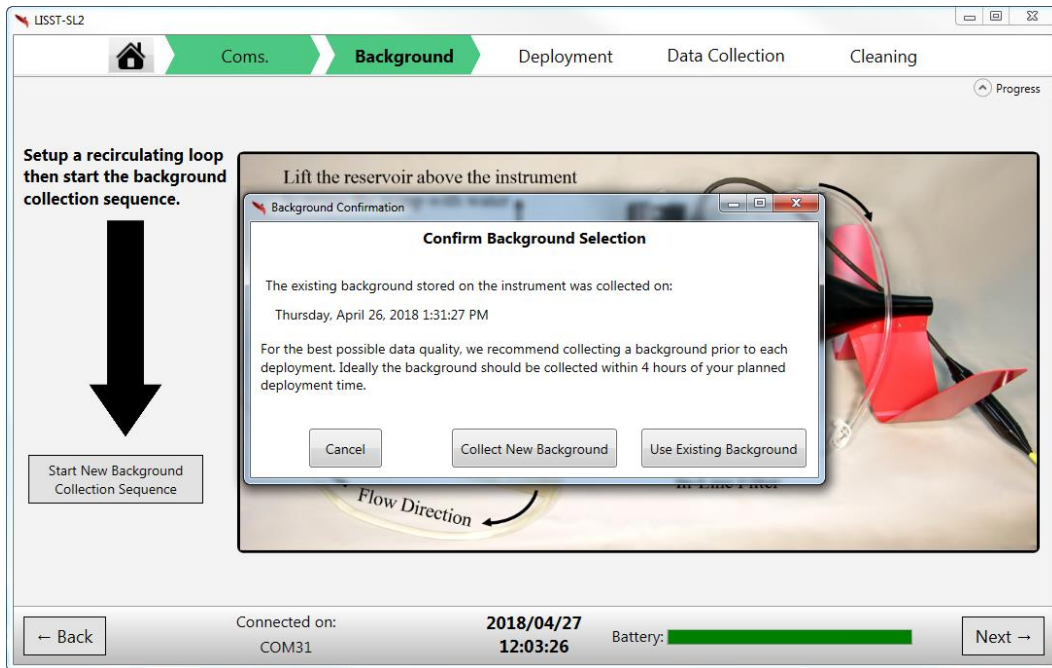


After a background is collected, a page is displayed to remind the user to fill the Pitot tube with water. See Appendix VII for more information.

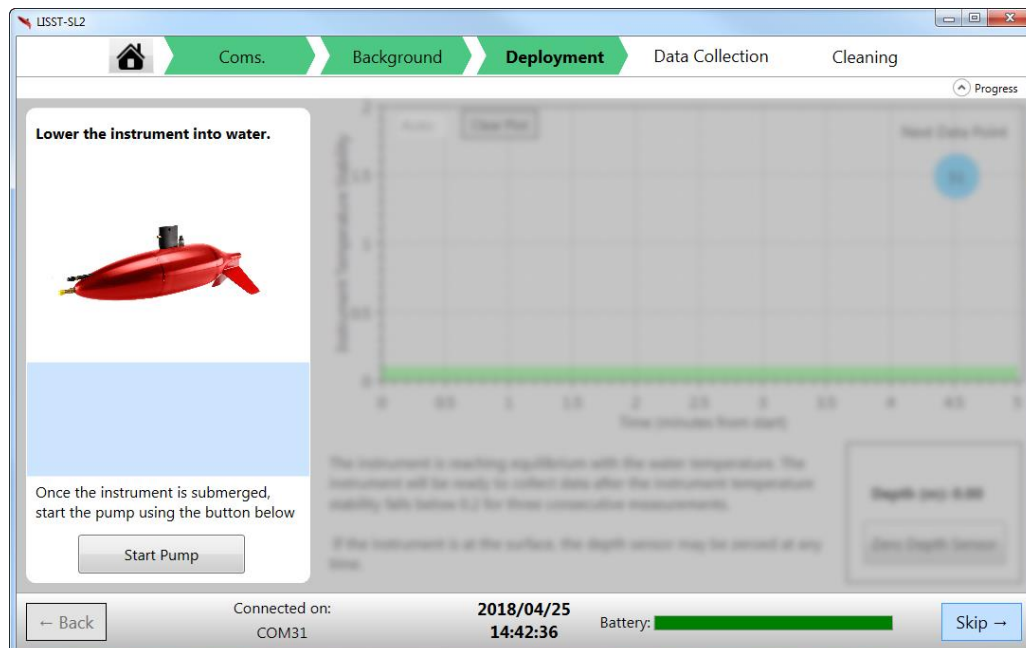
Data Collection

The 'Start New Data Collection' option on the home page is used to initiate data collection with the LISST-SL2. After connecting to the instrument, it will ask you to confirm the existing background on the instrument.

You have the option to use the existing background or to collect a new one. If you choose to use the existing background, it will use the background that is currently stored on the instrument (most recent). The date this background was collected is displayed in the window. If you choose not to use this background and to collect a new background, you will be brought back to the background page described in the previous section.



After confirming or collecting a new background, you are brought to the deployment screen. This indicates that the instrument could now be lowered into the water or used in the lab.

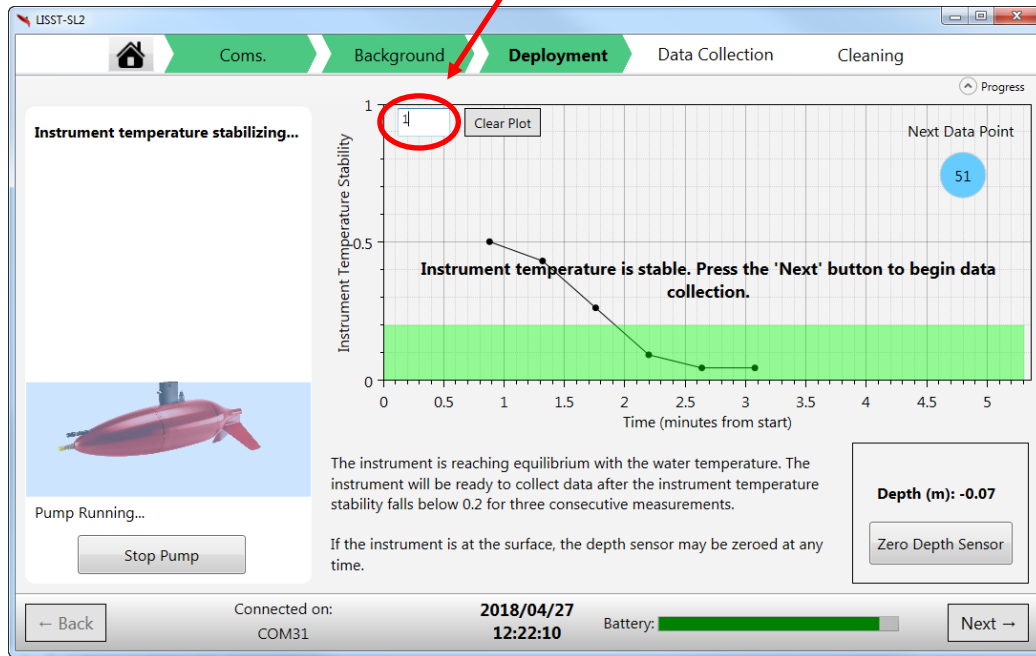


IMPORTANT: The pump should be started quickly after the instrument enters water. Delay in starting the pump can build up sediment in the LISST-SL2 flow passage. Press the 'Start Pump' button.

After the pump has started, the software will begin to monitor the instrument and water temperatures. It will show an Instrument Temperature parameter display (below). When the Instrument Temperature Stability parameter falls below 0.2 for three consecutive measurements, the instrument is considered stable, and ready to collect data. This process can take up to 10 minutes or more depending on the initial temperature difference.

This page also lets you zero the depth sensor. This is not required, but can be done while waiting for the instrument temperature to stabilize. Changes in atmospheric pressure, or drift of the pressure sensor may indicate an offset in the depth. Press the button with the instrument barely submerged to reset the depth sensor.

Option to manually set Y-axis scale



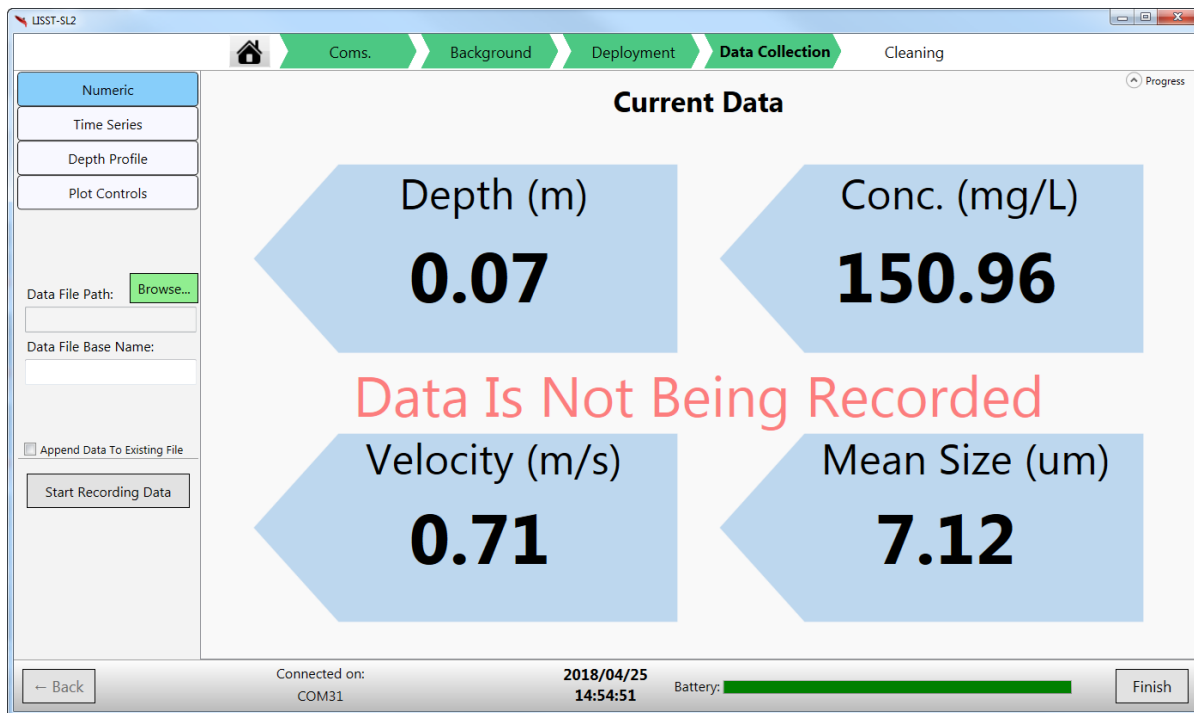
Pressing the 'Next' button will bring you to the data collection page.

Viewing Real Time Data

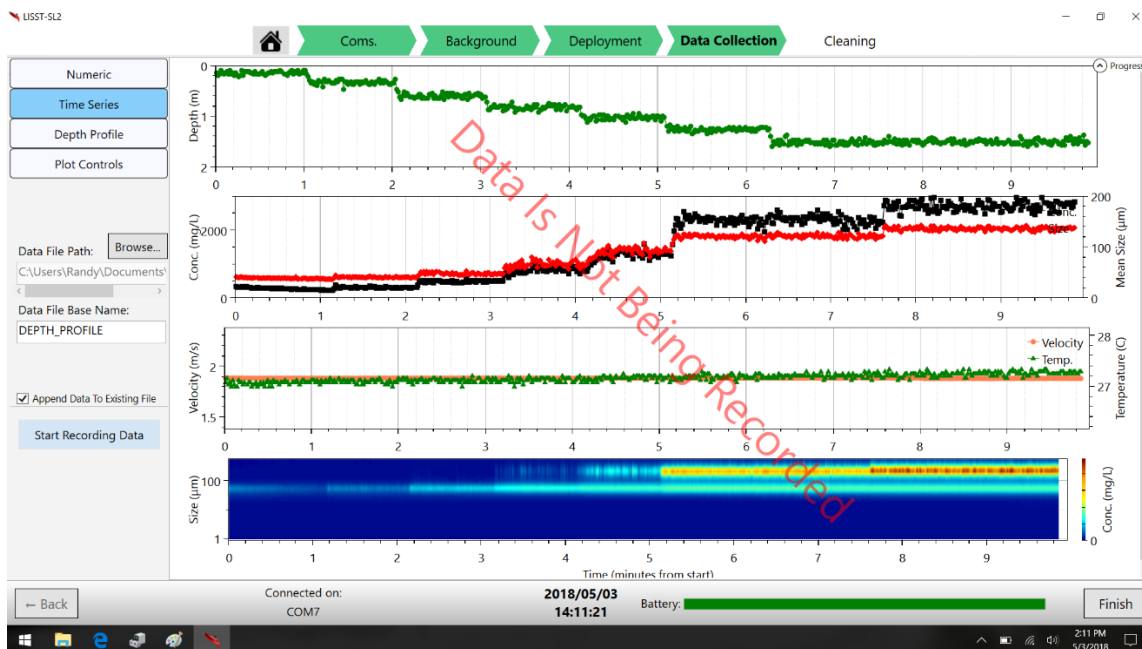
The data collection display (next page) has three different options for viewing real-time data: (i) Numeric, (ii) Time Series, and (iii) Vertical Profile.

These pages are updated every second, i.e. at the sampling rate of the LISST-SL2. Even though data are being displayed and plotted, it does not mean the data are being recorded to a file. Big red letters remind you! The user must initiate data recording. We will return to that. We explain these pages first.

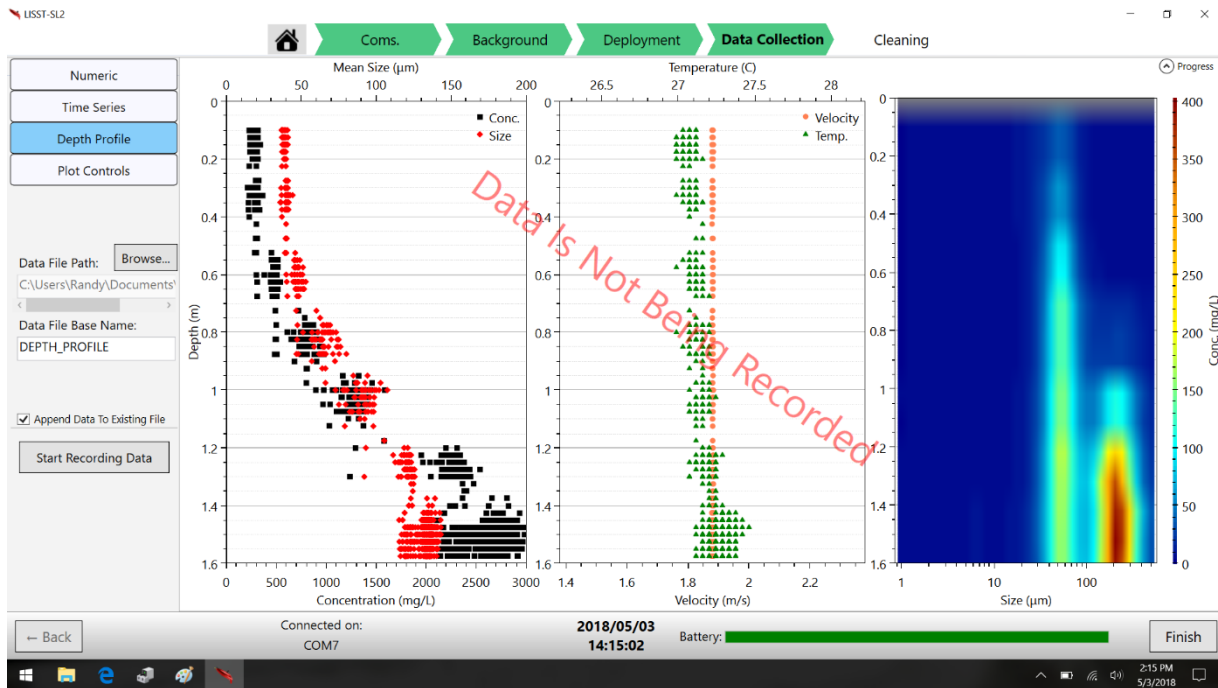
Selecting the Numeric tab simply displays depth, concentration, velocity, and mean grain size in large numbers. This tab is useful if you are viewing the computer screen from a distance, as you would in the field. We recommend that you use this view first after the LISST-SL2 enters river water, to do a quick reasonableness check.



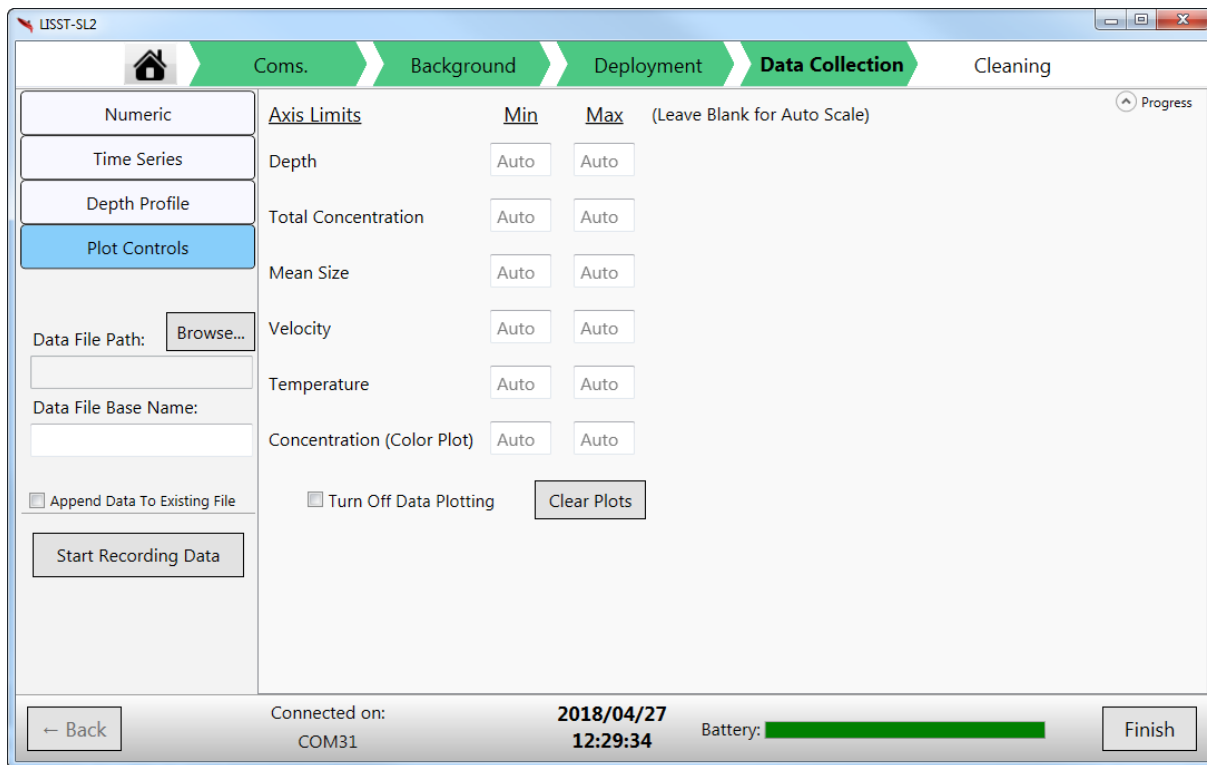
Selecting the Time Series tab shows (below) a running plot of the depth, concentration, mean size, velocity, temperature, and particle size distribution. By default, the axes are auto scaling, however, they can be manually adjusted from the 'Plot Controls' tab (last of 4 in top left of screen).



Selecting the third option - Depth Profile view shows the same concentration, mean size, velocity, temperature, and particle size distribution as a function of depth (below). This view is provided to instantly see variation of parameters with depth. Again, the axes are auto scaled by default.



You can view additional information in any of these plots by clicking and holding the mouse button down over a data point. The X and Y values will be shown for the data point.



Finally, selecting the 'Plot Controls' tab allows you to set minimum and maximum axis scales or clear the current data in the plots (figure on previous page, bottom). It also gives the option to turn off data plotting. The options on this tab only affect the data display and have no effect on the recorded data.

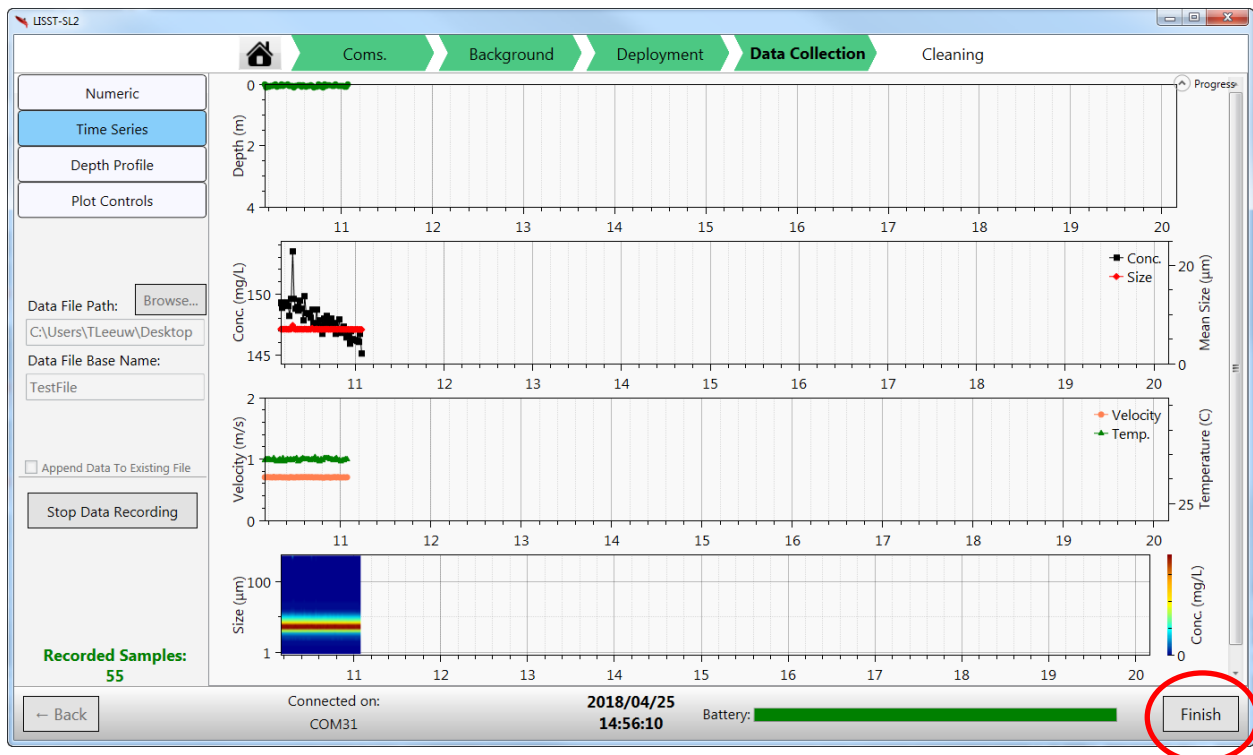
Recording Data

To record data to a file, a file directory and base name must first be specified on the Data Collection page. Use the 'Browse' button to select a directory. Use the text box to type in a base file name. This is called 'File Base Name' since two files will be generated using this name; an .RBS and a .ASC. The RBS file is a binary file that stores raw data from the sensor. Most users will not use this file. It may come in handy for troubleshooting or advanced data processing, so it is stored with your data. The .ASC file contains the processed data. See Appendix III for format of files.

The Start Recording Data button will start recording the data to the specified file. Data logging can be stopped and resumed. The software does not allow overwriting an existing file. However, you do have the option to append to an existing file by checking the Append Data checkbox above the Start Data Recording button.

When data are being recorded, the number of saved samples will be displayed in the lower left.

To finish and quit further data recording, press the FINISH button on bottom right. Not pressing the FINISH button leaves the pump operating. If taken out of river water, this would mean that the pump would be running dry. Damage to the pump can be caused.



IMPORTANT: The internal pump must be turned off quickly after removing the LISST-SL2 from the river. This is accomplished by pressing the 'FINISH' button in the lower right corner.

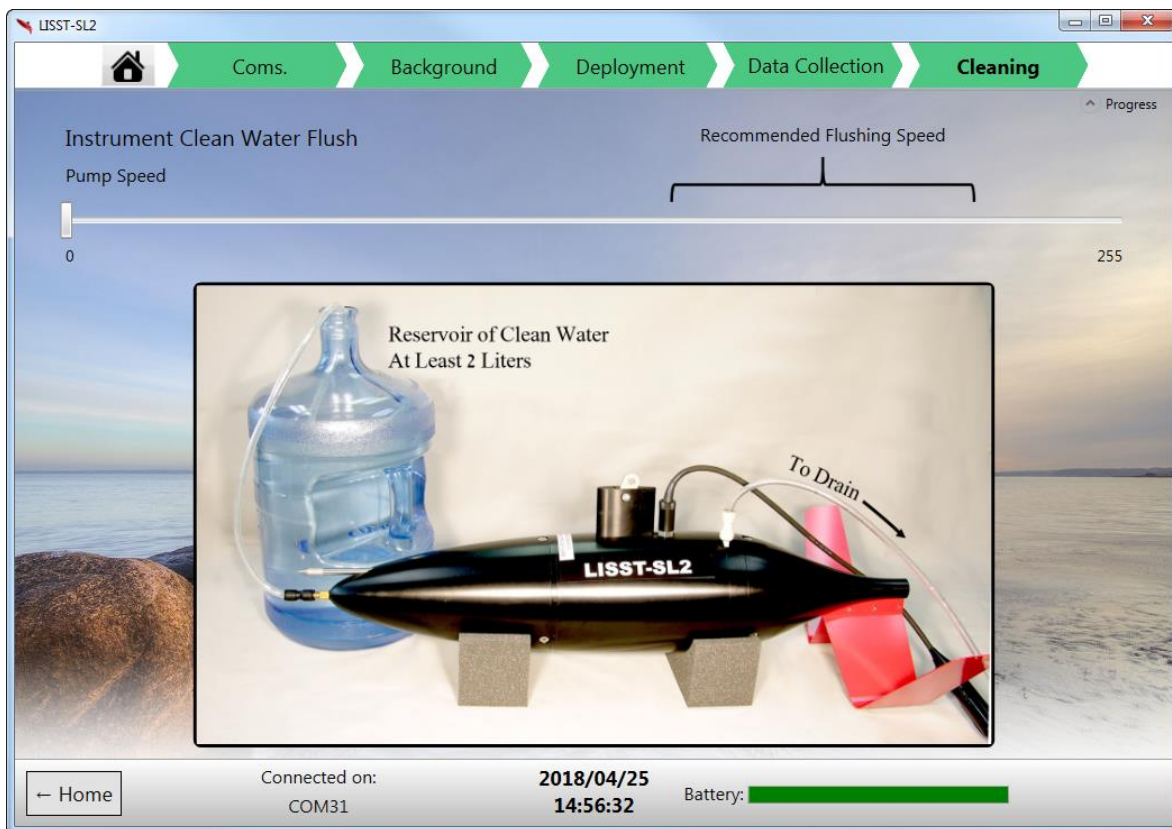
When you press the FINISH button on the data collection screen, you are brought to the Cleaning page as an immediate reminder to flush the instrument with clean water. Follow the procedure below.

Cleaning

You can come to the cleaning screen either directly from the home page, or after pressing FINISH during data collection. The cleaning page displays a slider that allows for manual control of the pump speed. Connect the instrument to a reservoir of clean water and then turn the pump on. Priming of the pump is likely to be required. Use the same procedure as you used for collecting a background (raise the source reservoir, with drain open to start flow). We recommend a high pump speed to ensure that any particles that might have adhered to optics are stripped off, and that large particles are flushed out of the system.

Cleaning should not be delayed. The likelihood of particles adhering to optics becomes higher with time. Immediate cleaning is best.

The setup for cleaning is displayed on the Cleaning page where you set pump speed. See figure on next page.

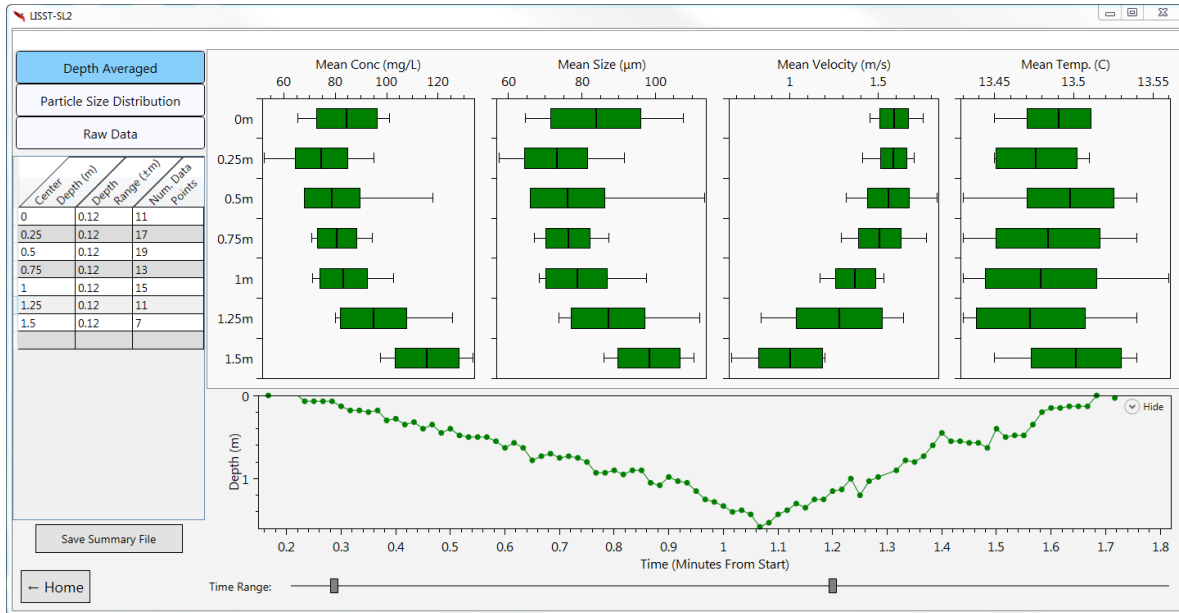


Viewing A Data File

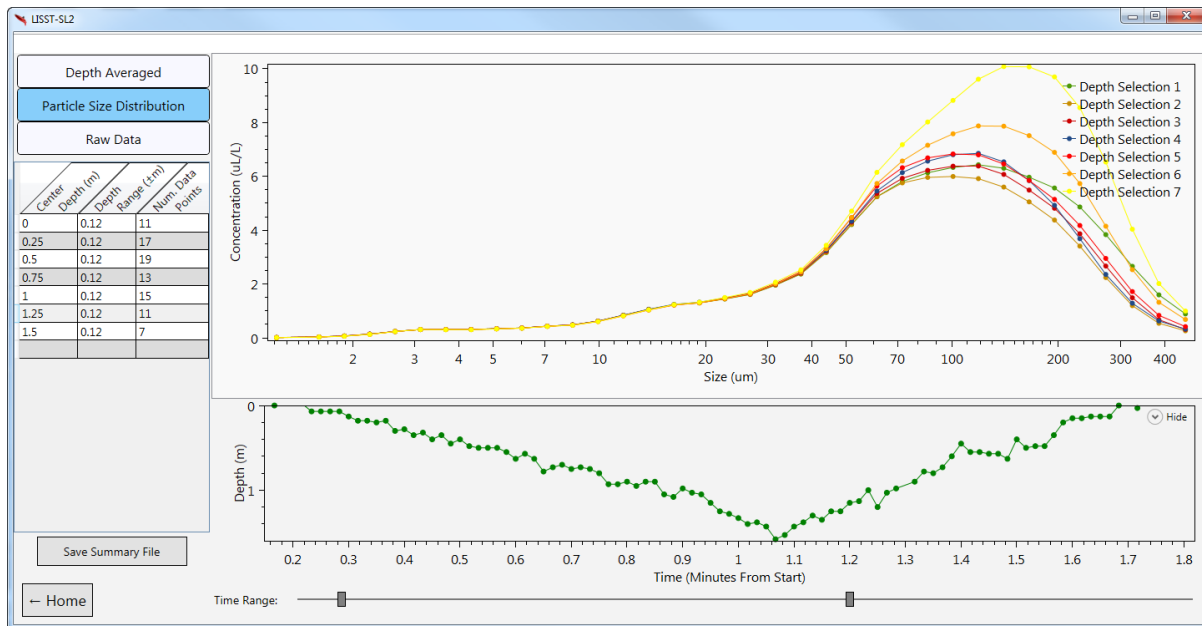
This feature allows you to load an existing .ASC data file into the plots seen in the 'Viewing Real Time Data' section. No connection to the instrument is necessary, since this used to view an existing file already stored on the computer.

Viewing Depth Averaged Data

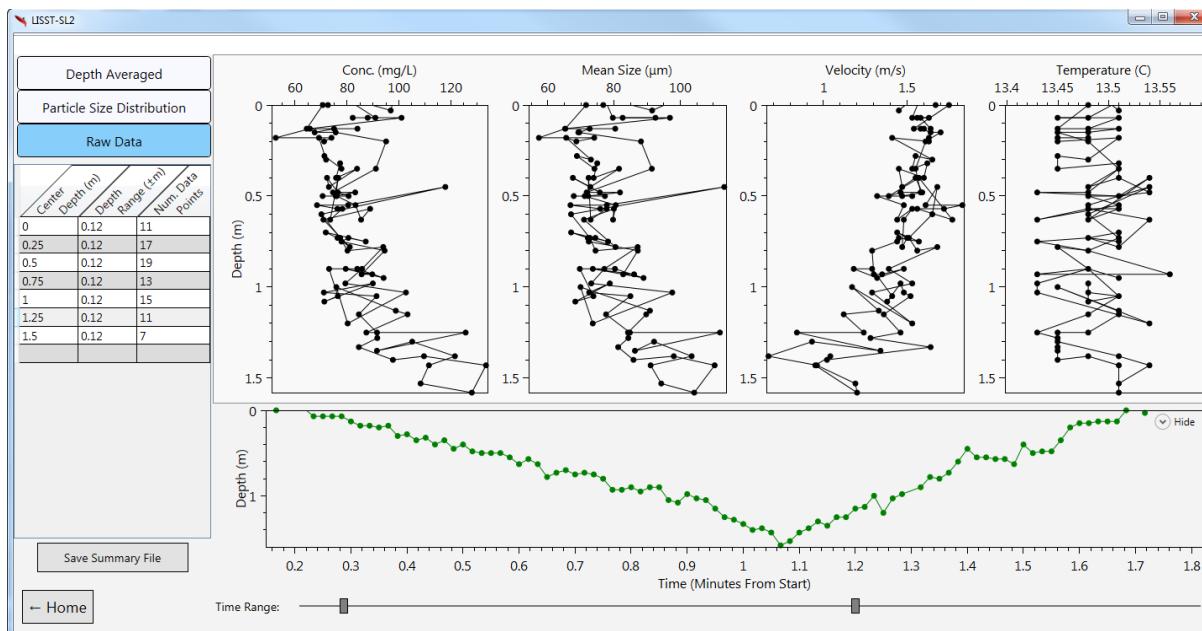
This feature of the software is for processing of a data file (.ASC file). It allows you to average the data according to your selected depth bins. This processing can be done immediately after data acquisition, or later, back in the office. The processing takes just a few seconds. The table on top



left allows you to specify different depth bins. A depth bin is selected by entering a center depth and a depth window. The resulting depth bin will be the center depth +/- the depth window. The number of data points falling in that depth bin will be listed in the third column of the table. The time range can also be constrained by moving the sliders at the bottom of the window.



The 'Depth Averaged' tab shows box and whisker plots for each of the depth selections. The whiskers show the minimum and maximum values in the bin, the solid vertical line shows the mean, and the green box covers the range from mean minus one standard deviation to mean plus



one standard deviation. The 'Particle Size Distribution' tab shows the mean particle size distribution from each depth bin. The depth averaged data can be saved in a text file by selecting 'Save Summary File.' The data format is explained in Appendix III.

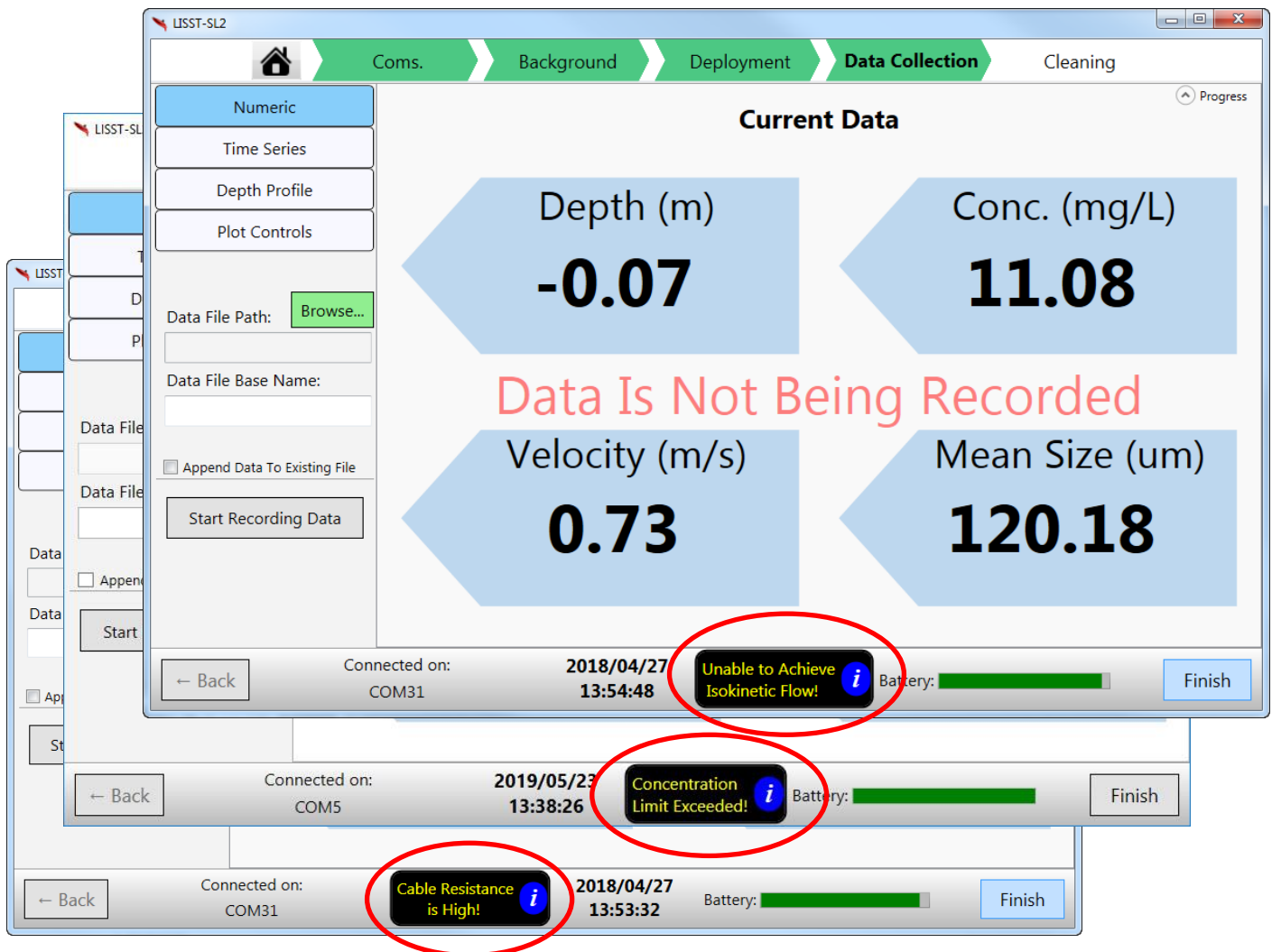
The 'Raw Data' tab shows the depth profile of the raw data.

Warnings

The software may produce three types of warning messages that appear in the bottom status bar.

1. Cable Resistance is High
2. Unable to Achieve Isokinetic Flow
3. Concentration Limit Exceeded

All the messages can be clicked on to obtain further information. If you receive a warning message that the cable resistance is high, the slip-ring of the B-reel may need to be cleaned. If you receive an Isokinetic warning, check the slip-rings for cleanliness also. If you receive a message that the concentration limit has been exceeded, the water is too turbid for proper operation of the LISST-SL2. At optical transmission values below 30% the concentration and size distribution produce by the LISST-SL2 may be inaccurate.



3. Getting Started: Test use in a Laboratory

The object of this section is to familiarize you with the first assembly and use of the component systems and to do an actual data collection in the laboratory. This is as a preparation for field use.

Laboratory testing can be done either with a water recirculation loop, or if a turbid water source can be connected to the intake of the instrument. The description below is for a recirculating loop.

Capturing a Background

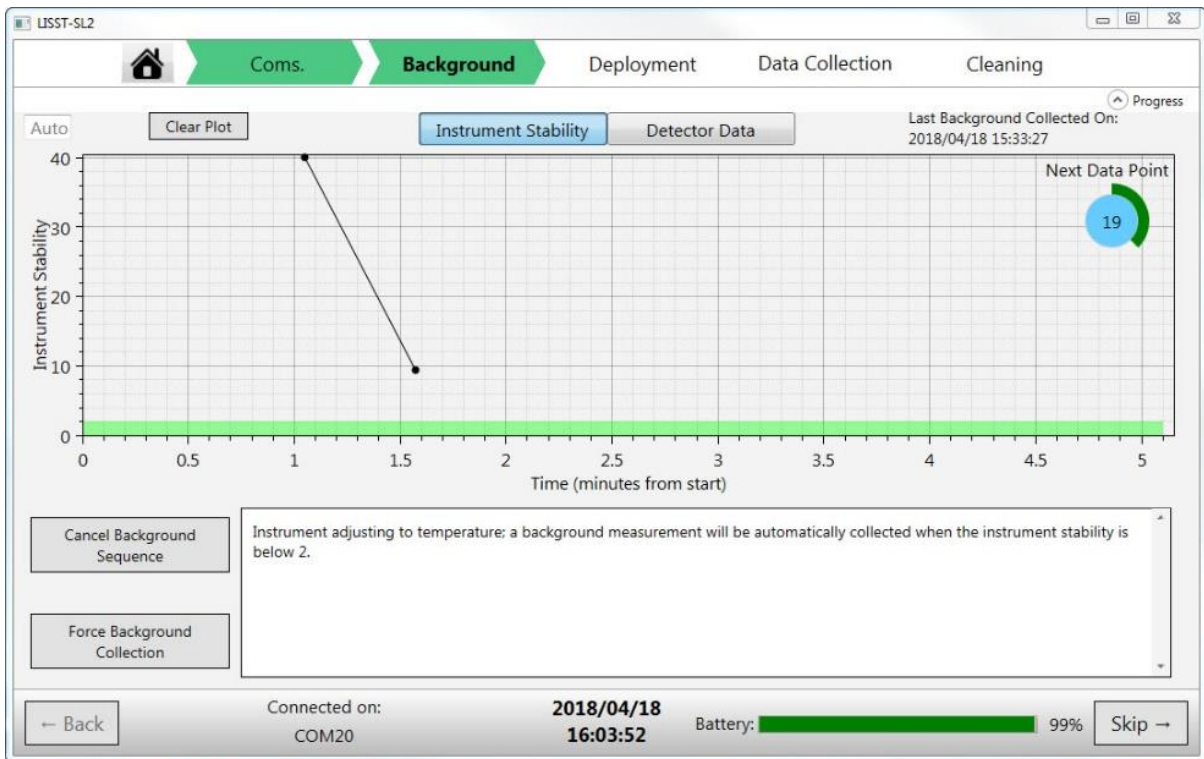
MAKE SURE THE POWER SWITCH ON THE TOPSIDE BOX IS OFF. TURN ON POWER ONLY AFTER ALL CONNECTIONS ARE MADE.

1. Before making any connections, check if battery is charged. You can do that by turning on the Power switch on the side of the TB before making any connections. Solid green LED indicates adequate state of charge. Flashing green indicates depleted battery. Fast blinking green means nearly dead battery. If necessary, use the charger supplied by Sequoia to fully charge the battery. Do not use a depleted battery.



2. Connect the LISST-SL2 instrument and TB via the yellow cable provided with the instrument package. Connect computer to TB using the USB cable or Bluetooth.
3. Fill the container provided for the purpose and connect the outlet to the intake of the LISST-SL2 sensor. Return the flow to the container. This sets up a closed loop. See photo below.
4. Raise the water container (about 1m), with the drain-end *now open and low* so that gravity starts the flow through the instrument. When flow is established, lower the reservoir and insert the drain end back into it. This sets up the closed loop for testing. If removed, insert filter; it traps air bubbles. Bubbles must not be allowed in the loop. Background will not pass.

5. Turn on power on the TB. The power switch is to the side of the TB, next to the LED's.
6. Launch software on computer.
7. On opening screen of software, select the 'Collect New Background' button.
8. Watch the display below. It will show Instrument Stability parameter, updated every 30 seconds (note the timing wheel on top right of chart). When this parameter reaches the green band at base of the plot frame, the instrument has reached stability. It will automatically acquire background data. This data is examined for quality and if found adequate, the user is informed. The background data can now be saved by the user. [This background is not visible to the user; it is incorporated into processing. The background can only be seen in the .RBS file.]



9. After completion of background data collection, you will be taken to the home screen.

Capturing Sediment Data

1. To capture a sediment datafile, add sediment to your water. Keep mixed. On the software opening screen, select Start New Data Collection.
2. A screen will open showing the connections to be made between the LISST-SL2, the TB and the B-reel. You should already be connected.
3. Press the Connect button on top to set up COMM port.
4. You may be prompted once again if you wish to save a more recent background. Choose 'Use Existing Background' if you have saved a recent Background file.
5. A new screen will open showing the LISST-SL2 being lowered into water. [This is the clue that you can lower the instrument into a river.] When done, press the Start Pump button.
6. The pump will start and a new chart will display a Temperature Stability parameter. The internal temperature sensors for water and optics temperature are compared. A display similar to the background display will show progress. A message will be displayed when the temperature has stabilized and data collection may begin.
7. On software, choose the mode of display – Numeric, or ...
8. *Note that data is not being saved unless you press the Start Recording Data button.* To save data, you must have first specified the file-path and file base name.
9. If you wish to save data, press Start Recording Data button.
10. You may Stop Data Recording and resume. If you choose Stop Data Recording, the Append Data To Existing File button becomes available. You can resume data recording and append to existing file. Or, you may select FINISH at bottom of the page.
11. When you finish, software takes you to the Cleaning page. This is our way of emphasizing timely and prompt cleaning of the water passage in the LISST-SL2.

Data file name conventions, content, and formats are explained in Appendix III.

Compute Averages

Once data collection is complete, you can save averages (such as point-averaged, or depth averaged) with the third function on the home screen. It prompts for the name of file to be processed (.ASC file) and saves the processed results in a .txt file.

Cleaning the Optics

After data collection, when you press FINISH, the software will take you to Clean the instrument page. For this purpose, connect the clean water container to the instrument as shown in the software window. Attach a fitting to the water exit and run the tube to a drain. Raise the water container well above the lifting point to provide some head for the flow and prime the pump. In software choose the pump speed setting. Set the pump speed in a high range (about 200) and run for 1-5 minutes or till the water runs out (about 5 1-s, max).

That marks the end of the first run. We hope you found it easy to learn.

4. Field Deployment of the LISST-SL2

We recommend that you review the following procedure a few times before a field trip, to get a good sense of what to do once you are there. Also, become fully familiar with the software back at the office. If you plan to connect to the instrument using Bluetooth, be sure to test this before the field deployment. Preferably somewhere with internet connection, as your computer may need to download and install the proper Bluetooth drivers.

Field deployment of the LISST-SL2 follows closely the same step by step procedure as the Laboratory practice session in Section 3. The only difference is the use of the B-reel cable, and a crane for suspending the instrument over the side of a bridge or a boat.

We highly recommend charging the battery overnight before field work.

We also recommend collecting a Background at the 'office' before leaving for fieldwork. If you forget, you can do that in the field also; but then you will need to carry clean water and a recirculation setup.

Pack List

We recommend that you pack the following to go with you to the field:

- LISST-SL2
- Topside Box
- B-reel
- Computer
- A crane for the B-reel.
- 5L or more of filtered clear water, for flushing optics after use.
- Cable to connect TB to B-reel.
- Convenience items, e.g. a picnic chair, a picnic table for your laptop, water for cleaning the body of the LISST-SL2, a sun-shade for your laptop...

Carry the rest of the accessories supplied to you as these may come in handy as well.

Battery Check

MAKE SURE THE TOPSIDE BOX POWER SWITCH IS OFF BEFORE MAKING CONNECTIONS.

Before leaving for fieldwork, check the battery; turn on power in the Topside Box. If charged, an LED will glow solid green. If the LED is flashing, the battery is not fully charged. Turn off power. You may need to charge the battery. The rest of the procedure follows the laboratory practice run, with a few differences.

Launch and Data Collection

1. If you did not save a new Background shortly before arriving at the field site, capture a new background. If a Background has been saved recently, continue.
2. Prepare the crane for launch of LISST- SL2. Mount the B-reel on to it. Feed the cable through the pulley. Suspend the LISST-SL2 sensor.
3. Connect the slip-ring end of B-reel to the Topside Box.
4. Connect the free end of the B-reel cable to the LISST-SL2 sensor.
5. Turn on power at the Topside Box. The green and red LED's should turn on.
6. Launch software on your computer.
7. On the computer, on the opening screen, select Collect Data. Let the comm port get setup.
8. Collect a new background, if needed.
9. Lower the LISST-SL2 into water. Hold just below surface so it is visible.
10. Start the temperature equalization process in the software.
11. If the instrument is held just below the surface, a jet should be visible from the LISST-SL2 exit.
12. When equilibrium is reached, press the 'Next' button to continue to data collection page.
13. If data appear good, enter a path and file name then press the Record Data button.
14. Continue data collection for a few minutes (e.g. 5 min.) to obtain good statistics. We recommend watching the data in the Time Series mode.
15. Lower the LISST-SL2 sensor to a new depth. You do not need to pause data collection, but you may do that if you like, and resume once at a new depth.
16. Proceed until you have profiled the water column.
17. **IMPORTANT:** Press 'FINISH' in the lower right of the data collection page before removing the sensor from the water. This will ensure the pump is off before it is removed from the water. Never run the pump dry!
18. Finishing data collection takes you to the Cleaning page. After bringing the instrument to bridge deck, set up cleaning, and flush the instrument. You may disregard this page if you need to continue operations.
19. If you like, choose the third option from the opening page of software, i.e. Compute Averages to see fully processed profiles right away. You will need to specify the center-point and depth range for each average.
20. You may move to another location across the river/water body and repeat steps 6 onwards.

Shut Down and Clean

21. When finished, turn off power at the TB. Pull up the instrument to the bridge deck.
22. Connect a clean water source to the intake of the LISST-SL2 as described in laboratory test section.
23. Turn on TB power.
24. On software, on the home page, choose Cleaning.
25. On the Cleaning screen, set the pump speed in a high range. High speed is more effective at cleaning the optics. Finish after a few minutes of flushing. Stop and exit.
- 26. TURN OFF POWER ON THE TOPSIDE BOX BEFORE DISCONNECTING CABLES.**
27. Disconnect cables.

NOTE: WHILE DISASSEMBLING EQUIPMENT ALWAYS FIRST TURN OFF POWER AT THE TB TO AVOID ELECTRICAL SHORTS.

Data collection is complete. Wash the instrument with clean water before storage.

We recommend you leave the TB charging.

5. Handling, Cleaning, Maintenance and Storage

Handling



When handling the instrument, at all times please remember that the LISST-SL2 is a high-precision optical instrument. Treat it as you would treat an expensive camera.



Avoid mechanical shocks and impact to the LISST-SL or the TCB as this may cause misalignment of the optical parts, or damage to electronic assemblies.

Cleaning and Maintenance



For lubrication of the underwater connector and the TCB connector, use ONLY silicone spray such as, e.g. 3M Silicone Lubricant.

DO NOT USE O-RING GREASE TO LUBRICATE THE CONNECTOR AND PINS – grease may build up in the connector on the B-reel and over time hinder communication to the LISST-SL.



Clean the LISST-SL body with fresh water each time after use, and before storage.



Remove the pitot tube cap and clean the screen. Put the cap back on.

Storage

IF PREPARING TO STORE THE INSTRUMENT SYSTEM FOR A LONG DURATION, IT IS A GOOD IDEA TO RUN CHLORINATED WATER THROUGH THE SYSTEM TO PREVENT BIOLOGICAL GROWTH ON INTERNAL SURFACES. STORE THE FILTER PROVIDED FOR BACKGROUND FILE COLLECTIONS IN A CHLORINATED WATER SOLUTION.

Put plastic caps on the intake and pitot tube openings. Place the LISST-SL2 on its foam stands or inside the shipping box.

Before storage, make once again sure to turn off power on the TB.

You should recharge the battery before use if the TB has not been used for long (month or more).

A 5 pin Impulse plug and sleeve is provided to protect the connector on the LISST-SL when the sensor is not in use. The 3 pin Impulse plug should be put on the TCB connector and the rubber cover put on the communications connector to keep the connections dry and clean.

6. FAQ's

What is the range of particle sizes measured by LISST-SL2

The particle size ranges from 1-500 microns. See Appendix for the specific size ranges.

What happens when particles outside the measurement range are present in water?

Particles outside the specified range are seen faintly in the nearest size bins (e.g. finer particles are seen in the 1-micron bin and nearby, and larger particles than 500 microns are seen in the largest bins. The sensitivity (mass reported/true mass) of these out-of-range particles decreases rapidly as particle size departs from the range. For details, see this [article](#) on Sequoia website.

Does the LISST-SL require any calibration?

No. All that is required is that the user makes a background measurement before a sample is taken. Laser diffraction method does not require recalibration. Calibration can change if the laser output changes, but we measure the laser output and compensate for drifts. No change in calibration is required.

What happens if I do not collect a recent background before field work?

It is important to have a recent background associated with a field use. Not having a recent background can degrade the quality of data.

Does the instrument measure NTU, FTU or any other turbidity units?

No. All laser diffraction based instruments measure the volume distribution of the suspended particles. This may or may not be related to NTU.

Can the LISST-SL be cross-calibrated with NTU's

No. The calibration of the NTU unit itself is based on a specific size of particles. With changing grain size, NTU itself changes, and it is meaningless to do a cross-calibration.

Can I overcharge the rechargeable battery inside the instrument?

If you charge the battery with the power adaptor supplied by Sequoia as part of the instrument system, you cannot overcharge the battery.

Do you have an FAQ not answered here?

Try the FAQ webpage on our website (<http://www.SequoiaSci.com/fag/?SectionName=fag>)!

Otherwise contact us at info@sequoiasci.com

7. Appendix I: Technical Specifications

- Parameters measured/derived:
 - Particle Size distribution
 - Total Volume Concentration
 - Optical Transmission
 - Velocity
 - Depth
 - Temperature
- Particle size range: 1.00 - 500 μm
- Particle size resolution: 36 size classes, log-spaced
- Optical path length: 0.3 cm
- Optical transmission: 12-bit resolution
- Data storage memory: Limited only by your datalogging device (computer/tablet).
- Sample rate: 1 size distributions per second (fixed)
- Temperature sensor
 - Range: -5 to 45 $^{\circ}\text{C}$
 - Resolution: 0.001 $^{\circ}\text{C}$
 - Uncertainty: approximately 1 $^{\circ}\text{C}$
- Velocity Sensor
 - Type: Differential pressure behind Pitot tube
 - Velocity Range: 0.056 – 3.6 m/sec
 - Differential Pressure resolution: 0.016 cm nominal; (expressed in head of water); [12 bit, 0.67 m full scale]
 - Velocity resolution: depends on velocity, $1.6 \times 10^{-3} * \text{Velocity in m/sec.}$
- Depth Sensor
 - Range: 0 to 30 m of water
 - Resolution: 1 cm
 - Uncertainty: approximately 1% of reading (if atmospheric offset zeroed)
- Battery:
 - 12 V x 35 A-hr Lead-acid
 - Hours of use: 6
 - Time to recharge: 12 hours.
- Dimensions:
 - LISST-SL2:
 - 17 cm (6.7") maximum \O x 87 cm (34.2") L
 - Weight in air: 19.5 kg (43 lbs)
 - Weight in water: / 8.2 kg (18 lbs)
 - Topside Box:
 - 42 cm (16.62") L x 21.5cm (8.62") W x 34 cm (13.32") H.
 - Weight in air: 15 kg (33 lbs.)

8. Appendix II: Contents of Ship Package



LISST-SL2 Topside Control Box Ship Case Contents

		Quantity
LISST-SL2 TCB		1
12" Clear Storage Case #1 - Charger	LISST-SL2 Battery Charger	1
12" Clear Storage Case #2 - Cables		1
	TCB to Winch Cable	1
	Sensor Test Cable	1
	TCB to USB Cable	1

LISST-SL2 Ship Case Contents

		Quantity
LISST-SL2 Sensor		1
Nozzle Guard / Background Chamber	(1)	1
Foam Instrument Stands	(2)	2
2 Part Tail Fin	(3)	1

10" Clear Storage Case		1
(4)	0.1um Filter, ETA (HC06-4N-B)	1
(5)	Tubing 1/4"ID x 3/8"OD Lengths: 1 foot, 2 feet, 4 feet	1 each
(6)	10187 Tapered Pump Nipples	2
(7)	3/8 Push to Connect, Black	1
(8)	3/8 Push to Connect, Gray	1
(9)	Pinch Clamps	2
(10)	Screen Filter Disks	25
(11)	Pick	6
(12)	Tweezers	1
(13)	Kimwipe Sheets (for window cleaning)	12
(14)	2-007 Vent Plugs (Nose/Tail)	6 spares
(15)	2-109 Brass Nipples (Nose Cone)	2 spares
(16)	2-250 Nose Cone	2 spares
(17)	2-125 Pump	2 spares
(18)	2-245 Tail Cone	2 spares
(19)	2-012 Window Plugs	2 spares
(20)	Pin and Clip	2
(21)	¼-20 x ¾ FFHD (nose cone, tail cone)	3 spares
(22)	Tail Screws, SHCS 6-32 x 1/4" SS, 6 required, 6 spares	12
(23)	8-32 x ¼ (vent plugs, nose/tail, pitot vent)	6 spares
(24)	4-40 x 3/8 SHCS (window plugs)	3 spares
(25)	Plastic Caps	6
(26)	3/16 Ball Driver (for battery service only, in Topside Box)	1
(27)	9/64 Ball Driver	1
(28)	7/64 Ball Driver	1
(29)	3/32 Ball Driver	1
(30)	5/32 Ball Driver	1
(31)	5/64 Ball Driver (for pump removal only)	1
(32)	L-Key T-15 Torx (for battery service only, in Topside Box)	1
(33)	Tube Locking Clips	10
(34)	Coffee Stir Sticks (for window cleaning)	12
(35)	Cotton Swabs	1 pack
(36)	SL2 Users Manual	1
(37)	Flash Drive (LISST-SL2 Software)	1

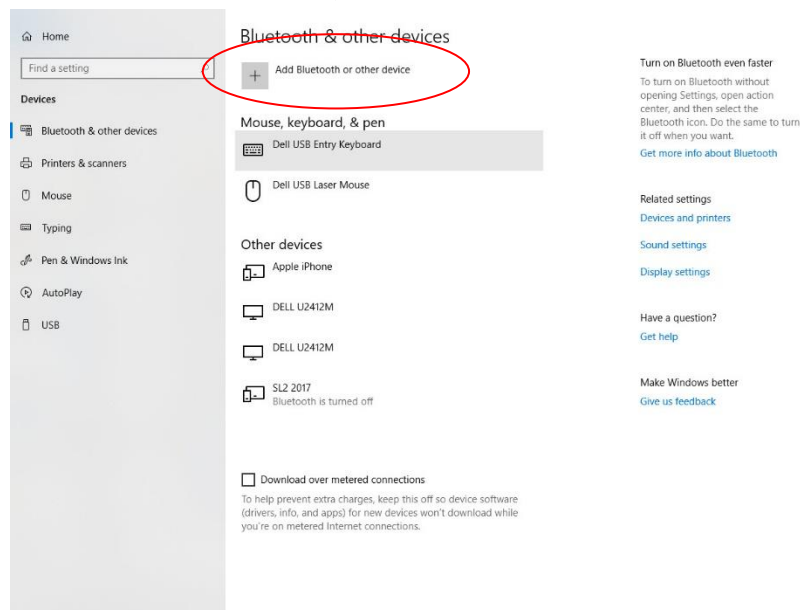
9. Appendix III: Establishing and Troubleshooting Bluetooth Connection

The LISST-SL2 has the capability of communicating over a USB or Bluetooth connection. Your computer must be equipped with Bluetooth version 2.1 or later. You may also use a USB Bluetooth dongle if your computer does not have Bluetooth capability.

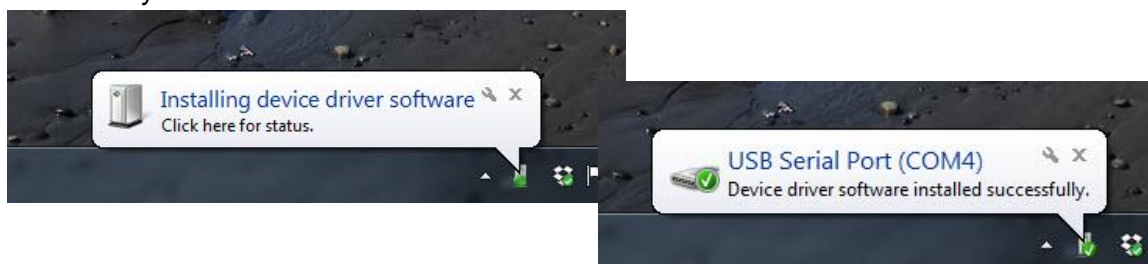
To use the Bluetooth connection, the topside box USB cable must be disconnected from the computer. If the USB cable is disconnected, the blue led on the topside box will blink, indicating the topside box is discoverable.

Next, you will need to pair the topside box with your computer. Turn on the topside box and ensure the USB cable is disconnected and the blue light is blinking. The pairing process will vary depending on what version of Windows is on your computer. Follow the steps below or visit <https://support.microsoft.com/en-us/help/15290/windows-connect-bluetooth-device>:

1. Click the 'Start' button in the lower right corner and search for 'Bluetooth'.
2. Click on 'add a Bluetooth device' or 'Bluetooth device settings'
3. Ensure Bluetooth is turned on, then click 'add Bluetooth Device'



4. The computer will search for nearby Bluetooth devices, 'SL XXXX' where XXXX is the serial number will appear.
5. Double click 'SL XXXX' to pair the device. If you are asked for a PIN, see the troubleshooting section below.
6. After pairing, Windows will automatically install additional drivers. This requires a connection to the internet. Please wait for this process to complete before continuing. It may take several minutes.



7. The LISST-SL2 is now available via a Bluetooth serial COM port.
8. Launch the software and connect to the instrument just like you would if the USB cable was plugged in.

Troubleshooting

When I initiate pairing, I am prompted for a pairing PIN code.

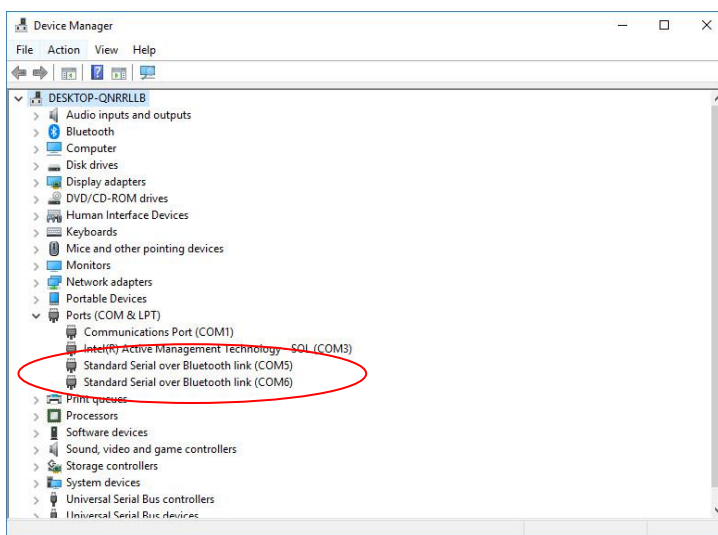
Your Bluetooth version may not be compatible with the LISST-SL2. Ensure you are using Bluetooth v2.1 or later. You may need to purchase a newer Bluetooth USB dongle in order to use the LISST-SL2 with older computers.

The SL2 does not show up in the list of discoverable devices.

Ensure the topside box is powered on and placed next to the computer. Ensure the topside box USB cable is not plugged in. The blue light on the topside box will be blinking when the instrument is discoverable. If the blue light is solid, it may be already connected to another computer.

The LISST-SL2 software can't find the instrument.

Ensure the topside box appears in your list of paired devices. If it appears there and the software still cannot find the instrument, unpair the instrument and re-pair the instrument with your computer. Restart the LISST-SL2 software and try again. Another possibility is the drivers did not install correctly. Go to the start menu and search for 'Device Manager', open device manager and expand the 'Port (COM & LPT)' list. You should see two ports listed as 'Standard Serial over Bluetooth link'



If these do not appear, and you have tried several times to pair the instrument while connected to the internet, please contact us. Sequoia can help you find the proper drivers for your computer.

10. Appendix IV: Data files, Formats and Contents

File Types and Extensions Used by the LISST-SL2 Software

Extension	Description	Format	Comments
.RBS	Raw Data	Binary	Raw data file produced by the LISST-SL2. Only for use with Matlab (not necessary except for debugging).
.ASC	Processed Data	ASCII	ASCII file containing the processed size distributions and auxiliary information (depth, velocity, temperature, etc.)
.TXT	Depth Averaged Data	ASCII	ASCII file containing depth averaged data.

Processed Data Format The values in the processed data file (.ASC extension) are stored in the order shown below. Each sample is stored in one row. The column names and units are also included in the header of the data file.

Column Number	Column Name	Units
1	Date	Year/Month/Day
2	Time	HH:MM:SS
3	Battery_Voltage	Volts
4	Depth	Meters OR Feet
5	Velocity	m/s OR f/s
6	Temperature	Celsius
7	Total_Concentration	mg/L [assumed mass density of 2.65 g/cm ³]
8	Mean_Size	Micrometers
9	Optical_Transmission	No units; it is a non-dimensional quantity
10	Beam_Attenuation	1/m
11...47	Size_x_x_Conc.	mg/L [assumed mass density of 2.65 g/cm ³]

Depth Averaged File Format The values in the depth averaged ASCII file (.TXT extension) are stored in the order shown below. The column names and units are also included in the header of the data file.

Column Number	Column Name	Units
1	Depth_Bin_Number	
2	Center_Depth	Meters OR Feet
3	Depth_Window	Meters OR Feet
4	Start_Date	Year/Month/Day
5	Start_Time	HH:MM:SS
6	End_Date	Year/Month/Day
7	End_Time	HH:MM:SS
8	Number_of_Measurements	
9	Velocity_Mean	m/s OR f/s
10	Velocity_Std_Dev	m/s OR f/s
11	Temperature_Mean	Celsius

12	Temperature_Std_Dev	Celsius
13	Concentration_Mean	mg/L
14	Concentration_Std_Dev	mg/L
15	Size_Mean	microns (μm)
16	Size_Std_Dev	microns (μm)
17	Optical_Transmission_Mean	No units
18	Optical_Transmission_Std	No units
19	Beam_Attenuation_Mean	1/m, or m^{-1}
20	Beam_Attenuation_Std	1/m, or m^{-1}
21...57	Size_x_x_Mean_Conc.	mg/L

11. Appendix V: Particle Size Bins

There are 36 size ranges logarithmically placed from 1.00 - 500 microns in diameter. The upper size in each bin is approximately 1.18 times the lower, except for bin 1. The table below shows the lower and upper limit of each size bin in microns, together with the median size (also in microns) for each size bin.

Size bin #	Lower	Upper	Median
1	1.00	1.48	1.21
2	1.48	1.74	1.60
3	1.74	2.05	1.89
4	2.05	2.42	2.23
5	2.42	2.86	2.63
6	2.86	3.38	3.11
7	3.38	3.98	3.67
8	3.98	4.70	4.33
9	4.70	5.55	5.11
10	5.55	6.55	6.03
11	6.55	7.72	7.11
12	7.72	9.12	8.39
13	9.12	10.8	9.90
14	10.8	12.7	11.7
15	12.7	15.0	13.8
16	15.0	17.7	16.3
17	17.7	20.9	19.2
18	20.9	24.6	22.7
19	24.6	29.1	26.7
20	29.1	34.3	31.6
21	34.3	40.5	37.2
22	40.5	47.7	43.9
23	47.7	56.3	51.9
24	56.3	66.5	61.2
25	66.5	78.4	72.2
26	78.4	92.6	85.2
27	92.6	109	101
28	109	129	119
29	129	152	140
30	152	180	165
31	180	212	195
32	212	250	230
33	250	297	273
34	297	354	324
35	354	420	386
36	420	500	459

12. Appendix VI: Clearing a Pump Jam due to Blockage

If very large particles enter the LISST-SL2 intake, i.e. about 2mm diameter, they can get wedged in the pump impeller. This leads to stalling of the impeller. If this happens, software generates a warning, see below.

To remove the jam, it is necessary to remove the tail section of the instrument. That exposes the pump motor. The pump can be removed easily. The impeller housing becomes accessible and can be cleaned. Reinstall the pump, and close the rear section. This is explained in the video below.

Please see video supplied on USB.

13. Appendix VII: Cleaning the Laser Optics inside the LISST-SL2

After extended use, thin film of sediments can build up on the optical windows of the instrument. The LISST-SL2 has been designed so that a user can easily access the optics for cleaning. We explain this procedure in an included video.

Please see video supplied on USB.

14. Appendix VIII: Purging Air from Pitot Tube and Cleaning Screen

Air in the Pitot tube can introduce error in velocity measurement. Consequently, we recommend that you purge air in it and clean the screen at the front end. Follow the steps below.

1. After the Background file collection, unscrew the Pitot Tube Cap.
2. Inspect the screen in Pitot Tube Cap. Simply rinsing the pitot tube cap and blowing it out may be sufficient to clean the screen. If the screen is clear, screw the cap back onto the pitot tube assembly and proceed to purge (step 5).



4. If the Pitot Tube Cap is clogged, replace the screen:
 - a. Use the pick provided to remove the 2-007 O-ring in the Pitot Tube Cap.



- b. Tap the cap to remove the 43 micron screen (simple to make from 325 x 325 mesh stainless steel screen, cut with a 1/4" paper punch)
 - c. Use the tweezers provided to install a screen.



- d. Install the 2-007 O-ring over the screen.
 - e. Screw the cap back on the Pitot Tube.

6. Move the background chamber tube from the Sampling Tube to the Pitot Tube.



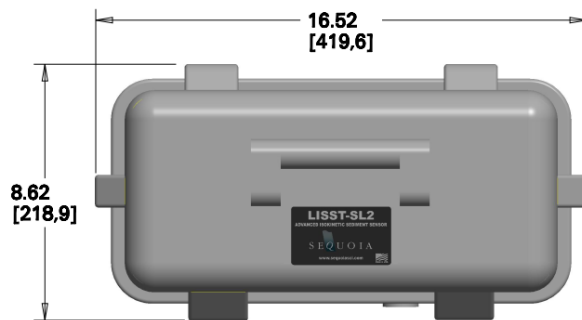
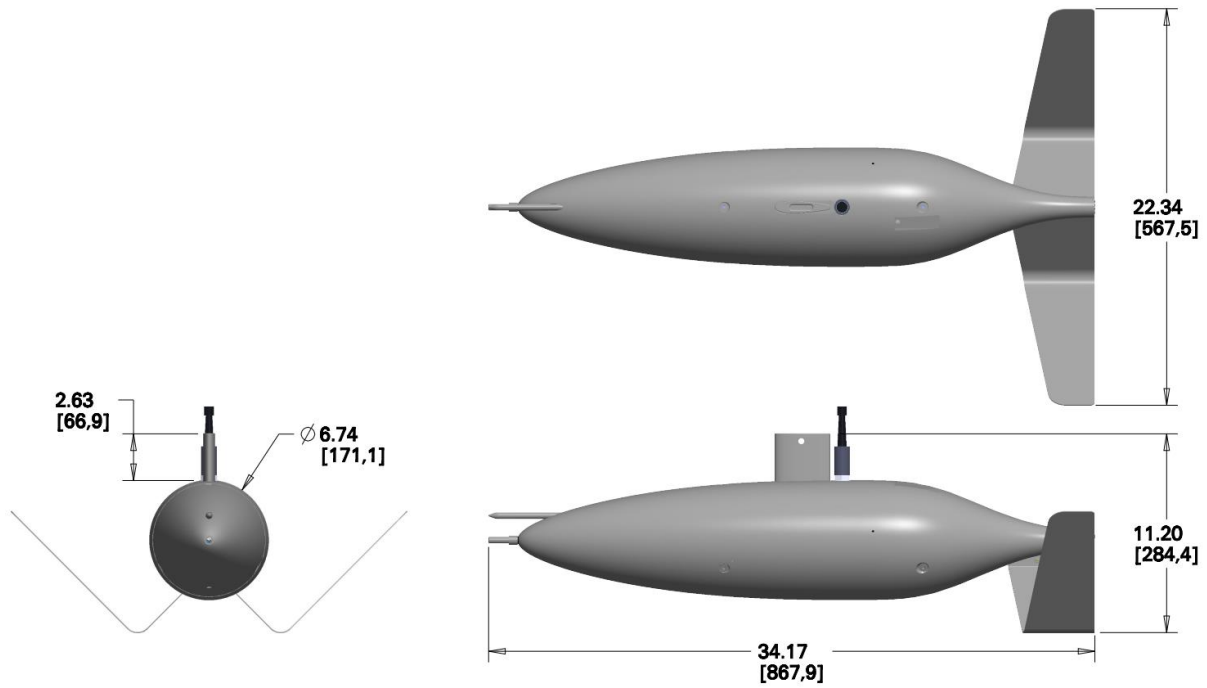
7. Remove the screw from the purge port on top of the nose cone.
8. Open the pinch clamp and elevate the background chamber. After the air has escaped and a steady stream of water is flowing, install the sealing screw into the purge port.
9. Pinch the clamp closed and remove the tubing.
10. If preparations are made hours before the deployment, put a black cap over the Pitot Tube Cap to prevent the water from draining out. Remove the black cap just before inserting the SL2 into the river.

15. Appendix IX: Advanced Data Processing for Scientists

Whereas all data processing for computing averages is done from the third function on software home page, the saved ASCII file is intended for use in Excel only.

A Matlab script for loading this file into Matlab command window is available for in-depth scientific data analysis. If you'd like to request a copy, please write at info@SequoiaSci.com

16. Appendix X: Mechanical Dimensions (in.[mm])



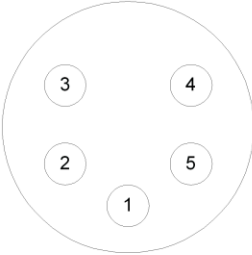
17. Appendix XI: 5-pin Connector and B-Reel Cable Termination

Connector Manufacturer: Teledyne-Impulse Enterprise, Inc. San Diego, CA, USA

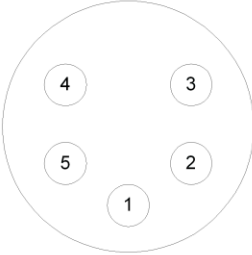
Connector Part Number (Bulkhead): MCBH-5-MP Stainless Steel

Mating Cable Part Number: MCIL-5-FS

Connector Pin #	Use
1	Power /Signal Ground
2	Power In (+24VDC)
3	Test Point 1
4	Test Point 2
5	Test Point 3

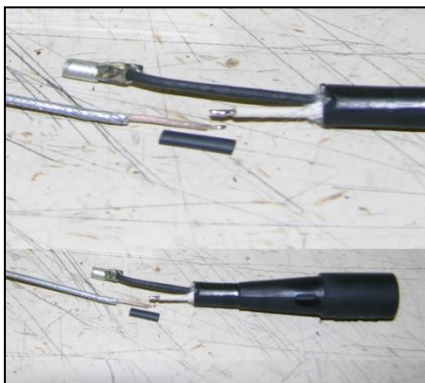


Bulkhead Endview



Cable Endview

The inner wire on the B-Reel steel cable is the Power In for the LISST-SL. The Signal Ground is the outer jacket of the steel cable. Appropriate sealing and potting compounds should be used to maintain a waterproof isolated connection to the Power In. The wires for the Test Points are not used, and should be terminated and sealed. The text and illustrations below describe the wiring details for this connector. If you have purchased your B-Reel from Sequoia together with the LISST-SL, the cable will already be appropriately terminated.



18. Warranty

STATEMENT OF LIMITED WARRANTY AND LIABILITY

This Statement of Limited Warranty applies to all Sequoia Scientific, Inc. ("SEQUOIA") products ("Products"). Any additional or different terms, including any terms in any purchase order, will be of no effect unless agreed to in writing by an authorized representative of SEQUOIA as reflected in a written SEQUOIA quotation.

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If any Product does not comply with the warranty set forth in 1(c) above, SEQUOIA will defend and indemnify Customer against any third-party claim asserted in any proceeding against Customer based on this noncompliance; provided that Customer gives SEQUOIA prompt written notice of the claim, SEQUOIA has exclusive control over the defense and settlement of the claim, Customer provides such assistance as SEQUOIA may request in connection with the defense and settlement of the claim (in which event SEQUOIA will reimburse the reasonable out-of-pocket costs incurred by Customer to provide such assistance), Customer does not settle the claim without the prior written consent of SEQUOIA and, upon SEQUOIA's request, Customer returns the Non-Complying Product to SEQUOIA for modification, replacement or a refund of the purchase price paid by Customer to SEQUOIA for the Non-Complying Product, less a reasonable allowance for Customer's use prior to return.

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In the event of any conflict or inconsistency between any provision of this Statement of Limited Warranty and any other provision of the Order, the provision of this Statement of Limited Warranty will control.

13. Controlling Law

This Statement of Limited Warranty will be governed by the laws of the State of Washington without reference to its rules relating to choice of law for the purpose of applying another jurisdiction's law. The U.N. Convention on Contracts for the International Sale of Goods will not apply.

19. MY NOTES