LISST-200X

Particle Size Analyzer

Including

LISST-HAB & LISST-Black

User's Manual

Version 2.0

October 2020

Store Software USB Card Here

SEQUOIA

2700 Richards Road, Suite 107
Bellevue, WA 98005-4200
Tel: (425) 641-0944 *Fax:* (425) 643-0595

SEQUOIA

Welcome to the LISST-200X Particle Size Analyzer

Using this manual

This manual is divided into two sections.

I. LISST-200X contains an introduction to the LISST-200X instrument and the principles of its operation.

II. LISST-200X Operation provides a detailed set of instructions for using and caring for the instrument.

Technical assistance

For technical assistance please contact your local Distributor or Sequoia. Please be sure to include the instrument serial number with any correspondence.

IMPORTANT: Please read Appendix I: Technical Assistance & Troubleshooting *BEFORE* you call or email.

Sequoia Scientific, Inc. contact information:
Telephone: +1(425) 641-0944
Email: info@sequoiasci.com

Table of Contents

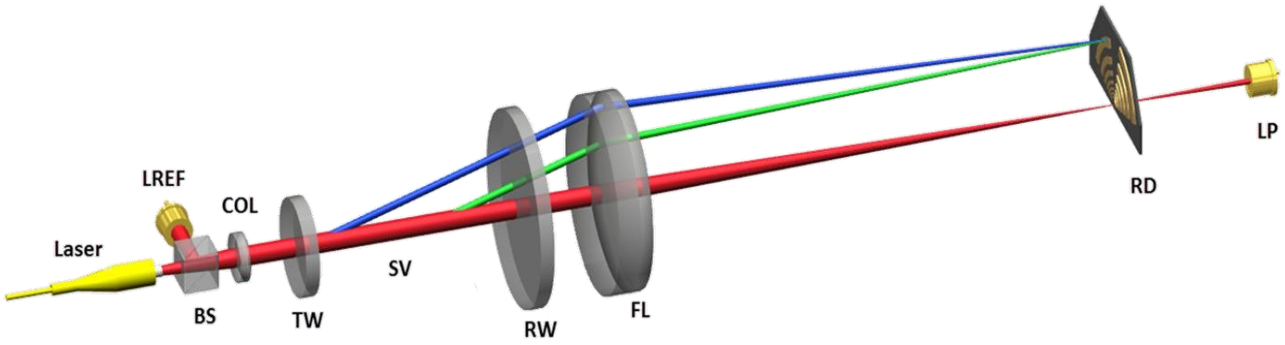
I. LISST-200X Introduction and Tutorial

A. Laser Diffraction and the LISST-200X

Measurement Principle and Optics

Particle sizing by laser diffraction is currently the most widely prevalent method in research and industry. It is a multi-parameter measurement. Just as a set of 3 equations can be solved for 3 unknowns, a measurement of light scattering at multiple angles can be solved for equally as many *concentrations* in different sizes. For example, the LISST-200X measures scattering into 36 angles; consequently, one obtains concentrations in 36 size classes of particles. This is called the particle size distribution (PSD). That is the essence of this method. In order that you appreciate the importance of some steps in operation of the LISST-200X, we recommend reading the rest of this chapter.

The measurement of scattering at multiple angles is done with a collimated beam illuminating particles in water. Laser light scattering at an angle from the beam arrives, through a daylight rejection filter, at the focal plane of a receive lens at the same angle from lens axis (see figure). Thus, distance from lens axis in the lens focal plane corresponds to scattering angle. The photodetectors in the LISST series instruments are a series of silicon rings spanning 60-degree arcs. Each ring covers a small range of scattering angles. Rings are used to achieve stability of *inversion* – conversion of set of multi-angle scattering measurements to the PSD.



Notice that the laser beam itself is focused by the receive lens and passes through a small aperture in the ring detector, centered on the rings. This beam is sensed by a photodiode placed behind the ring detector. This is the *transmission* sensor. As light is removed from the laser beam by scattering, the beam is attenuated, i.e. the light transmitted through water is reduced in intensity. A similar attenuation also affects the light that is scattered by particles and sensed by ring detectors. Thus, the transmission sensor provides a vital measurement to de-attenuate the measured scattered light.

Clean Water Backgrounds and Background QC

Imperfections, such as micro-scratches on glass windows and lenses, also scatter laser light. This is measured and stored; it constitutes a *Background* (formerly termed *zscat,* as in scattering by zero concentration of scatterers). This background is subtracted from the total signal seen by ring detectors. It is also helpful in determining if the instrument is properly aligned, and if all optics are clean and unscratched. A *factory background* acts as a reference to compare with, to identify degradation in laser output or fouling of optical surfaces. The LISST-200X stores its factory background data in its memory, as well as the user's acquired background data.

The LISST-200X incorporates a major advance over our previous LISST-100X. This is the automatic quality control of the background data (QC). During background acquisition, after grabbing a group of scans of all detectors, their means and variances are computed. Comparing with the on-board factory background, these are used to alert the user of possibilities such as laser degradation, possible optics misalignment, contamination of data by thermal microstructure in the water used for background, bubbles or particles in the supposedly clean water, scratches on windows etc. If no warnings are generated, the background passes QC and the user has the option to save it, or repeat.

Ambient Light Rejection

The laser diffraction method requires that the light arriving on the detector be due entirely to scattering of light that originates with the laser beam. Light from ambient sunlight can distort the results. The LISST physically shields the detector from much ambient light, but not all, so daylight at shallow depths can still be significant.

The LISST-200X now can measure the ambient light independently of scattered light, and subtract it to completely remove its effects. (Note that this function requires firmware version 1.4 or later, introduced in May, 2017). See section H for more about ambient light rejection (ALR).

Quick Estimates of Particle Concentration and Mean Size

The process of inverting laser diffraction data to produce PSD requires too much computation to execute in real time within the instrument. But the LISST-200X does provide real-time estimates of the total particle volume concentration and mean particle size. These are approximate quantities, not as accurate as the fully-processed PSD, but are useful for quick characterization of water conditions. For example, if used in conjunction with a CTD package in profiling applications, the CTD software could display the concentration and mean size as a depth profile, revealing any vertical structure in the particle distribution. (Note that real-time interface to a CTD requires proper configuration of the LISST-200X's auxiliary connector; see "Configuring the LISST-200X as a Sensor for a CTD" on page 57.)

The quick estimates are based on weighted sum of the net scattered light. One set of weight factors yields the total volume concentration; the other yields the area concentration of particles. The volume/area ratio provides mean diameter, also known as the Sauter Mean Diameter (SMD). Notably, SMD can be quite different from D_{50} in broad or multi-modal size distribution situations. The SMD output is set to zero in very clear waters, i.e. when transmission is above 98%. In such clear waters, the SMD can become erratic. [*For an explanation of this method of SMD derivation, see: Shaped Focal Plane Detectors for Particle Concentration and Mean Size Observations*; Agrawal, Y.C. and O.A. Mikkelsen, (2009), Optics Express, v 17, n 25, pp 23066-23077].

Particle Shape Models – Spheres or Irregular Shape

The multi-angle scattering can be interpreted via inversion as arising from spherical particles, or from irregularly shaped particles. Provided software gives you the choice and the resulting PSD files are named differently to distinguish them. As to which particle model to use, we suggest that when working with natural waters, use the irregularly shaped model. Only in exceptional circumstances, the spherical model is appropriate.

B. LISST-200X General Description

Instrument Description

The LISST-200X is capable of autonomous operation when used with external battery packs. Windows software (compatible with Windows XP through Windows 10) is provided to program the instrument for a specific sampling schedule. The primary measurements delivered by the LISST-200X are the small-angle scattering properties of particles in water, the laser optical transmission, depth, and temperature. An Auxiliary port is available for that can be configured for recording data from an external device such as a turbidity or fluorometer or output summary data (mean size and total concentration) as analog voltages. For details of the possible configurations of the Auxiliary Port, see Appendix E: Connectors on page 93.

After recovery of the instrument, small-angle scattering data are off-loaded from the instrument and subsequently *inverted* mathematically on a computer to produce the particle size distribution. The inversion function is included in the Windows software. For MATLAB users, inversion scripts are available for download from Sequoia's website: www.SequoiaSci.com.

The LISST-200X instrument is a laser diffraction device. It consists of optics for producing a collimated laser beam, a specially constructed detector array, electronics for signal pre-amplification and processing, data storage and scheduling computer, and an external battery system.

The principal measurement—angular scattering distribution— is obtained over 36 ring-detectors whose radii increase logarithmically from 102 to 20,000 microns. The detector is placed in the focal plane of the receiving lens. The rings cover an angular range from 0.00085 to 0.34 radians. This angular range corresponds to size ranges from 1.00 to 500 µm. See Appendix B: Particle Size Bins on page 86 for more information.

The LISST-200X consists of the following parts: a solid-state diode laser operating at 670 nm wavelength and fiber-optically connected to a laser beam collimating system, a beam manipulation and orienting system, a two pressure windows, a scattered-light receiving lens, the custom designed 36-ring detector, preamplifier electronics, a ring-selecting multiplexer circuitry, and a data logger. All these components are inside the black-anodized pressure housing.

The LISST-200X does not have internal batteries and therefore should not need to be opened.

Data Storage and Interface

The LISST-200X includes high-capacity data logging and storage. The logging functions are programmed via the provided software. It can be programmed with different start and stop conditions as well as different sampling rates and average durations. The data logger stores the data in non-volatile Compact Flash memory which can be later downloaded and processed into size distributions and concentration using the provided software.

The data logger will also accept commands via the RS232 interfaces. These commands can be used to program the instrument or to exchange data with another instrument.

Depth and Temperature

In addition to measuring the particle size and concentration, the LISST-200X also has depth and temperature sensors. The depth sensor has a 1000 psi full-scale range[1]. The stainless steel fitting on the Connector endcap is used for testing this sensor, and keeps contamination such as salt and sediment out of the pressure sensor. The temperature is measured using a high precision thermistor imbedded into a stainless steel probe on the Connector end cap. Both values are stored automatically in the LISST-200X data file.

External I/O Port

The LISST-200X is also equipped with an external Auxiliary port which is available via a 6-pin connector in the endcap. This port can be configured in different ways by the user.

The Standard Configuration has one analog input and two digital inputs. The analog voltage on this input is recorded with the size distribution data. The digital inputs can be used to start and stop the instrument.

The Analog Input Configuration has two analog inputs and switched power which can be used to power the external sensor. Both analog voltages are stored with every size distribution.

The Analog Output Configuration allows the Mean Size and Total Concentration information to be output as analog voltages. The 6-pin connector is wired to match the SeaBird CTD Auxiliary Input. This allow the LISST-200X to obtain power from the CTD and output the mean size and total concentration in real time to the CTD while the detailed size distribution data is stored internally for later downloading.

The Auxiliary port can be reconfigured by the user by moving mechanical jumpers on the main circuit board inside the instrument. Contact Sequoia Scientific for instructions on how to access the jumper on the circuit board.

[1] A gauge pressure sensor is calibrated to measure the pressure relative to a given atmospheric pressure, as opposed to an absolute pressure sensor, which measures pressure relative to a vacuum. The pressure sensor on the LISST-200X will read 0 at atmospheric pressure.

Battery Life

The LISST-200X does not contain internal batteries (except a small battery to maintain the real-time clock), but can be powered from multiple sources including a USB computer cable, Small or Large Battery Packs (provided with the instrument) or an external instrument such as a CTD.

The standard Small Battery Pack supplied with the LISST-200X uses two NiMH rechargeable D-cell batteries and will provide about 12 hours of continuous sampling.

The Large Battery Pack contains 16 standard alkaline D-cells. For profiling applications, where the instrument is sampling continuously, the Large Battery Pack has about 200 hours of sampling time or 200 days of stand-by. Powering down the instrument between samples can greatly extend the deployment times. An Excel spreadsheet that can estimate the battery consumption is included with the software on the Ship Disk you received with your instrument. The spreadsheet can also be downloaded from www.sequoiasci.com/product/lisst-200x, click Library, then Downloads, then LISST-200X.

For laboratory or tethered usage, power can be supplied through the communications connector on the endcap. A 2-meter USB cable is provided that will power the instrument from the computers USB port. No additional power is required to operate the instrument.

Cables up to 50 meters can be provided to supply external power and communication with the instrument. This can allow real-time observation of the size distributions.

Included Accessories

The instrument is shipped pre-aligned and tested. A small chamber is provided for obtaining measurements of background scattered light from optical surfaces. This background is subtracted from actual particle scattering measurements to obtain the true particulate scattering. Additionally, small tools used to open endcaps, spare batteries, and communication cable is supplied so that a user need only provide a PC running Windows.

For extended laboratory applications various chambers are available from Sequoia.

Software is provided to communicate with the instrument, schedule an experiment, offload the data, and invert the measurements to obtain particle size distribution and volume concentration. For laboratory use or for monitoring the progress of an experiment, the software can be used for real-time processing.

C. LISST-200X Quick Start Tutorial

This section gives step by step instructions to unpack your LISST-200X, load software, and acquire data in the lab. For more detailed instructions on specific steps, background on how the instrument works, or specific technical information such as cable pinouts please refer to the full User's manual following this Quick Start Tutorial.

Contents of Shipping Case

Let's assume that you are opening the LISST-200X shipping case for the first time. Inside you will find the following:

- User's Manual,
- USB memory card (credit card size) with the software,
- LISST-200X instrument,
- Plastic Instrument stands,
- Small Volume Test Chamber,
- USB Communications cable,
- Insulated stainless steel clamps,
- Small Battery Pack (without batteries),
- Larger Battery Pack with alkaline batteries installed,
- LISST-200X-to-Battery Pack cable,
- NiMH batteries and charger.

Step 1: Remove Instrument from Shipping Case.

Start by removing the white plastic instrument stands and set them on a flat working surface. Remove the LISST-200X from the case and set it on the stands. The LISST-200X has two distinct ends that we will refer to as the Optics endcap and the Connector endcap.

Optics Endcap

The optics endcap contains the optical windows that the laser beam passes through to make a measurement. The internal optics and laser electronics are mounted to the inside of this endcap.

Connector Endcap

The connector endcap has three underwater connectors that are used for communication, external power, and connecting to optional accessories or instruments:

3-pin connector: Used for BioBlock, an anti-biofouling accessory

5-pin connector: Used for serial communication and external power.

6-pin connector: Used for analog in/out and digital in/out signals.

See Appendix E for a full description of the wiring of the underwater connectors and mating cables.

A temperature sensor is located between the 3-pin and 6-pin connectors. In the center of the endcap is an LED that blinks when the instrument is sampling. The stainless steel fitting with small tube is the port for the depth sensor. This fitting can be removed to allow the port to be cleaned should sediment or salt deposit build up.

Also on the Connector endcap is a white plastic lever. This mechanical lever has a strong magnet embedded in the plastic. This magnet can be used to trigger a digital switch inside the instrument which can be programmed to start and stop the LISST-200X sampling.

The final item on the endcap is the zinc anode. The sacrificial zinc anode protects the instrument from corrosion during long periods of time in salt water.

Step 2: Check for Clean Windows

At this time, check the optical windows to make sure that they are clean. There are two windows: The receive window (or large window) and the transmit window (or small window). Both window need to be very clean in order to get good measurements.

The best way to check the windows is by using a flashlight. By shining light from one side and viewing from the other the surface of the windows can be easily checked for cleanliness.

If there is dirt or fingerprints on the windows clean them first by rinsing them with lukewarm water and a mild soap solution (e.g. mild hand soap, liquid dish soap) and then rinsing off all soap residue with clean, particle free water such as deionized water, distilled water or bottled drinking water. The windows can also be wiped clean with a soft cloth (e.g. a lens cloth) or glass cleaner. It is not recommended to use stronger solvents, such as acetone or toluene. Also, do not use any abrasive cleaners or wipes. Treat the windows as you would an expensive camera lens.

Step 3: Attach Communication and Power Cable

Remove the Communications cable from the plastic accessory case within the shipping case. It is the 3 meter cable with the USB connector on one end and the 5-pin underwater connector on the other. Remove the underwater cap from the Communications connector. The connectors will all look similar when the protective cap is installed. The Communication connector is the only 5-pin connector and is located next to the stainless steel pressure sensor fitting. After removing the cap install the cable making sure that proper alignment of the cable is maintained, so that the connector pins are not bent. Plug the USB cable into the computer. Please note that USB drivers may automatically install the first time the USB cable is plugged into the computer. If the driver installed correctly, you should see the green light on the USB cable blinking. For more information on establishing and troubleshooting communication with the LISST-200X see the Step-by-Step guide on page 29 of the User's Manual.

Step 4: Install the Horizontal test chamber

Remove the Small Volume Horizontal test chamber from the Accessory Case if it is not already installed on to the instrument. This one-piece chamber is designed to slip between the optical windows of the instrument such that the space between the windows can be filled with water for testing or calibration.

We can now fill the chamber with clean, particle-free water. Sequoia uses steam-distilled bottled water filtered through a 0.2 micron filter. Tap water may contain too many particles and may also contain dissolved gas that can release and form small bubbles on the optical surfaces. Pressurized filtered water can also contain dissolved gas. Often the best source of clean water is bottled drinking water.

Step 5: Install LISST-200X Software

At this point the instrument is ready to go. We now need to install the software that is required for operation of the instrument. A USB memory card the size of a credit card is included with each instrument. In addition to the communication and processing program the disk also contains digital copies of this manual and other support files. Insert the memory card into a USB port on your PC to install the software. You must install the software on a computer running Windows XP or later (it is not compatible with Mac or Linux operating systems).

On the memory card you will find the 'LISST-200X_Installer.exe.' Double click the installer executable to begin installing the software. Follow the onscreen instructions and the installer will transfer the necessary files to your computer and place a shortcut on your desktop and start menu. Do not remove the memory card from your computer until the installation is fully completed.

Please note the following with respect to the LISST-200X software:

- On a 64-bit Windows PC, the software will be installed in the following folder: C:\Program Files (x86)\Sequoia\LISST200X, while on 32-bit Windows machines, the install folder will be C:\Program Files\Sequoia\LISST200X
- The LISST-200X software **WILL NOT** work with the older LISST-100 or LISST-100X instruments. It is NOT possible to use the program to offload data from a LISST-100 or LISST-100X instrument, only a LISST-200X will work with this software.

Step 6: Start LISST-200X Application

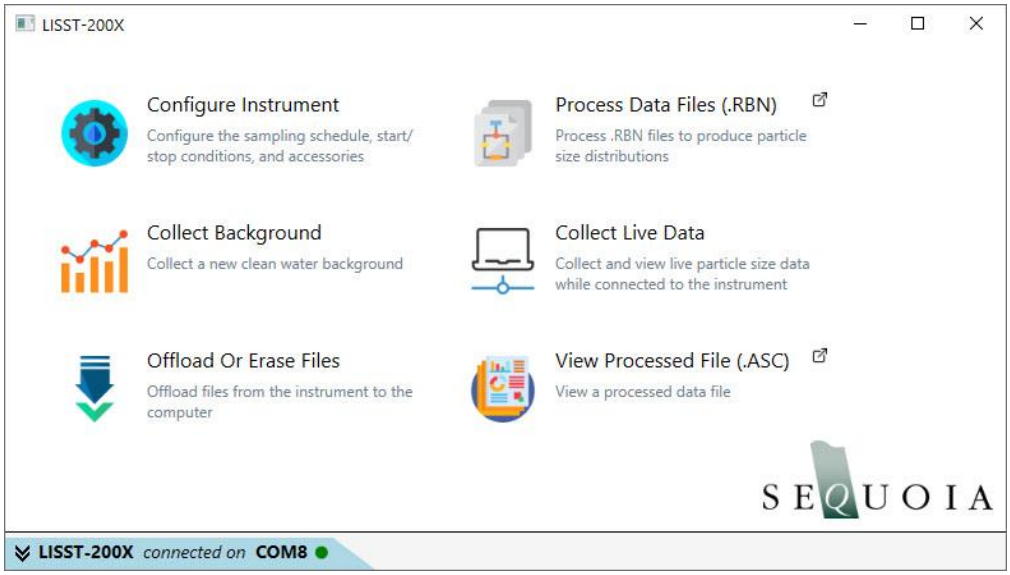
Start the LISST-200X software by selecting the shortcut the installer placed on your desktop.

Step 7: Establish Communication with the LISST-200X

The LISST-200X does not have an internal battery. Power is supplied to the instrument via a battery pack or USB cable. Please note that the LISST-200X USB cable has a USB-to-serial convertor and special power supply that converts the +5V to +11V to run the instrument built into cable. When using this cable no other power source is required.

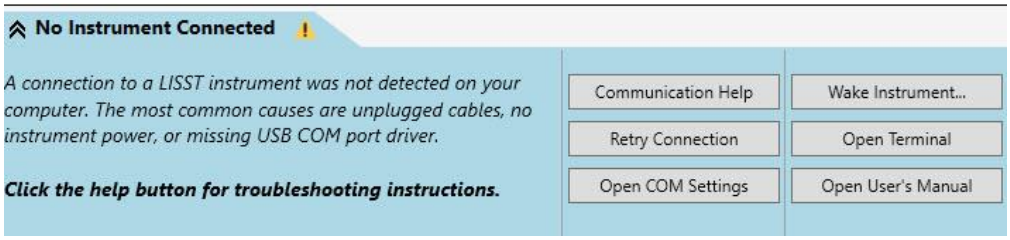
Power can also be provided by the Small and Large External Battery Packs or another external power source such as a CTD. When using an external battery the serial communication passes through the battery pack. However, the power from the USB is not used power the instrument. Power will be drawn from the battery only.

The LISST-200X software will automatically detect and connect to a LISST-200X instrument if it is connected to the computer.



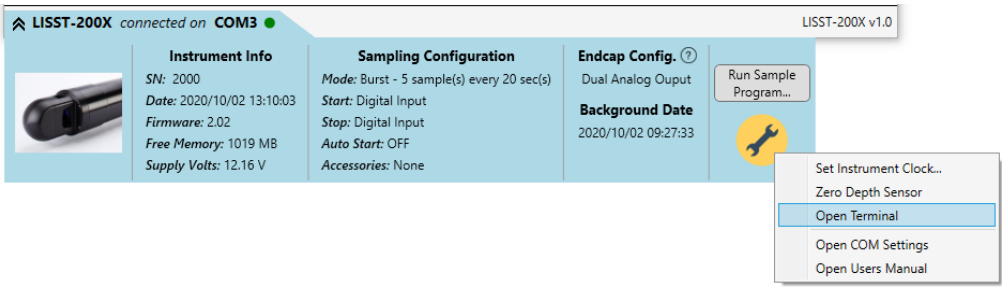
If an instrument is found, it will display ‘Connected’ in the lower left corner.

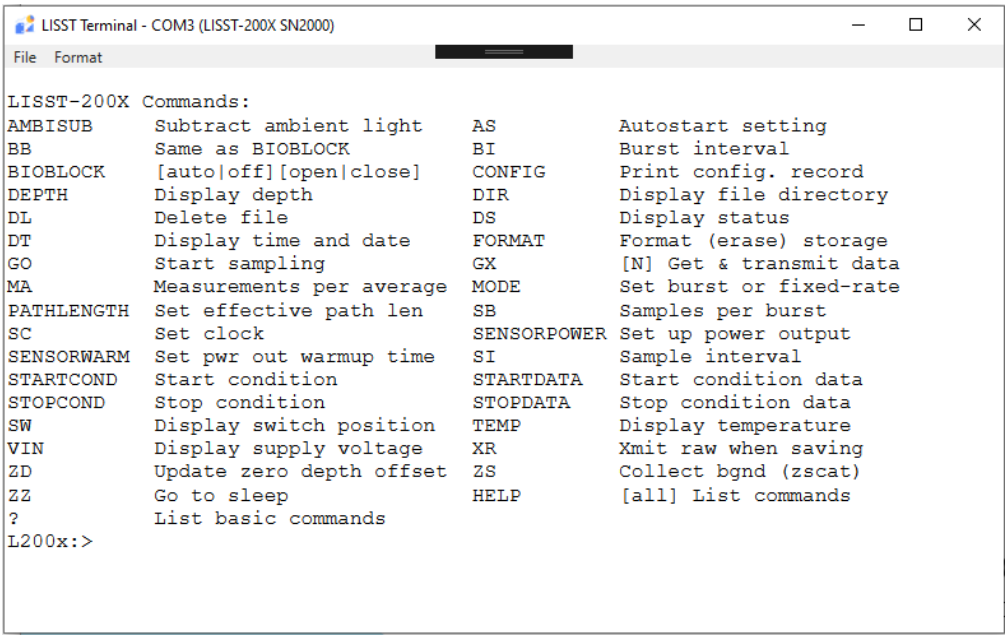
If your instrument is connected to the computer, but not found by the software, click on the ‘No Instrument Connected’ message to see list of options. Click on the ‘Communication Help’ button for troubleshooting help.



Step 8: Open Terminal window

The LISST-200X software has a terminal window that allows the user to communicate directly with the instrument using a set of commands. To open the Terminal window click on the connected instrument message in the lower left, then click on the wrench icon and select 'Open Terminal'



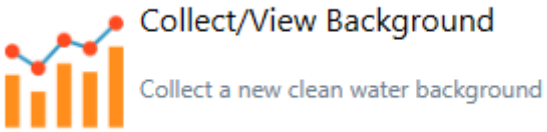


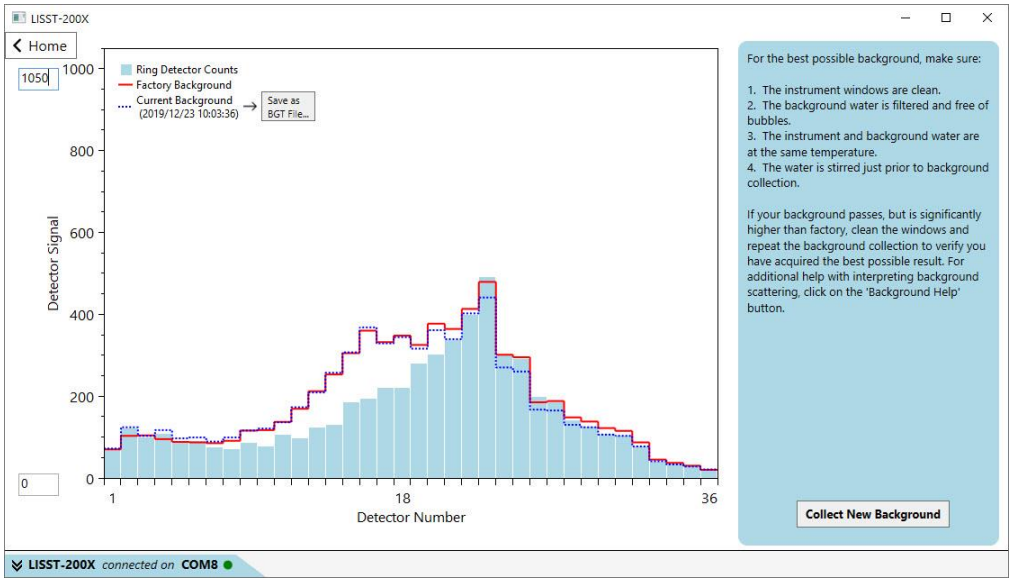
A command can be typed into the box in the lower section of the window. When the Enter key is pressed the command will be sent to the instrument. A list of the commands that can be sent to the LISST-200X is displayed when the terminal opens or they can also be found in the section LISST-200X Command Summary on page 62.

Step 9: Acquiring Clean Water Background Measurement

The background scattering measurement is critical to good instrument performance. It is especially critical for clean water applications where the optical transmission is greater than 90% over the 2.5cm path. The background scattering will also check the overall health of the instrument. It will verify that all of the systems are functioning and that

the optics is still in alignment. The current background will be acquired and displayed relative to the factory background scattering and the most recently saved background that is stored on the instrument. The image below shows an example of this display. It is opened by selecting the *Collect/View Background* button.





The factory background file will be automatically acquired from the instrument and displayed as a red line on the screen. The ‘Current Background’ is the last background that was collected and saved on the instrument (the date of collection is displayed in the legend). Tips for collecting a background are also displayed on the screen. Pressing the ‘Background Help’ button will open a PDF with additional information about background measurements. When the *Collect New Background* button is pressed, 20 samples will be collecting. The average of these measurements will be displayed as a black line on the screen.

The graph shows the value of the 36 light scattering detectors. The red line is the factory values, the black line is the average of all 20 measurements. If the background is close to factory levels the message displayed will indicate a pass or acceptable background.

If the water or windows are not clean or if there is a problem with the instrument, error messages and suggested actions will be displayed. Dirty water or windows will generally cause higher values across the middle rings. Large bubbles or particles in the water can cause higher values on the inner rings or left hand side of the display. High values on the inner rings combined with a lower transmitted laser power value can also be an indication of optical misalignment.

If needed you can update the background, such as after cleaning the windows or replacing the water, by pressing the *Collect New Background* button again.

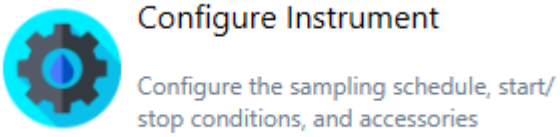
In general, the lower the background values the better the background. The goal is to get values that are at the same values as factory line. However, as the instrument is used the background may increase due to small scratches and slight alignment changes. It may not be possible to get the background down to the original factory values.

If the values are acceptable the values can be saved both onboard the instrument and to a file on your computer. The LISST-200X handles the background files differently than the LISST-100X. The background file is stored on the instrument and is saved as part of every data file that is recorded. When processing a data file the background will be automatically extracted and used during processing. Saving, tracking and selecting a background file to use for processing is no longer required. The background stored on the instrument will continue to be saved in new data files until a new background is recorded.

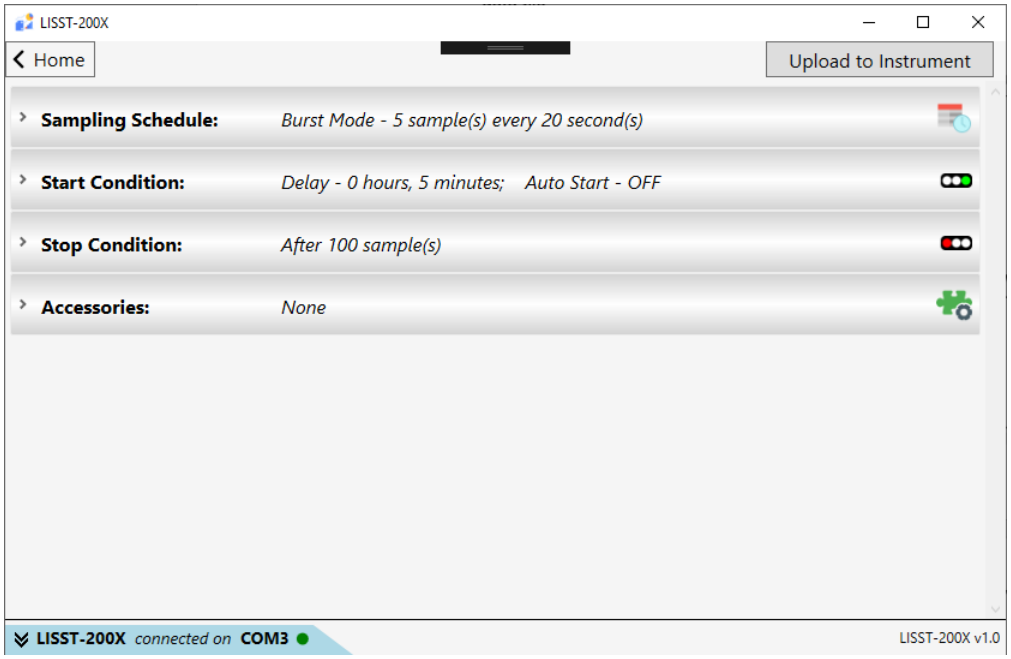
If you wish to store a background file on your computer as well as on the instrument, click the 'Save as .BGT file' after you have accepted and saved the background. It is not necessary to store the background on your computer, however, these saved backgrounds can be used during processing instead of the background saved in the data file.

Step 10: Configuring Instrument for Deployment

The Configure Instrument window is used to configure the deployment parameters. To open the window, choose *Configure Instrument* from the home page.



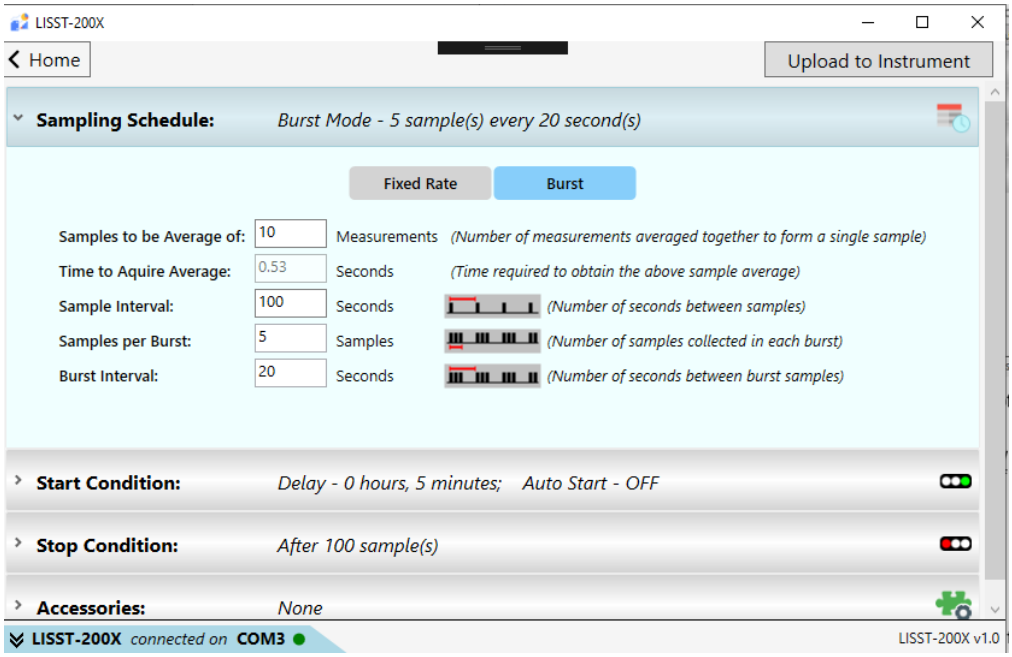
A window similar to the one shown below will appear. The window has four accordion style tabs: Sampling Schedule, Start Condition, Stop Condition, and Accessories.



With the accordion tabs collapsed, the page shows a summary of the instrument's current configuration.

Step 11: Setting Operating Mode

By selecting the *Sampling Schedule* Tab at the top of the main window the screen below appears. This screen is used to set the type of sampling; Fixed Sample Rate or Burst. You can also select the samples per average and sample rates on this screen.



Burst and Fixed Rate Modes

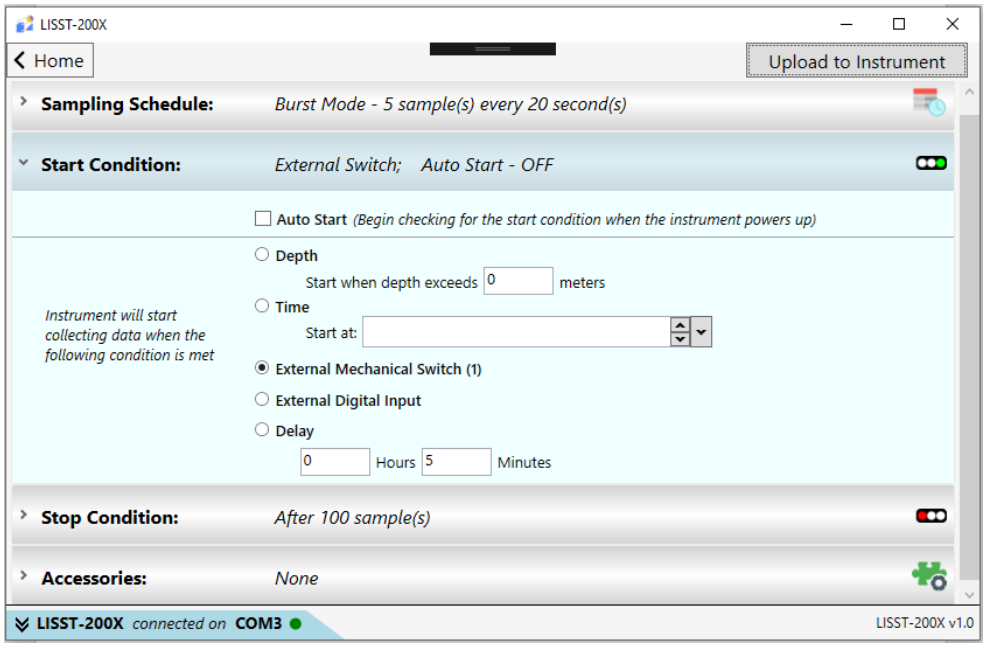
The Burst and Fixed Sample Rate modes are used to save data to a raw data file on board the instrument. The icons next to the various values give a better understanding of their meaning. The software automatically checks the values entered to make sure that there is no

conflict. For example, when a 'Sample to be Average of' value is entered, the minimum sample interval is computed. If this value is less than the minimum permitted the value will be changed to the minimum and the text will turn red.

The LISST-200X measures internally at ~20 Hz, but the data cannot be stored to the data logger at this rate. The individual measurements are averaged into a sample, and it is this sample average that is stored at a maximum sample rate of 1 Hz. For the example shown above, the instrument is set to sample in the Fixed Sample Rate mode at a 1 Hz rate with 10 measurements per average. This average is obtained in 0.53 seconds.

Step 12: Setting Start Conditions

After selecting the sampling schedule, the start and stop conditions can be selected. Choose the *Start Condition* tab.



There are five options: Depth, Time, External Mechanical Switch, External Digital Input, and Time Delay. Select the mode by clicking on the button next to its label. Select the correct parameters as required. For this example let's select the External Mechanical Switch Start Condition.

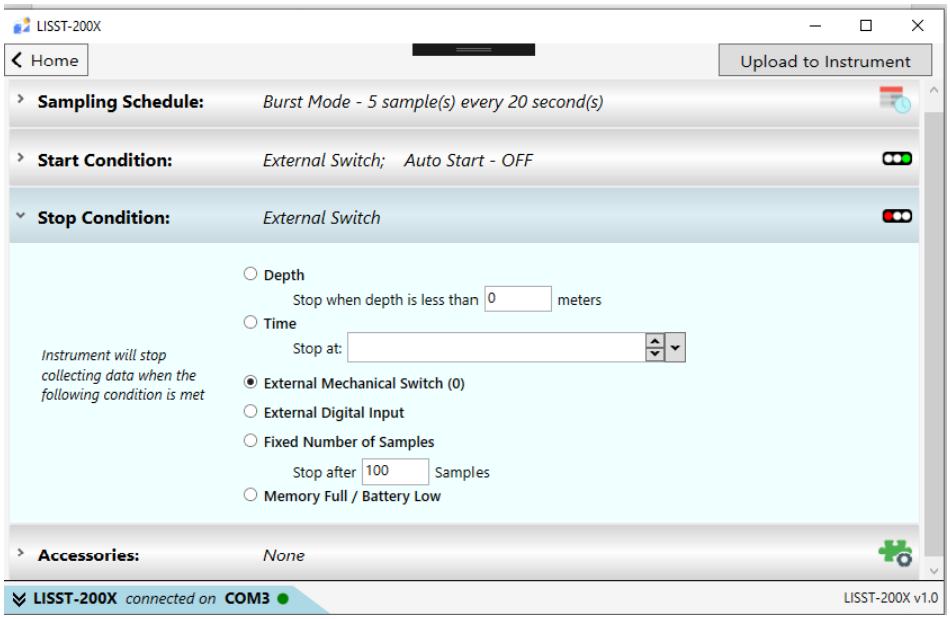
AutoStart

If the AutoStart check box is selected, the LISST-200X will start the sampling program when power is applied to the instrument. If this is not selected the user must select the 'Run Sample Program' button from the instrument status bar or send the 'GO' command to start the sampling programing after applying power.

NOTE: AutoStart will not occur if the power is connected to LISST-200X in low power sleep mode.

Step 13: Setting Stop Conditions

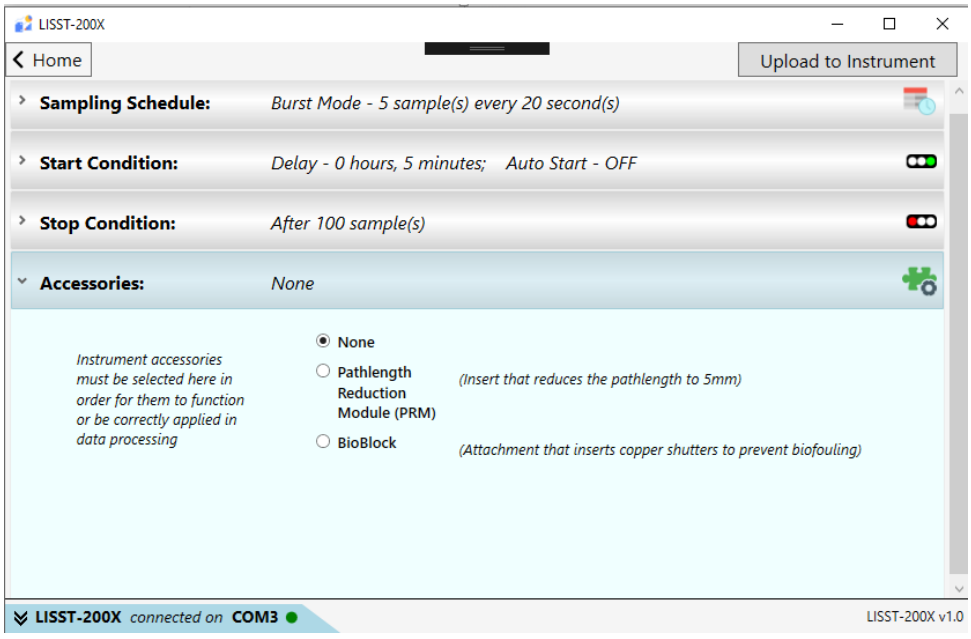
Similarly the Stop conditions can also be selected. Click on the *Stop Condition* Tab to open the Stop Condition window. The available stop conditions are: Depth, Time. External Mechanical Switch, External Digital Input, Fixed number of Samples, and Memory Full (<less than 6.5 V).



For this example, choose the External Mechanical Switch as the Stop condition.

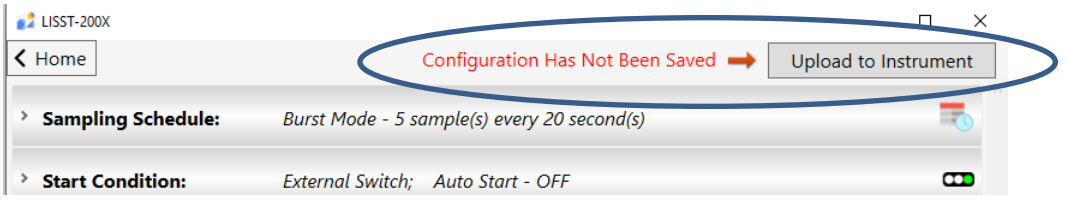
Step 14: Configure Accessories

The accessories tab allows you to select which LISST-200X accessories are connected to the instrument. The accessories must be selected here for them to function properly. If there are no accessories, select 'None'.

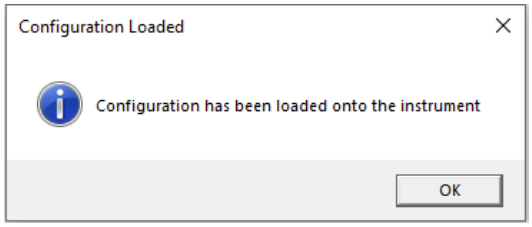


Step 15: Upload Configuration to Instrument

After configuring the instrument settings, they must be uploaded to the instrument. A message will be displayed on the top of the screen when you have unsaved changes to the instrument configuration



Click on the 'Upload to Instrument' button to load the configuration onto the LISST-200X. A confirmation message will be displayed when the upload is finished.

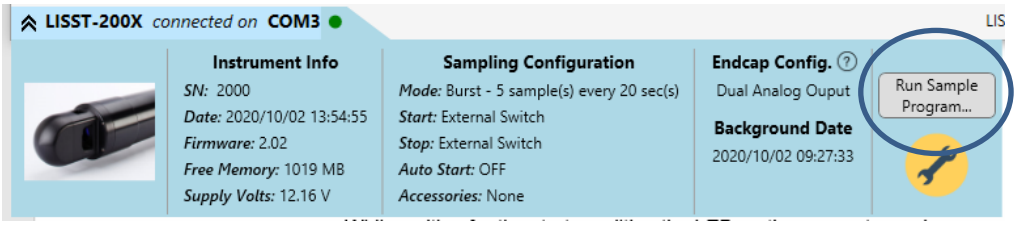


Step 16: Start Instrument

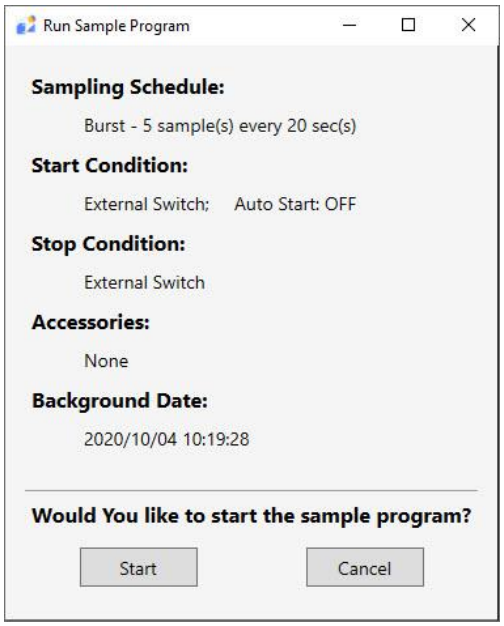
The instrument is now configured for deployment, **however, it is not yet running**.

You MUST start the instrument in order to start the samping program you just configured. If you do not do that, the LISST will never start sampling or react to the start and stop conditions.

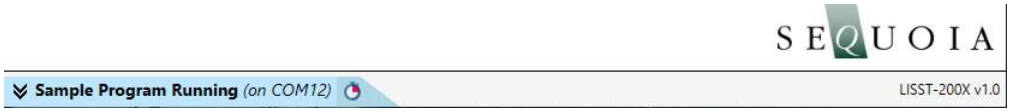
To start the sampling program. Click on the 'Run Sample Program…' button in the instrument status bar.



You will be asked to confirm your sampling program, start/stop conditions, accessories, and background date.



If the sampling program is started. You will see the status bar change to 'Sample Program Running.' At this point the user will know that the instrument is running and is ready to be deployed.



Note that starting the instrument is not necessarily the same as starting sampling (unless you have a delay start of 0 minutes set as your start condition). For example, if you have selected the mechanical switch as the start condition, the instrument will only react to the swtich after the sampling program has been started. Only then will actual sampling begin.

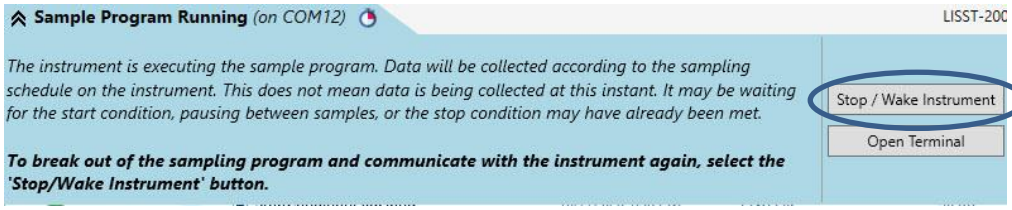
While waiting for the start condition the LED on the connector endcap will double blink every few seconds to alert the user that the instrument is running but not yet sampling. During sampling the LED will illuminate during the actual measurement of an averaged sample. For example if the sampling is set for 1 Hz sampling with measurements per average set to 20 then the LED will blink once per second. If settings are set for a 30 second average every 15 minutes then the LED will illuminate for 30 seconds every 15 minutes.

Step 17: Collecting Data

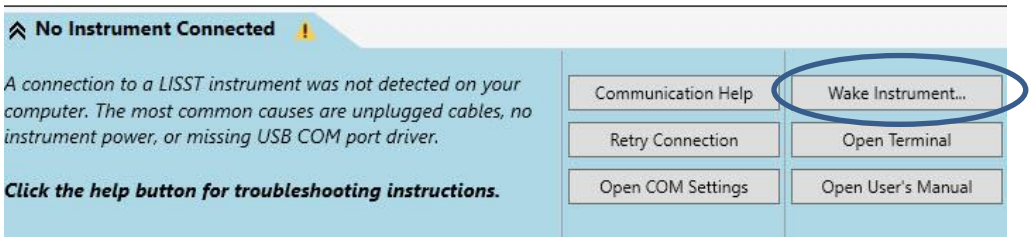
For our example we can move the white plastic lever on the endcap to the "1" position. Sampling will start. Data collection will continue until the Stop Conditions are met. In our case, until the switch lever is returned to the "0" position.

If the Start and Stop Conditions are set to Depth, External Mechanical Switch, or External Digital Input the program will return to checking for the Start Condition. This will only be true if the Start and Stop conditions match. For example, Depth Start and Depth Stop. For non-matching Start and Stop Conditions, such as fixed number of samples or Time Stop, the program will terminate and the instrument will go into a low power sleep mode.

To stop a running program, or wake it from low power sleep mode, use the 'Stop / Wake Instrument' button from the status bar.

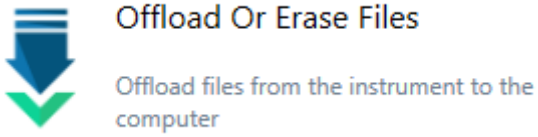


Note that the above options will only be available if you started the sample program from the software. If you plug in an instrument that is already executing a sampling program, you will need to manually wake the instrument by selecting the 'Wake Instrument…' button and selecting the COM port the instrument is connected to.

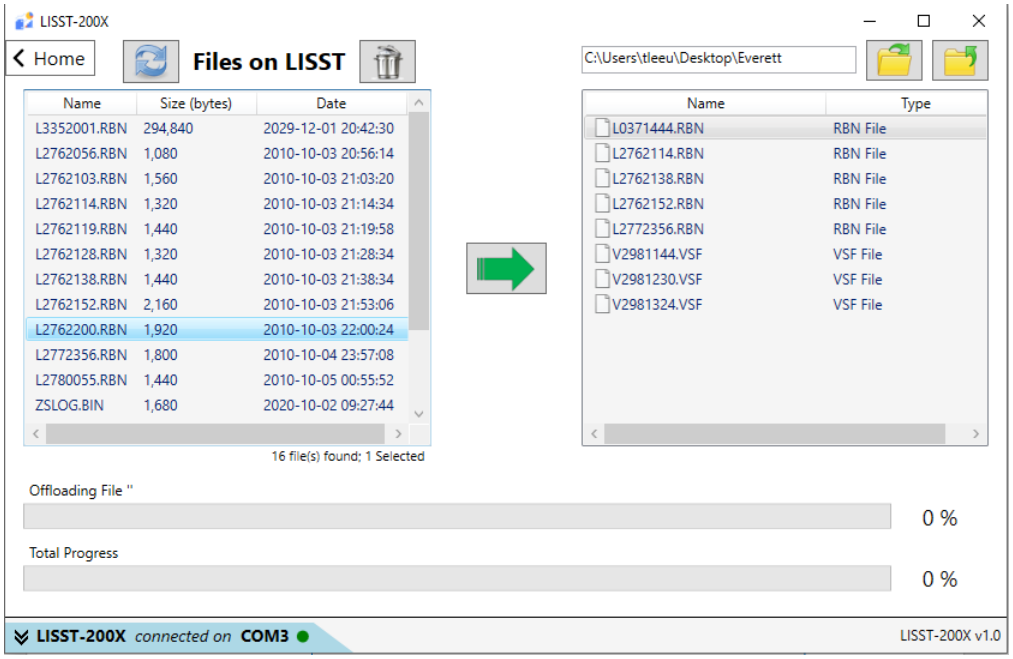


Step 18: Downloading Data

The instrument has now stored data in the on-board memory card. Select 'Offload Or Erase Files'. A list of files will appear:



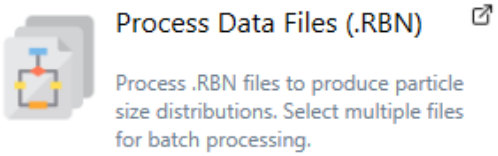
Choose the files to offload by clicking on them while holding down the CTRL key. The Shift key can also be used to select a range of files. Choose a location to offload the files to on the right side.



The files will be saved with names in the following format: L*dddhhmm*.RBN, where *ddd* is the day of the year, *hh* is the hour, and *mm* is the minute that the file was first written to. As the data is downloading a the status bars at the bottom will update. The data is offloaded at 115K baud.

Step 19: Processing Raw Data

We now have the data transferred from the instrument to the PC. To process the data file choose *Process Data Files* from the home page.

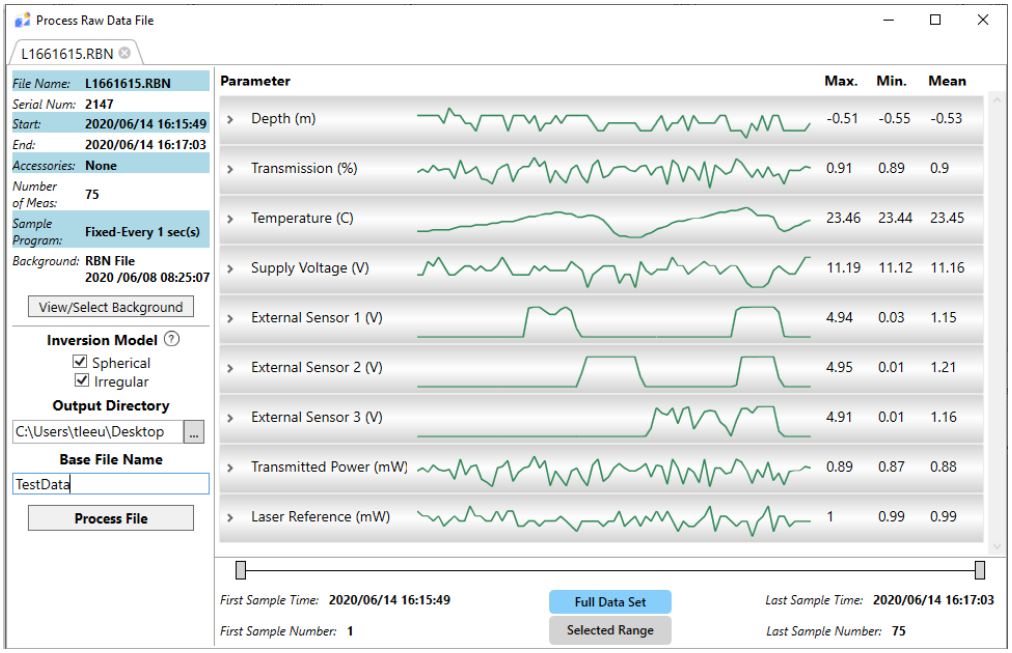


You will be prompted to select the raw data file to open (selecting multiple files will open up the batch processing window). Raw data files have the extension .RBN, and are offloaded directly from the LISST-200X data logger. Below is list of the file types you can expect to see when using the LISST-200X.

Extension	Discription	Format
.RBN	Raw Data	Binary
.RTX	Raw Data	ASCII
.CSV	Processed Data	ASCII
.BGT	Background File	ASCII

Every LISST-200X data file contains all the necessary information to process the file. Therefore, the software will automatically determine the instrument serial number, factory background, current background and other instrument specific parameters.

A raw data file display will be generated for your selected data file.

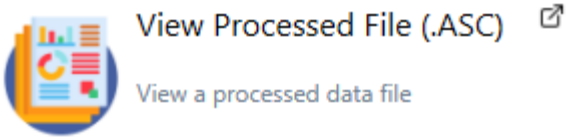


The range of samples to process can be selected by moving the sliders at the bottom of the display. This can be used to exclude data from the beginning or the end of the file. The default selection is to process the complete file.

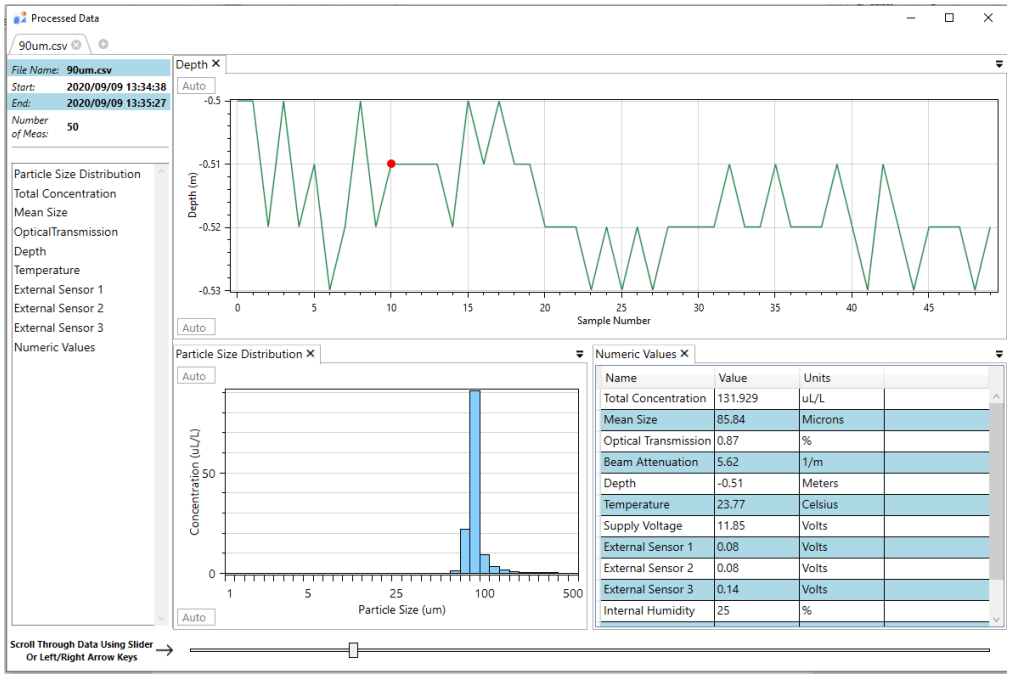
Select the output directory and choose a base file name. Press the *Process File* button to convert the raw file into processed size distributions. For more details on the available options when this window is open please see the detailed Instruction for Processing Raw data files. When the processing is complete a new tab will open, showing the processed results. You can navigate back to the raw data tab if you'd like to change the processing settings and process the data file again.

Step 20: Viewing Processed Results

Processed data files are stored as ASCII files (.CSV). When a raw file is processed the resulting .CSV file is displayed automatically. You can also open any LISST-200X .CSV file by selecting the View Process File button from the home page.



A display similar to the one below will open. A list of available parameters is displayed on the left. Clicking one of the parameters will open a new window where the parameter will be displayed. The parameter windows can be reorganized by dragging and dropping. The slider at the bottom is used to scroll through the data file. A red point on some graphs will indicate which sample is being displayed.

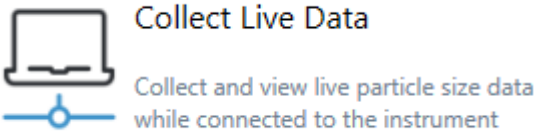


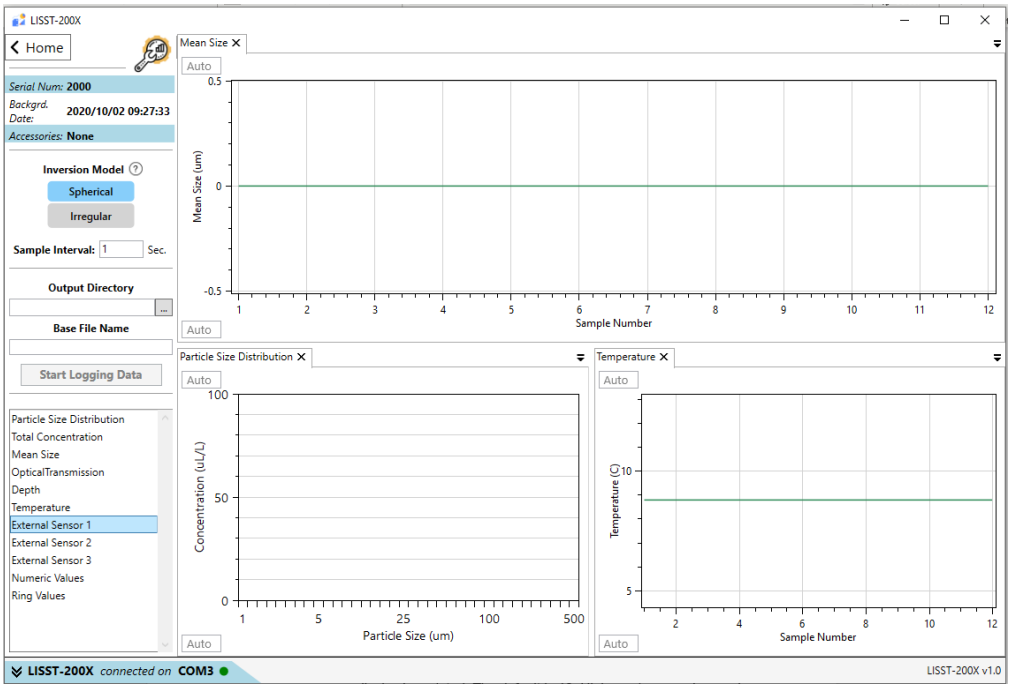
Step 21: Opening a Real Time Session

The LISST-200X software also supports the ability to acquire, process, and display size data it in real time. The Start and Stop conditions will not be used and therefore their settings are not relevant.

Before opening a real time session, you should collect a new background and store it onboard the instrument. The real time session will use the last background stored on the instrument to process the data in real time. Therefore, you must ensure the background on the instrument is up to date before continuing.

To open the Real-Time session, choose *Collect Live Data* from the home page.





Choose a location to save the data by filling out the output directory and the base file name. The sample interval can also be adjusted by entering the number of seconds between sample in the sample interval text box.

Even though data is displayed to the screen, it is not saved until you select the Start Logging Button.

The Spherical / Irregular Shape radio buttons can be selected in order to display the results as being processed under the assumption that the particles are spheres or randomly shaped (natural grains) particles.

Data using both models is saved and the buttons only represent what is displayed on the screen.

A list of available parameters is displayed on the left. Clicking one of the parameters will open a new window where the parameter will be displayed. The parameter windows can be reorganized by dragging and dropping.

Deploying the LISST-200X in the Field

The above steps should have given you a good understanding on the how to operate the LISST-200X. More details on all of the steps can be found in the User's Manual following this tutorial. The following steps go into deploying the instrument in the field.

Step 22: Preparing for Transport

The LISST-200X has been designed to be a robust field instrument. However, it is still a highly sensitive optical instrument and needs to be treated with care. This is especially true during shipping. The LISST-200X is shipped in a custom case with specially designed foam cushioning. Anytime the instrument is transported it should be in this

case. We highly recommend using air shipping when possible to eliminate the extended vibrations that ground shipping can cause.

Because the LISST-200X does not have an internal battery there is no need to worry about putting the instrument into low power sleep mode. You can simply disconnect it from the battery pack.

The Large External Battery Pack, which has alkaline batteries, can be stored for extended period when fresh batteries are installed.

The Small External Battery Pack, which has NiMH rechargeable batteries, should be opened and the batteries removed during transport. There are not restrictions on shipping NiMH batteries. However, the batteries will have a small drain when installed in the Small Battery housing. Therefore it is recommended that they be removed until the battery is ready to be used. The batteries should also be stored in a fully charged state.

The LISST-200X can be pre-programmed with the desired sampling program such as start and stop conditions and sampling rates. These settings will remain in non-volatile memory until power is applied. Therefore it is possible to prepare the instrument for sampling before shipping it out. It is even possible to program the instrument to automatically start upon power up. This is described in the next step.

Step 23: Configuring AutoStart

The LISST-200X can be configured to start running the sampling program upon power up. In some situations this ability can be quite helpful as you do not need to connect the instrument to the PC to start the sampling. The instrument can be preconfigured with the desired settings and the wait for the battery to be plugged in or external power from the CTD to be present before looking for the Start Condition.

To configure the LISST-200X to start its sampling program upon power up use the LISST-200X software or the configure auto start from the terminal window. If using the terminal window, use the AS command (short for Auto Start). The AS command can be issued when the 200X> prompt is displayed in the Terminal Window. When AutoStart is enabled a message will be displayed as part of the Status command or the Query instrument results.

When the LISST-200X is powered up a message will be displayed to the Terminal window (or via the RS232 interface) that will prompt the user that the instrument will auto start in 5 seconds. Pressing the stop key or sending two CTRL-C characters will stop the instrument from starting and return to the 200X> prompt.

Step 24: Connecting to External

The LISST-200X had the ability to connect to external sensors and instruments such as other dataloggers or CTDs through the 6-pin Auxiliary connector on the endcap. The details of using the Auxiliary connector can be found in the Step-by-Step instructions on page 56.

Sensors or Instruments

In short, the Auxiliary connector can be configured in one of four ways: 1) Analog and Digital inputs, 2) Dual Analog Inputs, 3) Dual Analog Outputs, or 4) Triple analog input. When using the Analog or Digital inputs it is possible to provide power to an external sensor. By default this power output is switched off. It will need to be enabled before power will be available. You can also configure the warmup time required for the sensor after power is applied before sampling will begin.

The Analog Output configuration sends out two analog voltages, Mean Size and Total Concentration. This summary information is updated each time data for the full size distributions is recorded. When using the Analog Output configuration power can be received through the Auxiliary connector. The wiring of the connector is designed to match the SeaBird CTD Auxiliary Input connector simplifying the connection.

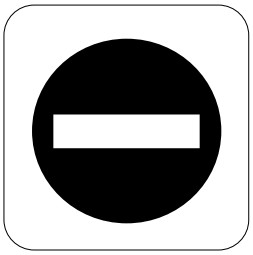
II. LISST-200X Operation Details

Section Organization

This section contains detailed instructions for performing various procedures. These are either in the form of step-by-step instructions or detailed descriptions of the various aspects of instrument operation (e.g. command list, instrument mounting and deployment).

General Precautions

- LISST-200X is a sensitive optical instrument - please handle it gently as you would handle a very expensive camera.
- Critical alignments may be disturbed if the instrument is subjected to shock or rough handling.
- Evidence of shock/rough handling will void the warranty.
- Whenever in transit, store the instrument in the provided padded shipping case.
- If placing the instrument vertically on the standoffs, be sure to do so gently as the Compact Flash Memory Card inside may otherwise come loose.



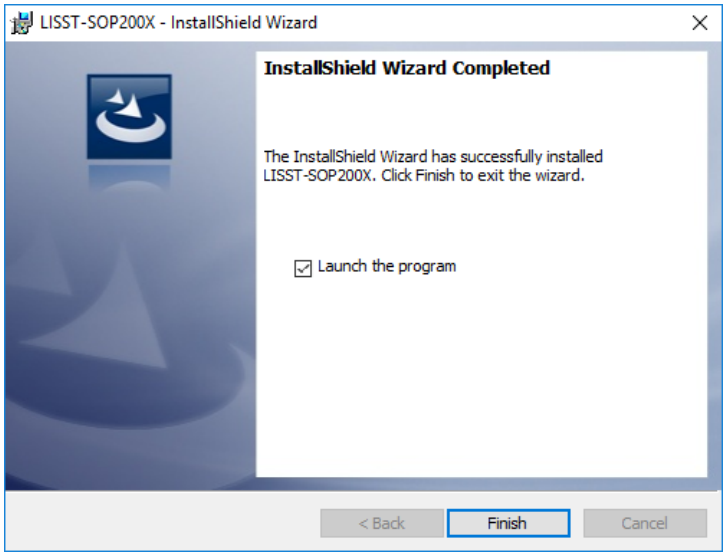
WARNING

The LISST-200X uses a laser diode emitting a maximum of 1 mW of visible (red) light at a wavelength of 670nm. The laser beam under normal circumstances is not a threat. However, if objects are placed in the path of the laser beam, the light could be reflected into the eye causing permanent damage.

D. Step by Step Procedures

1. Installing LISST-200X Software

Software for the PC is used to configure the LISST-200X and for downloading and processing the size distributions.

STEP	ACTION	RESULT
1	• The LISST-200X comes with a USB memory card. Plug the provided memory card into a USB port on your computer. Locate the 'LISST-200X_Installer.exe' executable on the memory card. Note that this software it is not compatible with Mac or Linux operating systems. Your operating system must be Window XP or newer to run the software.	Installer was found on LISST-200X memory card
2	• Double click the 'LISST-200X_Installer.exe.' Follow the onscreen instructions and the installer will transfer the necessary files to your computer and place a shortcut on your desktop and start menu. Do not remove the memory card from your computer until the installation is fully completed: 	Software installation complete

2. Establishing Communication with the LISST-200X

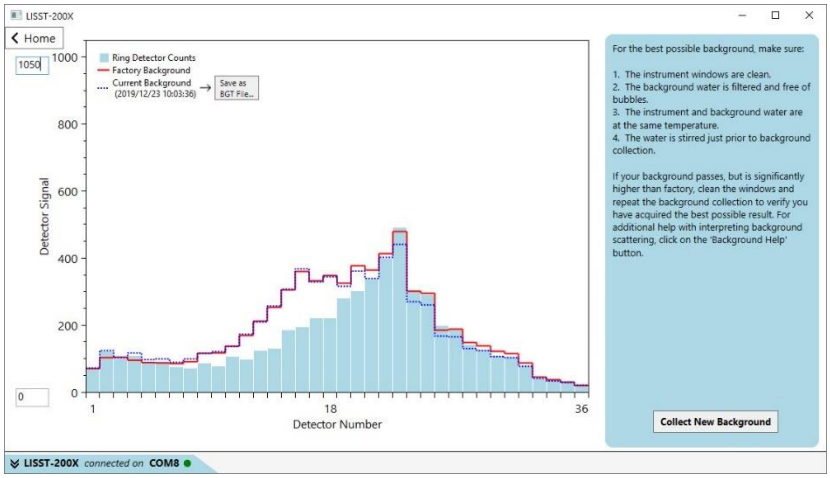
Establish communication with LISST-200X using the supplied software and USB cable. Communicating with the LISST-200X via the software should be automatic. Should there be a problem you can use these step-by-step instructions to troubleshoot the problem.

STEP	ACTION	RESULT
1	• If the LISST-200X software is open, close the program, then plug the USB communication cable from your computer.	LISST-200X will be powered on
2	• After plugging the USB cable back into your computer, the drivers for the USB to serial converter should install automatically. You should see a notification on the task bar that drivers are being installed. If you are unsure if the drivers installed, you can install the drivers manually by running 'CDM USB Drivers.exe', located on the memory card that came with your instrument.	Computer is now set up to communicate with the LISST-200X
3	• After the driver installation is compete, open the LISST-200X software.	Software appears onscreen
4	• The software should automatically search and locate your LISST-200X instrument among the serial ports on your computer • If no instrument is found you will see "No Instrument Connected" displayed in the lower left corner. • Try selecting the 'Retry Connection' button or try to wake the instrument using the 'Wake Instrument' button.	Software will attempt to automatically connect to the instrument
5	• If further troubleshooting is needed click on the 'Communication Help' button to explore the communication troubleshooting document.	Open Troubleshooting Document

3. Saving and Evaluating Clean Water Backgrounds

In order to properly compute the size distribution, it is necessary to remove the light scattering from the internal optics and window surfaces so that only the light scattering from the particles of interest are used to compute the size distribution.

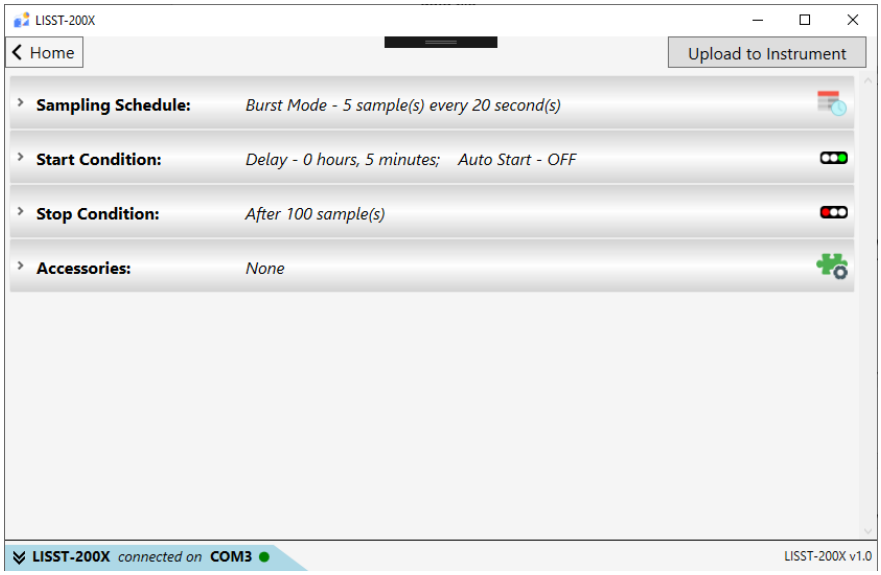
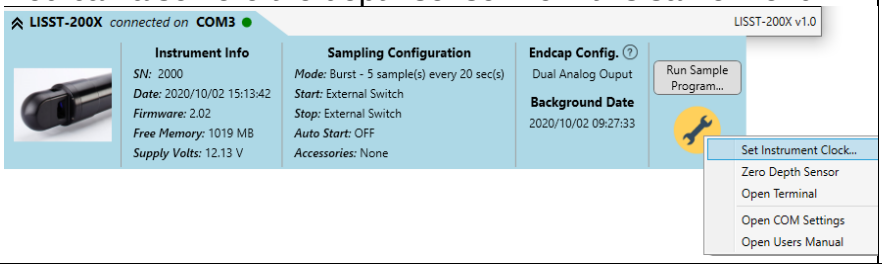
STEP	ACTION	RESULT
1	• Connect the instrument to the computer and establish communication in the LISST-200X program. (see Step-by-Step Procedure: Establishing Communication with the LISST-200X)	Software open and communicating with LISST-200X.
2	• Clean instrument and install Clean Water Background Test chamber. • Fill with clean filtered water and make sure no bubbles are in the water or on the windows. • The water and instrument should be at the same temperature. Using water a significantly different temperature from the water can impact the quality of the background. • Stir the water well before obtaining a background to make sure the water is well mixed. • For the best Background, make sure the instrument is clean; the water you use is filtered, and free of bubbles. Temperature fluctuations in water will seriously degrade the background. Use water at the same temperature as the instrument. Stir well.	Optics submerged in water
3	• Select *Collect/View Background* from the software home page. The factory background file will be automatically acquired from the instrument and displayed on the screen. • The current signal from the 36 ring detectors will also be displayed in real time. • When the *Collect New Background* button is pressed 20 samples will be collected and the average displayed to the screen.	Background collected and displayed on the screen

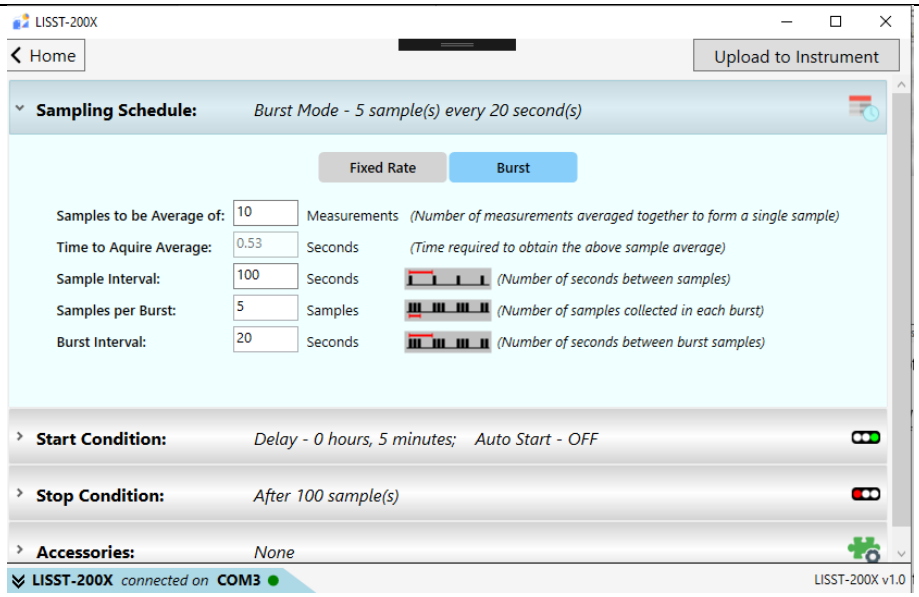
		
	• The graph shows the value of the 36 light scattering detectors. The red line is the factory values, the blue line current background saved on the instrument. A newly collected background will be displayed as a solid black line. If the background is close to factory levels the message displayed will indicate a pass or acceptable background. Even if your new background passes, but is significantly higher than factory, clean the windows and repeat to verify you have acquired the best possible result.	Acceptable Background
	• If the water or windows are not clean or if there is a problem with the instrument, error messages and suggested actions will be displayed. Dirty water or windows will generally cause higher values across the middle rings. Large bubbles or particles in the water can cause higher values on the inner rings or left hand side of the display. High values on the inner rings combined with a lower transmitted laser power value can also be an indication of optical misalignment. If needed you can update the background, such as after cleaning the windows or replacing the water, by pressing the *Collect New Background* button again.	Unacceptable Background

4	• In general, the lower the background values the better the background. The goal is to get values that are at the same values as factory line. However, as the instrument is used the background may increase due to small scratches and slight alignment changes. It may not be possible to get the background down to the original factory values. • Multiple cleanings or using better filtered water may be required to get the best possible background.	
	• When you have an acceptable background press the Save button to store the background on the instrument. You also have the option to save the background to a file on your computer. After the background is saved, select the 'Save as .BGT File' button. The LISST-200X handles the background files differently than the LISST-100X. The background file is stored on the instrument and is saved as part of every data file that is recorded. When processing a data file the background will be automatically extracted and used during processing. Saving, tracking and selecting a background file to use for processing is no longer required. The background stored on the instrument will continued to be saved in new data files until a new background is recorded.	Background Accepted and saved.

4. Configuring Data Collection

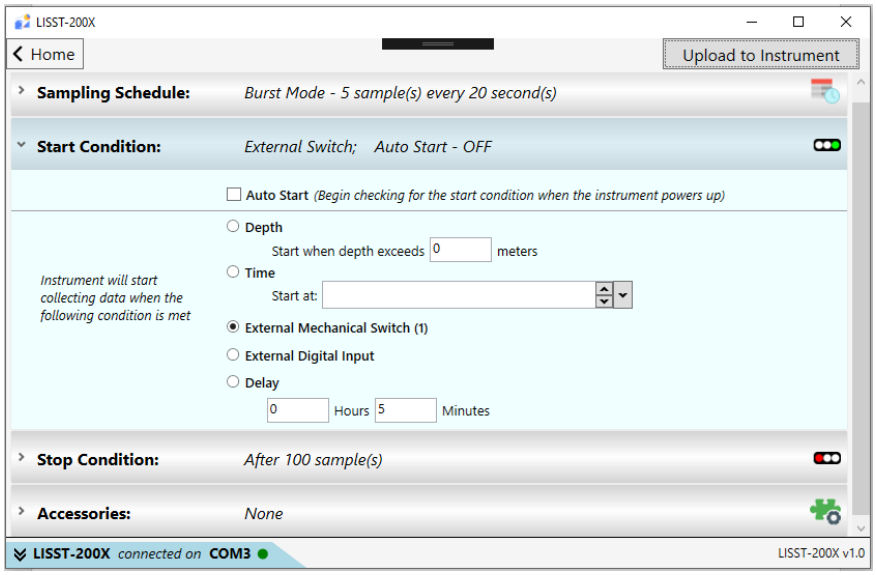
The LISST-200X software can be used to configure the Start and Stop Conditions, Fixed Rate or Burst sampling and sample rates.

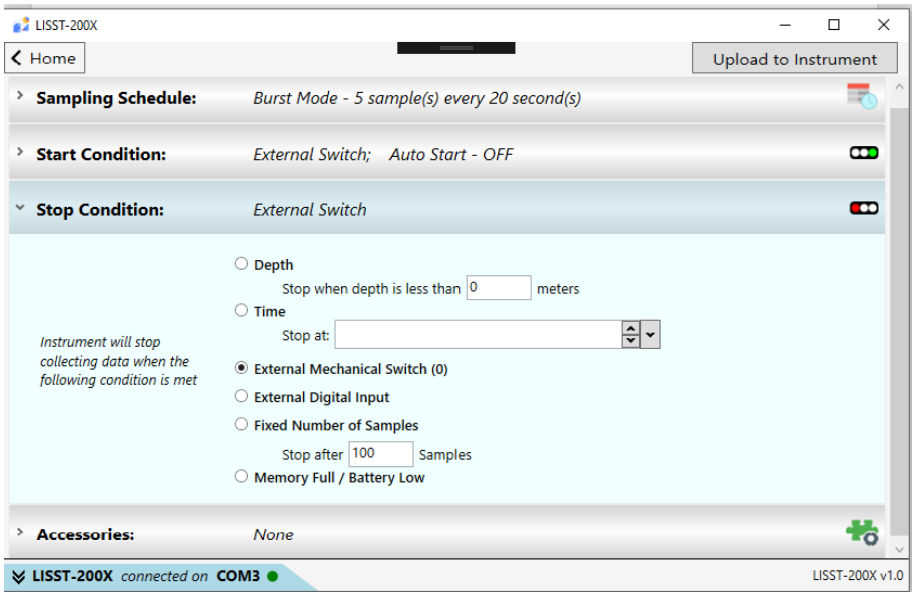
STEP	ACTION	RESULT
1	• Connect the instrument to the computer and establish communication in the LISST-200X program. (see Step-by-Step Procedure: Establishing Communication with the LISST-200X)	Software open and communicating with LISST-200X.
2	• Open the Sampling Programs window by choosing *Instrument Configuration* from the home page.  • To set the LISST-200X data logger clock to the computer clock, open the status bar, click the wrench icon, and select 'Set Instrument Clock'. • You can also zero the depth sensor from this same menu. 	Instrument Status Displayed. Clock set
3	• By selecting the *Sampling Schedule* Tab at the top of the main window the screen below appears. This screen is used to set the type of sampling: Fixed Rate or Burst. You can also select the samples per average and sample rates on this screen.	Operating Mode set

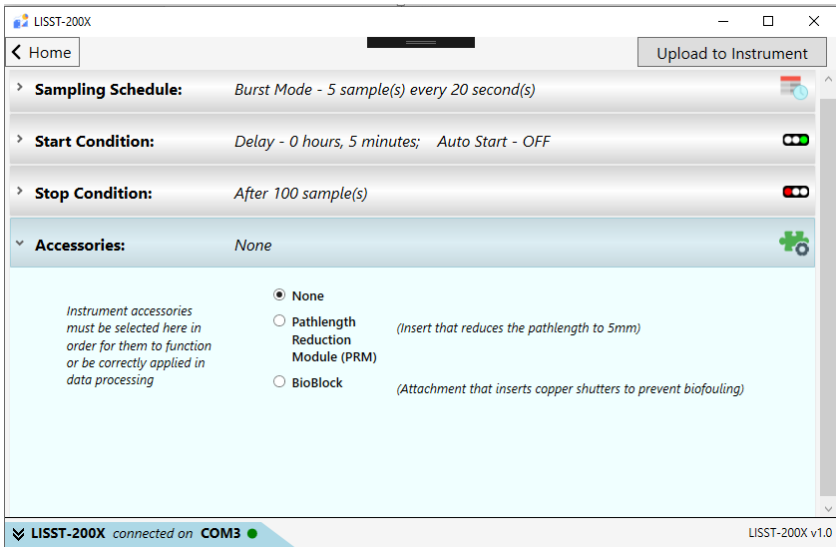
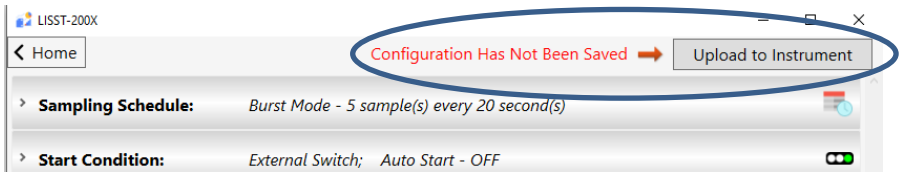
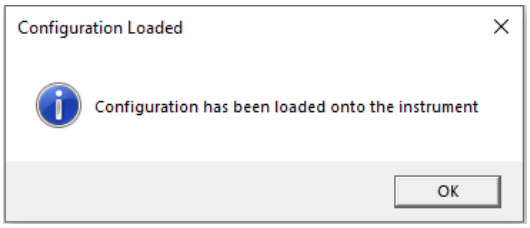


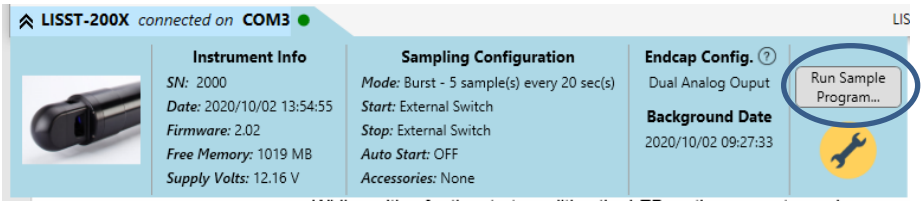
- The Burst and Fixed sample rate modes are used to set up a sampling program that will save data onboard the instrument. The icons next to the various values give a better understanding of their meaning. The software automatically checks the values entered to make sure that there is no conflict. For example, when a Samples per Average value is entered, the minimum sample interval is computed. If this value is less than the minimum permitted the value will be changed to the minimum and the text will turn red. A similar test is done on the Burst Interval setting.

4	• Select the Start Conditions tab to configure when the instrument will begin sampling. • There are five options: Depth, Time, External Mechanical Switch, External Digital Input, and Time Delay. Select the mode by clicking on the button next to the its label. Select the correct parameters as required.	Start Condition Set



	• If the AutoStart check box is selected, the LISST-200X will start the sampling program when power is applied to the instrument. If this is not selected the user must send the 'GO' command to start the sampling programing after apply power. • NOTE: Auto Start will not occur if the power is connected to LISST-200X in low power sleep mode.	
5	• Choose the Stop Conditions Tab to select the conditions when sampling should stop. • The available stop conditions are: Depth, Time. External Mechanical Switch, External Digital Input, Fixed number of samples, and Memory Full.  • If the Stop Condition is Depth, External Mechanical Switch, or External Digital Input and the Start Condition is also one of these three options the Base Program on the instrument will return to waiting for the Start condition. For example, if the start and stop conditions were set to External Mechanical Switch then multiple sampling sessions can be obtained by flipping the switch on and off. This is useful when doing profiles. It eliminates the need to communicate with the instrument between profiles.	Stop Condition Set

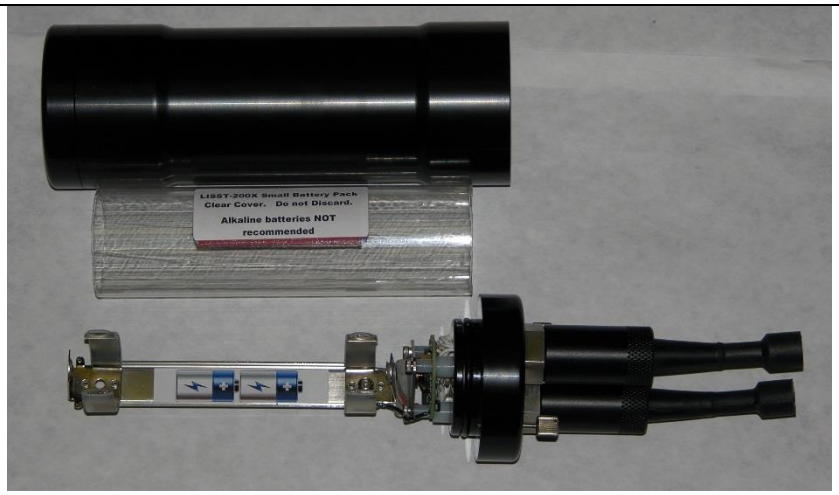
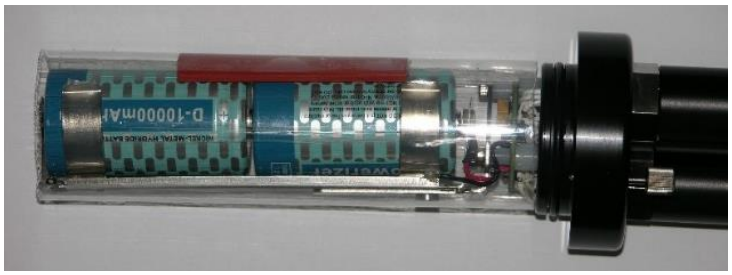
6	• Choose the Accessories tab to configure LISST-200X accessories. The accessories must be selected here in order for them to function properly. 	
7	After configuring the instrument settings, they must be uploaded onto the instrument. A message will be displayed on the top of the screen when you have unsaved changes to the instrument configuration  Click on the 'Upload to Instrument' button to load the configuration onto the LISST-200X. A confirmation message will be displayed when the upload is finished. 	Upload Configuration

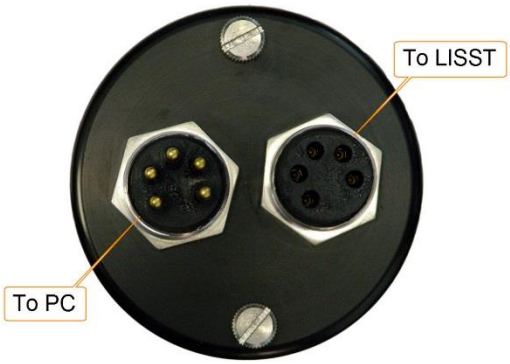
8	• The instrument is now configured for deployment, **however, the sampling program running**.  • You MUST start the sampling program in order to collect data. If you do not do that, the LISST will never start sampling or react to the start and stop conditions. • Note that starting the sampling program is not necessarily the same as starting sampling (unless you have a delay start of 0 minutes set as your start condition). For example, if you have selected the mechanical switch as the start condition, the instrument will only react to the swtich after the sampling program has been started. Only then will actual sampling begin. • When the instrument has been started, you will receive a confirmation message that the program has started, and the instrument will become disconnected from the computer. At this point the user will know that the instrument is running and is ready to be deployed.	Start Sampling Program

5. Using the Small External Battery Pack

The LISST-200X comes with a Small External Battery Pack that can be used for short term deployments. The instructions in this section describe how to use the Small Battery including installing and charging the NiMH rechargeable batteries.

STEP	ACTION	RESULT
1	• The LISST-200X Small External Battery Pack uses two rechargeable NiMH D-cell batteries. Four of the 1.5V 10000mAh batteries and a charger are included with the battery pack. The batteries are not installed when the instrument a new instrument is shipped. It is recommend that the batteries be removed from the battery housing when not in use. Leaving the batteries in the battery housing will cause the batteries to discharge and could cause damage to the cells. • Fully charge the batteries using the provided charger. Fully discharged batteries will take about 8 hours to charge. 	Batteries fully charged.
2	• The Small Battery housing is made of plastic and has an endcap with two underwater connectors and two captive thumbscrews on one end. • Loosen the thumbscrews. Note that the screws will not need to be fully removed. They are designed to be removed from the main housing but still remain attached to the endcap. The screws can be removed if you continue to rotate the screws through the threaded holes in the endcap. • Slide the endcap with battery holder attached out of the main housing.	Battery open and ready for batteries

		
3	• Slide the clear cover off of the battery holder and install the two D cell batteries. The orientation of the batteries is shown on a label on the battery holder.  • Slide the clear cover over the batteries such that the rubber pad is pushing against the batteries as shown in the picture above	Batteries installed.
4	• Check that the o-ring in the endcap and the mating surface on the main housing are clean. Lightly grease with silicone grease as needed. • Carefully insert the assembly back into the main housing until the o-ring makes contact with the housing. Align the thumbscrews with the holes in the main housing and push the endcap on until it is flush with the housing. • Tighten the thumbscrews by hand **(DO NOT USE ANY TOOL). DO NOT OVERTIGHTEN.**	Battery assembled and ready for use.

5	• The battery pack can be connected to the LISST-200X using the provided 5-pin Male to 5-pin Female cable. • Connect the Male end of the cable to the Female Bulkhead connector on the Small Battery Pack.  • Connect the other end of the cable to the 5-pin Male bulkhead on the LISST-200X. • Power is now going to the LISST-200X. If AutoStart is enabled the instrument may be looking for the start condition.	Instrument is powered and ready to collect data
6	• If desired connect the Communications cable to the male 5-pin bulkhead connector on the Small Battery Pack. Communications will pass through the battery to the LISST-200X. • The battery and communications cables are shown below. 	

6. Using the Large External Battery Pack

The Large External Battery Pack is used to provide power to the LISST-200X for long term deployments or extended profiling operations.

STEP	ACTION	RESULT
1	• The LISST-200X Large External Battery is shipped with 16 Alkaline D batteries pre-installed and is ready for use. The following steps describe how to open the battery and replace the batteries. Skip to Step X to connect the battery to the LISST-200X. • The new alkaline batteries can be left in the battery housing for storage. However, it is not recommended that fully discharged batteries be left in the battery housing during long term storage.	Battery ready to use when shipped.
2	• To access and replace the batteries in the Large Battery pack you will need remove the endcap with the connectors and handle.  • Remove the four 6-32 X ¾ long socket head cap screws from the connector endcap using the provided 7/64” ball driver. Remove the screws uniformly or hold the cap down against the light spring force.	Endcap ready for removal

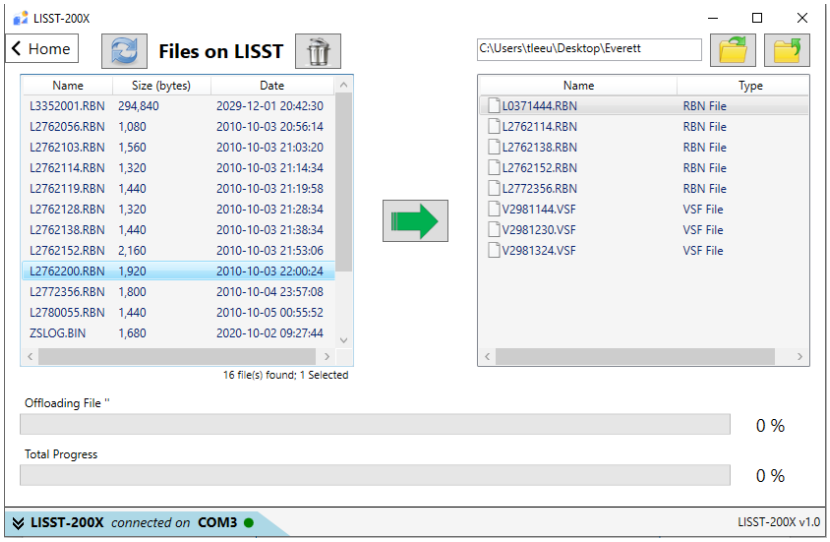
3	• Pull out the connector endcap. There are no wires or other connections. Set the endcap to the side.  • Remove the batteries making note of their orientation. • Insert the batteries into the pressure case. Labels on the inside surface of the center divider will guide you on the correct orientation of the batteries for each stack.	Endcap removed and batteries replaced.
4	• Inspect the o-ring on the endcap and the seating surface on the pressure case to make sure there is no debris that could affect the seal. Lightly grease the surfaces as needed. • Align the tab in the center of the endcap to the slot in the post in the center of the pressure case	Endcap re-installed
5	• Screw the connector endcap onto the pressure case with the four 6-32 x ¾ socket head cap screws. If necessary, apply anti-seize compound onto the threads.	Battery assembled and ready for use.

6	• The battery pack can be connected to the LISST-200X using the provided 5-pin Male to 5-pin Female cable. • Connect the Male end of the cable to the Female Bulkhead connector on the Large Battery Pack. The connector will be labeled with “TO LISST”.  • Connect the other end of the cable to the 5-pin Male bulkhead on the LISST-200X. • Power is now going to the LISST-200X. If AutoStart is enabled the instrument may be looking for the start condition.	Instrument is powered and ready to collect data

7	• If desired connect the Communications cable to the male 5-pin bulkhead connector on the Large Battery Pack which is labeled “TO PC”. Communications will pass through the battery to the LISST-200X. • The battery and communications cables are shown below. 	

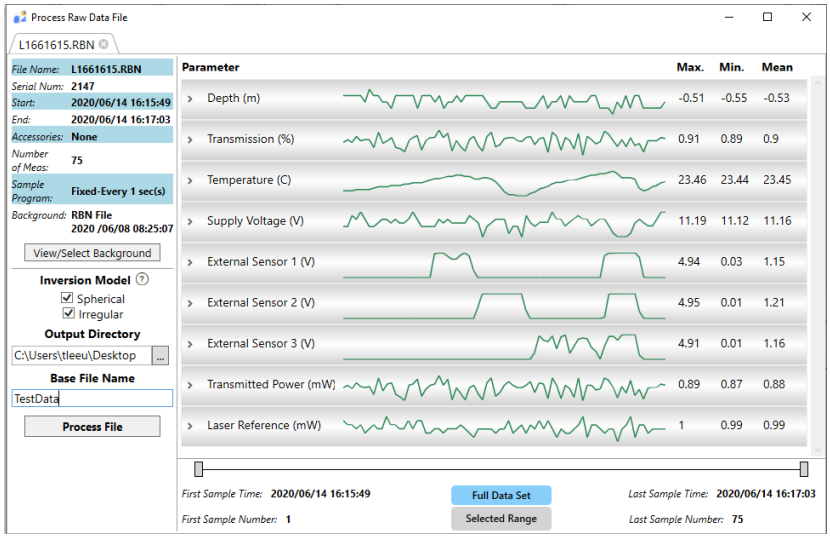
7. Offloading and Deleting Data Files from Internal Memory

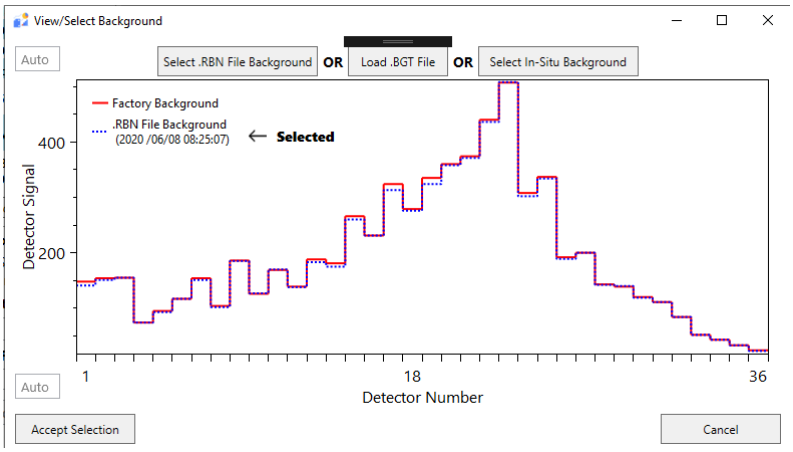
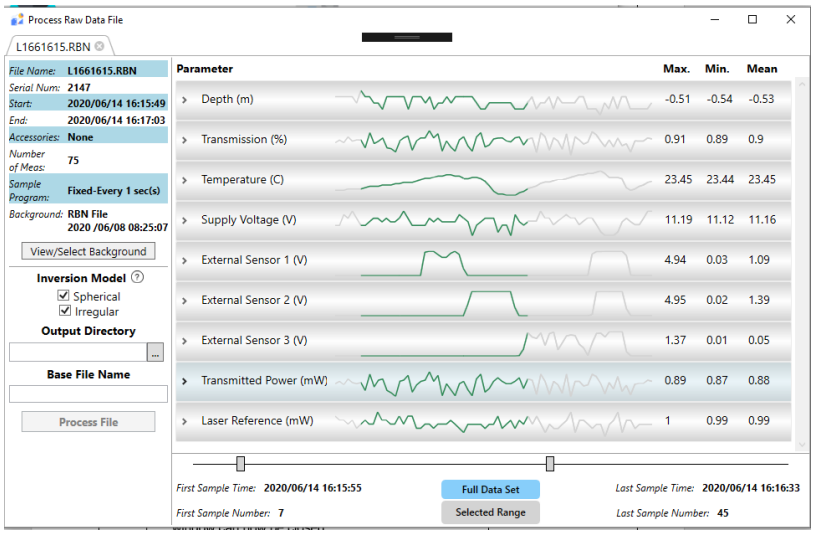
Data collected using the LISST-200X is stored on the internal data logger. This section describes how to offload and delete files from the internal data logger.

STEP	ACTION	RESULT
1	• Connect the instrument to the computer and establish communication in the LISST-200X program. (see Step-by-Step Procedure: Establishing Communication with the LISST-200X)	Software open and communicating with LISST-200X.
2	• Select *Offload Or Erase Files* from the home page. 	Shows a list of files currently stored onboard the instrument
3	• Select a directory to save the offloaded files on the right side. Select individual or multiple files on the LISST to delete or offload (by holding down either shift or ctrl). Press the green arrow.	Select files to delete or offload
4	• The progress bars at the bottom of the screen will update as files are offloaded or deleted	Files are offloaded or deleted

8. Processing a Single Raw Data File

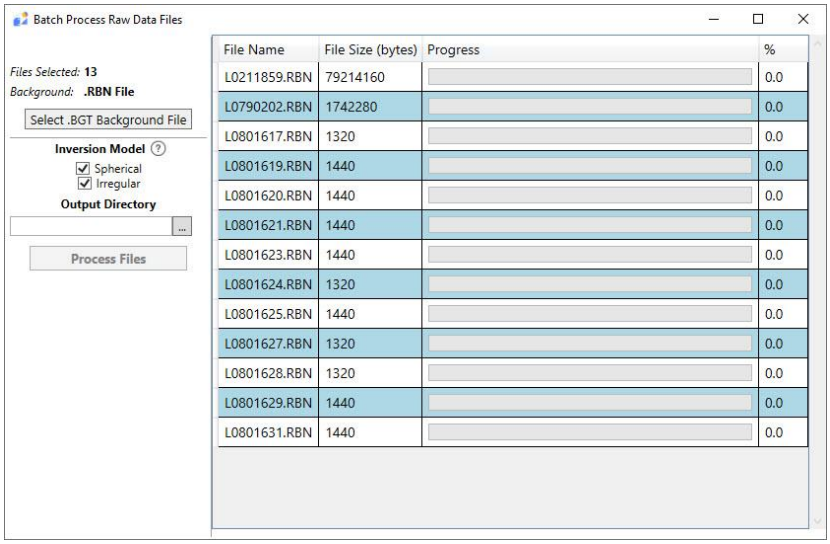
Data that has been downloaded from the datalogger is in a raw binary file (.RBN extension). It must be processed into particle size by the LISST-200X program.

STEP	ACTION	RESULT
1	• Start the LISST-200X program	Program started.
2	• Select *Process Data Files* from the home page. Select the file you want to process. A display similar to the one shown below will appear.  • A summary of auxiliary data is shown on the screen. More detailed plots can be viewed by clicking on the parameter.	Select file types to be created.
3	• You must also select the inversion model to be used when processing the data: Spherical, randomly shaped or both. • For a description of the particle models, see Appendix G: Spherical and Random Shape Particle Models. • If you have selected Randomly shaped Particle Inversion Model, the processed files will have an' _rs' suffix	Select inversion method(s) to be used – spherical, randomly shaped or both.
4	• Standard raw data processing will use the background file contained in the .RBN file. If you would like to use a different background file than the one in the RBN file, or use a data record as a background, select the 'View/Select Background' button	Select to process a file using the background in the data file or an external .BGT file

	 You can view and make background selections from this window.	
5	• Next, select the output data file name. Fill in the output directory and the base file name. Several files will be created. • The CSV file is a space delimited ASCII file containing the fully processed and calibrated data. This is useful for loading into spreadsheets such as Excel etc. • The RTX file is a space delimited ASCII file containing the raw data from the LISST-200X data logger. This is useful for looking at the raw data in a spreadsheet such as Excel etc.	Name out output file.
6	• To select the range of raw data to process, move the sliders at the bottom of the display. 	Range to process selected.
7	• After selecting the range to process, press the *Process File* button. The display will show the processing progress and the resulting data will be displayed when processing is complete.	Processing Completed.

9. Batch Processing Multiple Raw Data Files

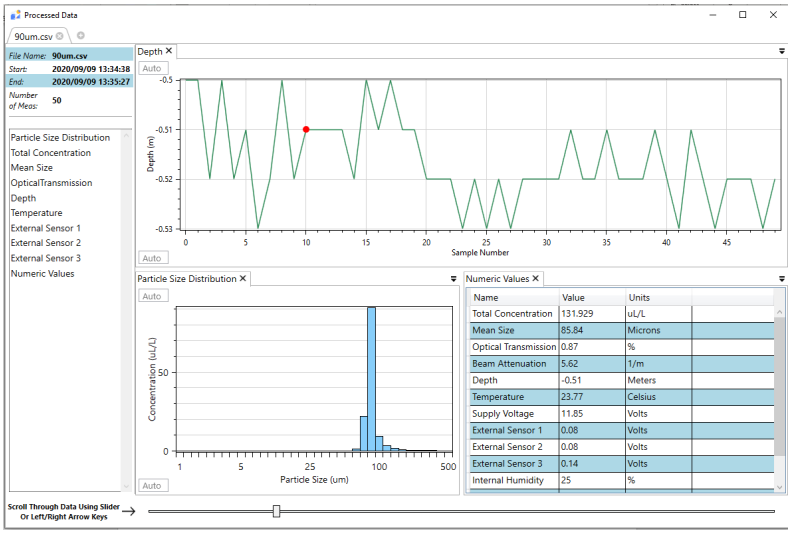
Data that has been downloaded from the datalogger is in a raw binary file (.RBN extension). It must be processed into particle size by the LISST-200X program. If you have multiple raw data files to process (e.g. from a series of profiling deployments), follow these processing steps that allows you to process all files in one operation.

STEP	ACTION	RESULT
1	• Start the LISST-200X program	Program started.
4	• Select *Process Data Files* from the home page. Select multiple files to process (by holding down either shift or ctrl). 	Select Files
5	• By default, batch processing will use the background stored in the raw data files to process the data. If you would like to use an external .BGT file, press the 'Select .BGT Background File' button.	Select source of background files
6	• You must also select the inversion model to be used with the real time data processing: Spherical, randomly shaped or both. • For a description of the two particle models, see Appendix G: Spherical and Random Shape Particle Models. • If you have selected Randomly shaped Particle Inversion Model, the processed files will have an' _rs' suffix	Select inversion method(s) to be used – spherical, randomly shaped or both..

7	• Select the Output Directory for the processed files. • Files will be named with the same name as the raw data files but with different extensions. Several files will be created. • The CSV file is a space delimited ASCII file containing all the processed data. • The RTX file is a space delimited ASCII file containing the raw data from the LISST-200X data logger.	Select Output Directory
	• Press the “Process Files” button. • The files will be processed in order and the progress bars will indicate the status of each file	Process files

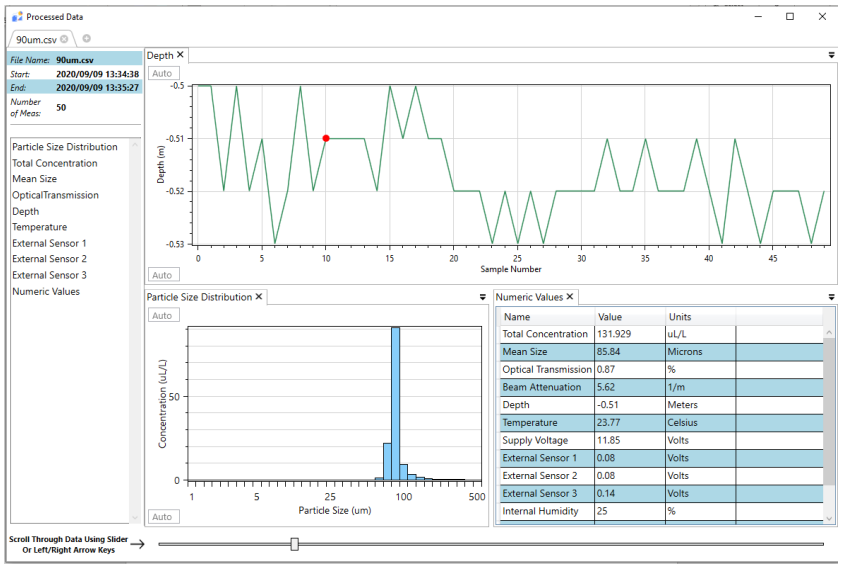
10. View Processed Data File

After processing of the data into a .CSV, the data can be viewed to the screen. This step-by-step procedure covers the viewing of data and optional displays.

STEP	ACTION	RESULT
1	• Start LISST-200X program	Program started.
2	• Select View Processed File from the home page	
3	• Select the processed data file (.CSV) from the file selection window. Double click the file or type the file name and press Open.	Processed data file selected.
4	• After selecting the processed file, a window similar to the one shown below will appear.  • A list of available parameters is displayed on the left. Clicking one of the parameters will open a new window where the parameter will be displayed. The parameter windows can be reorganized by dragging and dropping. The slider at the bottom is used to scroll through the data file. A red point on some graphs will indicate which sample is being displayed.	Particle size distribution displayed on screen
5	• Additional processed files can be opened simultaneously by pressing the plus button next the open tab at the top left of the screen. • When multiple tabs are open, the tabs can be dragged out into their own windows, allowing for easy comparison between files.	Open additional Files

11. Data Quality Control

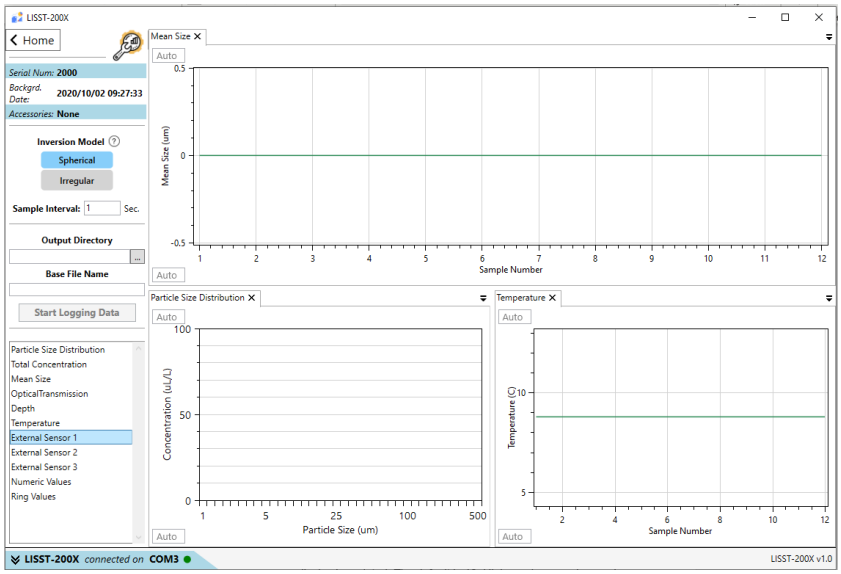
Making sure your data make sense.

STEP	ACTION	RESULT
1	• Follow steps 1-5 in the previous section: View Processed Data File	Data file loaded
2		
3	• The first thing look for is to check the Transmission values. The transmission must be a number between 0 and 1. • It is physically impossible for the transmission to be negative or larger than 1 (one). • Tip: The transmission value is in column 56 of the .CSV file. • If transmission shows up as being larger than 1 (one), then your measurement is most likely taken in very clear water and/or you have a bad zscat measurement obtained with dirty water and/or dirty windows. • If your zscat measurement was obtained using dirty water, it may be possible to redo the zscat using clean water and re-process the data, then check to see if the transmission values drop below 1 (one).	It is physically impossible for the Transmission value to be less than 0 (zero) or larger than 1 (one).
4	• If your transmission values generally are in the 0.98-0.995 range, your measurements are taken in very clear water. • This means that the signal-to-noise ratio will be low, and the data may have a lot of noise in them, but can most likely still be used.	Transmission values very close to 1 yields noisy data.

6	• If your transmission values are < 0.10 (or 10%), the water is too turbid. Disregard these data.	Data with transmission values < 10% should be disregarded.
7	• If your transmission values are > 0.995 (or 99.5%), the water is too clear. Disregard these data.	Data with transmission values > 99.5% should be disregarded.
8	Summarizing • Disregard data if transmission is > 0.995 (> 99.5%). • Disregard data if transmission is < 0.10 (< 10%). • Be wary of data collected at transmission values between 0.98 and 0.995 – low signal-to-noise ratio. • Be wary of data collected at transmission values between 0.30 and 0.10 – generally decreasing data quality as the transmission decreases below 0.30 (30%).	Quick quide for data QC

12. Simple Real-Time Data Processing

This step-by-step procedure covers the acquisition, display and storage of processed data in real time.

STEP	ACTION	RESULT
1	• Connect the instrument to the computer and establish communication in the LISST-200X program. (see Step-by-Step Procedure: Establishing Communication with the LISST-200X)	Communication established.
2	• The background currently stored onboard the instrument will be used to process the data as it is collected in real time. • Be sure to collect a new background and store it onboard the instrument before beginning a real time session	Background is current
3	• Select *Collect Live Data* from the home page	Open Instrument selected.
4	• A display will appear on the screen. It is similar to the main window of the View Processed Data function. 	

	• A list of available parameters is displayed on the left. Clicking one of the parameters will open a new window where the parameter will be displayed. The parameter windows can be reorganized by dragging and dropping. • The 'Sample Interval' text box allows you to adjust the time between samples in seconds. • The Sample Number value displayed underneath the plots will increment each time a sample is saved. • The buttons labeled 'Spherical' and 'Irregular' allow you to display the volume distribution calculated with either the spherical or random shape particle model. The buttons only effect the display and have no effect on the data that is saved in the .CSV file. Data from both particle models is always saved.	
5	• Select an output directory and a base file name. Several files will be created. • The CSV file is a space delimited ASCII file containing all the processed data. • The RTX file is a space delimited ASCII file containing the raw data from the LISST-200X data logger.	Select output directory and file name
6	• Data will not be saved until the 'Start Logging Data' button is pressed.	Start Data Logging

13. Collecting Data from an External Analog Sensor

The LISST-200X can supply regulated 12V power to an external sensor, and measure one or two analog voltages, depending on its hardware configuration and firmware settings. If the 12V power output is activated, it will turn on each time the 200X collects a sample or burst of samples, and turn off each time the 200X goes into a waiting state of more than a few seconds. If using the 12V output, you can specify how long it should turn on before sampling, as a warmup time for the sensor.

To provide these functions, the auxiliary connector on the LISST-200X must be in one of three configurations: Analog & Digital Input (which provides a single analog input), Dual Analog Input configuration (which provides two), or Triple Analog Input configuration (which provides three).

STEP	ACTION	RESULT
1	• Determine current configuration of Auxiliary connector: in LISST-200X Software, open the instrument status bar. Look for the Endcap Configuration. If it is not one of the analog-input configurations, you will need to change it; contact Sequoia for assistance.	Auxiliary Connector configuration determined
2	• Make the appropriate connections between the 6-pin auxiliary connector of the LISST-200X and your sensor. To see the pin assignments, type the CONFIG command in the LISST-200X terminal window; page 64). Or see Appendix E: Connectors.	External sensor connected
3	• Type SENSORPOWER into the terminal window, and respond to its prompt to select the appropriate option. • Type SENSORWARM in the terminal window to set a warmup time (in seconds). • WARNING: a USB cable may not provide enough power for external sensors. Use a battery pack or other power source to provide enough power to run external sensors.	Configured for analog collection
4	• Set the standard sampling parameters to control the sampling schedule and other options (see • Configuring Data Collection on page 34).	Ready to collect data

14. Configuring the LISST-200X as a Sensor for a CTD

The LISST-200X can operate as an analog-output auxiliary sensor for a CTD. For this purpose the LISST-200X's auxiliary six-pin connector must be in its "Dual Analog Output" configuration. The two analog outputs represent the total volume concentration of particles, and the Sauter mean diameter (SMD). These values are approximations for the convenience of real-time display. For highest-quality data you will still need to offload and process the detailed data from the LISST-200X after deployment.

The LISST-200X updates its analog outputs each time it collects a sample, at a maximum of 1 Hz.

STEP	ACTION	RESULT
1	• Determine current configuration of Auxiliary connector: in LISST-200X software, open the instrument status bar. Look for the Endcap Configuration. If it is not in the Dual Analog Output configuration, you will need to change it; contact Sequoia for assistance.	Auxiliary Connector configuration determined
2	• Make the appropriate connections between the 6-pin auxiliary connector of the LISST-200X and your sensor. To see the pin assignments, type the CONFIG command in the LISST-200X terminal window (see LISST-200X Command Details on page 64), or see Appendix E: Connectors.	Connected to CTD
3	• In LISST-200X software, set the sampling parameters as follows (see • Configuring Data Collection on page 34): o Operating mode: Fixed sample rate o Sample to be average of 20 measurements o Sample interval: 1 second o Automatically start sampling program upon power up Start condition: delay 0 minutes o Stop condition: memory full	200X will collect data at 1 Hz whenever the CTD supplies power to it

E. Instrument Communication

Overview

The cables Sequoia supplies with the LISST-200X send data through a standard USB port. However, the LISST-200X itself communicates through RS-232 serial protocol. The 5-pin male connector on the LISST-200X carries the RS-232 signals (and power). The cables incorporate adapters that convert between RS-232 and USB.

If you use a different cable that does not include the RS-232-to-USB adapter, you can use an external adapter, or connect directly to an RS-232 port if your computer has one (which is rare on any recent computer). In Windows, both RS-232 and USB connections will appear as COM ports.

If interfacing to a data logger or controller system other than a Windows computer, you will likely also use a direct RS-232 connection.

The RS232 link communicates at 9600 baud, 8 data bits, No parity, and 1 stop bit. For offloading data files, the LISST-200X software uses YMODEM protocol at 115K baud. The transfer rate can be changed in the settings of the LISST-200X software. A slower speed may be required when downloading data over cables longer than a few meters.

Using the LISST-200X Terminal Window

In the LISST-200X software, you can open a terminal window to directly view communications with the LISST-200X, and enter commands. When the LISST-200X is connected and the terminal window is the front window, the LISST-200X should respond to pressing the enter key with the L200X:> prompt. If the instrument is in the deep sleep mode, you can wake it by pressing the Stop button.

Direct Commands

In most cases, LISST-200X software will be used to configure and operate the LISST-200X. However, some functions are available only through direct commands in the terminal window. Also, in some applications the LISST-200X may need to communicate to another datalogger or custom program. For this purpose, a large set of commands is available to operate the instrument. See the LISST-200X Command Summary on page 62 for detailed descriptions of each command.

Start Condition

The LISST-200X software or two letter commands can configure the LISST-200X with one of five Start conditions:

1. Depth,
2. Time,
3. External Mechanical Switch,
4. External Digital Input, and
5. Time Delay.

The details of each condition are described below.

Depth Start

The built-in depth sensor of the LISST-200X is used to check the current depth to determine if the desired start depth has been exceeded. The instrument is powered up and 5 measurements of the depth are averaged over a two-second period. If the depth exceeds the threshold the program will proceed to the data collection routine. If the depth does not exceed the threshold the instrument will power down and wait 28 seconds before checking the depth again. The program will continue checking until the depth is exceeded or until the program is stopped.

Time Start

The program will check the current time every second and compare it to the Start Time. If the Start Time is equal to or earlier than the current time the program will go directly to the data collection routine. It will continue checking the time until the Start Time is reached or until the program is stopped.

External Mechanical Switch Start

The LISST-200X has a white plastic lever on the endcap. This lever has a magnet imbedded in it. This magnet can activate a switch inside the pressure case. The base program looks at the status of this switch once a second. If the switch is in the on or “1” positions the program will go directly to the data collection routine. It will continue checking the switch status until the switch is moved to the “0” position or until the program is stopped. When in the “0” position the lever is up against the zinc anode.

External Digital Input Start

If the auxiliary connector is configured for analog and digital inputs (see Appendix E: Connectors), pin 2 of the 6-pin connector is the digital input. The program will check the status of the digital input once a second. If the digital input is greater than 2 volts (relative to digital ground, pin1) the program will go directly to the data collection routine. It will continue checking the status of the digital input until voltage drops below 0.7 volts or until the program is stopped.

Time Delay Start The time delay start condition will cause the program to wait the specified number of seconds before continuing on to the data collection routine.

Data Collection Routine The LISST-200X software can configure the sampling program with one of six Stop conditions: Depth, Time. External Mechanical Switch, External Digital Input, Fixed number of samples, and Maximum Memory or Low Battery. The details of each condition are described below.

Stop Condition The LISST-200X software can configure the LISST-200X with one of six stop conditions:

1. Depth,
2. Time,
3. External Mechanical Switch,
4. External Digital Input,
5. Fixed number of samples, and
6. Memory full.

When storing data in the Fixed Sample Rate mode the Stop conditions are checked after each averaged sample has been saved. When storing data in the Burst mode the Stop conditions are only checked after a full Burst has been completed. The Start and Stop conditions have no effect on the Real-time sampling mode. The details of each condition are described below.

Depth Stop The depth sensor of the LISST-200X is used to check the current depth to determine if it is less than the desired Stop depth. If the depth is less than the threshold the sampling will stop. If the Start Condition is Depth Start the program will return to checking for the start depth. For all other Start Conditions the when the current depth is less than the threshold the LISST-200X will stop and go into deep sleep.

Time Stop The program will check the current time after each sample or burst and compare it to the Start Time. If the Start Time is equal to or later than the current time, it will stop and go into deep sleep.

External Mechanical Switch Stop

After each sample or burst the status of the Switch lever is checked. If the switch lever is in the off or “0” position sampling will stop. If the Start Condition is a Switch Start the program will return to checking the start condition. For all other Start conditions the instrument will stop and go into deep sleep.

External Digital Input Stop

The status of the digital 1 input is checked after each sample or burst. If the voltage at the input is less than 0.7 volts the sampling will stop. If the Start Condition is a Digital Input Start the program will return to checking the start condition. For all other Start conditions the instrument will stop and go into deep sleep.

Fixed Number of Samples

The program will acquire a fixed number of samples before stopping. When the number of samples to be saved has been reached the program will stop and go into deep sleep.

Memory Full

Sampling will continue until the memory is full, or the power input falls. If the memory fills, the instrument will go into deep sleep.

F. LISST-200X Command Summary

NOTE: Command are shown in upper case for clarity, but are not case-sensitive.

Display Commands

CONFIG	Display instrument hardware configuration information
DD, DIR	Display current disk directory
DEPTH	Display current depth
DS	Display current instrument status information
DT	Display current time and date
HELP, ?	Display general help messages and command list
SW	Display mechanical switch position
TEMP	Display current temperature
VIN	Display input supply voltage

Setup Commands

MODE, OM x	Set operating mode (burst or fixed-rate)
ST x, STARTCOND x	Set start condition.
TD x, STARTDATA x	Set start condition data
SP x, STOPCOND x	Set stop condition
PD x, STOPDATA x	Set stop condition Data
SI x	Set sample interval
MA x	Set samples per average equal to x
BI x	Set burst interval
SB x	Set samples per burst

SC yyyy/mm/dd hh:mm:ss	Set clock with time and date, where *yyyy*=year, *mm*=month, *dd*=day, *hh*=hour(24 format), *mm*=minute, *ss*=seconds,
AS x	Set autostart
STOREDATA x	Suppress data storage (WARNING: can cause loss of data!)
ZD	Reset depth sensor offset
SENSORPOWER x t	Set whether power output turns on during logging
SENSORWARM t	Set external sensor power warmup time

Acquisition/Action Commands

DL filename	Delete file
GO	Start data collection using current parameters
GX	Grab sample and transmit it
XR	Transmit raw data when average saved
ZS	Acquire 20 samples and evaluate them for quality.
ZZ	Go into deep sleep mode (minimum power consumption)

G. LISST-200X Command Details

1. Display Commands

CONFIG	Display instrument hardware configuration
Syntax:	CONFIG
Description:	The current hardware configuration including Auxiliary I/O connector configuration
Example:	input: CONFIG output: Serial Number: 2001 Firmware Version: 1100 (1.100) VCC: 59371 Full Path Length: 2500 (25 mm) Eff. Path Length: 2500 (25 mm) BioBlock Installed: 0 Start Condition: Digital input (4) Start Condition Data: 0 Stop Condition: Switch (3) Stop Condition Data: 0 Measurements Per Average: 10 Sample Interval: 1 seconds Burst Mode: 0 Samples Per Burst: 5 Burst Interval: 25 minutes Transmit Raw Data: 0 Lifetime Sample Count: 529554 Lifetime Laser On Time: 1703980 seconds Endcap Configuration: 0 (Analog & digital in) Wiring of MCBH6MP connector: 1: Ground 2: Digital input 1 3: Digital input 2 4: +12V output 5: Analog input 1 6: Ground

DD, DIR	Display Disk Directory
Syntax:	DD or DIR
Description:	Display current disk directory in DOS type format. Includes total bytes used and bytes available.
Example:	input: DD output: LISST-200X Disk Directory Volume in drive C is NONAME Volume Serial Number is 778B-155F Directory of C:\ L040305_.BIN 4,136 03-05-04 6:30p L183705.BIN 1,672 03-05-04 6:37p 2 file(s) 5,808 bytes 0 dir(s) 15,933,440 bytes free L200X:>

DEPTH	Display current depth
Syntax:	DEPTH
Description:	The current depth is displayed to the screen.
Example:	input: DEPTH output: Current depth: 567.1 meters

DS	Display current status information
Syntax:	DS
Description:	The instrument settings and status are displayed to the screen.
Example:	input: DS output: LISST-200X Status and Settings Serial number = 1004 Endcap Configuration: 0 (Analog & digital in) Firmware Version 1.126 Apr 26 2016 18:45:52

	Current Date/Time: 2016/04/27 10:27:02 Current Day of the Year: 118 Supply voltage: 12.00 V Operating Mode: Burst Mode AutoStart OFF Delay Start with 0 minute delay Measurements per Average: 10 Sample Interval: 1 Stop after 5 samples External sensor power during logging: off External sensor warmup time: 0 seconds Free memory: 1023 Mbytes input: DS 1 output: LISST-200X Current Status and Settings SN = 1004 OM = 0 ST = 5 TD = 0 SP = 5 PD = 0 MA = 10 SI = 1 BI = 1 SB = 1 BB = 0 AS = 0 SENSORPOWER = 0 SENSORWARM = 0 Current Time = 2016/04/27 10:32:15 Battery = 1200 Switch = 0 Memory= 1023639552 Bytes Endcap = 0

DT	**Display current time and date**
Syntax:	DT
Description:	Displays current time and date to the screen.
Example:	input: DT output: Date/Time: 2001/01/05 21:05:03

HELP, ?	**Display general help messages and command list**
Syntax:	HELP or ?
Description:	Displays the list of command to the screen.
Example:	input: HE output: LISST-200X Commands (followed by 30 lines of text)

SW	**Display current Mechanical Switch position**
Syntax:	SW
Description:	The current position of the Mechanical Switch is displayed to the screen.
Example:	input: SW output: Current Switch Position: 0

TEMP	**Display current temperature**
Syntax:	TEMP
Description:	The current temperature is displayed to the screen.
Example:	input: TEMP output: Current temperature: 20.3 deg C

VIN	**Display Battery Voltage**
Syntax:	VIN
Description:	The current supply voltage is displayed to the screen.
Example:	input: VIN output: Current Input Voltage: 8.90 volts

OM	**Set Operating Mode**
Syntax:	MODE x or OM x
Description:	Sets the Operating Mode to one of the following types: 0 = Fixed rate 1 = Burst Mode OM command only without a parameter will initiate a prompt for the Operating mode.
Example:	input: OM 1 output: New Operating Mode: Burst Mode

ST, STARTCOND	**Set Start Condition**
Syntax:	ST x or STARTCOND x where x is the start condition code described below
Description:	The ST command sets the start condition to be used when the GO command is issued. The start condition options are: 1 = Depth Start 2 = Time/Date Start 3 = Mechanical Switch Start 4 = Digital Input Start 5 = Delay Start If no value follows command, prompts will be displayed for the value. After setting the start condition to Depth, Time or Delay, use STARTDATA to set the applicable condition value.
Example:	input: ST 5 output: New Start Condition Setting: Delay Start

TD, STARTDATA	**Set Start Condition Data**
Syntax:	TD x or STARTDATA x where x is the start condition data described below
Description:	The TD command sets the start condition data to be used when the GO command is issued. The start condition data is used with the Start Condition setting as follows: • If the Start Condition is Depth Start (option 1) the input will be start depth in meters. • If the start condition is set to Time/Date Start (option 2) the input for TD will be the start date and time. • If the Start Condition is Delay Start (option 5) the input will be time delay in minutes. • The TD setting is ignored for Mechanical Switch Start (option 3) or Digital Input Start(option 4). If no value follows command, prompts will be displayed for the value.
Example:	input: TD 3 (if Start Condition = 1 (Depth Start)) output: New Start Condition data = 3 Start Condition: Depth Start at 3 meters input: TD 2016/12/31 23:59:59 (if Start Condition = 2 (Time/Date Start)) output: New Start Condition data = 2016/12/31 23:59:59 Start Condition: Time Start at 2016/12/31 23:59:59 Input: TD 2 (if Start Condition = 5 (Delay Start)) Output: New Start Condition data = 2 Start Condition: Delay Start with 2 minute delay

SP, STOPCOND	**Set Stop Condition**
Syntax:	SP x or STOPDATA x, where x is the stop condition code described below

Description:	The SP command sets the stop condition to be used when collecting data. The stop condition options are: 1 = Depth Stop 2 = Time/Date Stop 3 = Mechanical Switch Stop 4 = Digital Input Stop 5 = Number of Samples Stop 6 = Maximum memory or Low Battery Stop If no value follows command, prompts will be displayed for the value. After setting a stop condition of Depth, Time/Date or Number of Samples, use STOPDATA to enter an appropriate parameter value.
Example:	input: SP 5 output: New Stop Condition Setting: Fixed Number Stop

PD	**Set Stop Condition Data**
Syntax:	PD x or STOPDATA x where x is the stop condition data as described below
Description:	The PD command sets the stop condition data to be used when the collection data. The stop condition data is used with the Stop Condition settings as follows. • If the Stop Condition is Depth Stop (option 1) the input will be stop depth in meters. • If the stop condition is set to Time/Date Stop (option 2) the input for PD will be the stop date and time. • If the Stop Condition is Fixed Number Stop (option 5) the input will be the number of samples to collect before stopping. • The PD setting is ignored for Mechanical Switch Stop (option 3), Digital Input Stop (option 4) or Maximum memory or Low Battery Stop (option 6).
Example:	input: PD 3 (if Stop Condition =1 (Depth Stop)) output: New Stop Condition data = 3 Stop Condition: Depth Stop at 3 meters input: PD 2016/12/31 23:59:59 (if Stop Condition = 2 (Time/Date Stop)) output: New Stop Condition data = 2016/12/31 23:59:59 Stop Condition: Time Stop at 2016/12/31 23:59:59

	input: PD 2 (if Stop Condition = 5 (Fixed Number of Samples Stop)) output: New Stop Condition data = 2 Stop Condition: Fixed number Stop at 2 samples

SI	**Set Sample Interval**
Syntax:	SI x, where x is the number of seconds between samples, from 1 to 10,000.
Description:	In either fixed-rate or burst mode, the sample interval is the number of seconds between two consecutive samples, each composed as an average of a number of measurements (specified by the MA command).
Example:	input: SI 5 output: New Seconds between Samples: 5

MA	**Set measurements per average**
Syntax:	MA x The exact result depends on whether ambient light rejection (ALR) is active. Starting with firmware version 1.4 (May, 2017), ALR is on by default, and the actual number of samples averaged will be approximately x/10. That is, MA 32 will result in 3 ALR cycles per average. With or without ALR, 32 is the maximum MA value that allows 1 sample per second.
Description:	Each recorded or displayed measurement is based on an average of measurements. MA sets the number of measurements per. If no value follows command, prompts will be displayed for the value.
Example:	input: MA 32 output: New Measurements per Average: 32

BI	**Set Burst Interval**
Syntax:	BI x, where x is the number of seconds between the start of 2

	consecutive bursts, from 1 to 10,000 seconds.
Description:	In Burst Mode (MODE = 1), the burst interval is the number of seconds between two consecutive bursts, each burst composed of a number of samples per burst (specified by the SB command).
Example:	input: BI 900 output: New Seconds between Bursts: 900

SB	**Set Samples per Burst**
Syntax:	SB x, where x is the number of samples per burst. Each sample is taken at the sample interval (in seconds) set by the SI command. If no value follows command, prompts will be displayed for the value.
Example:	input: SB 10 output: New Samples per Burst: 10

SC	**Set Clock with time and date**
Syntax:	SC yyyy/mm/dd hh:mm:ss Where yyyy=year, mm=month, dd=day, hh=hour (24 hour format), mm=minute, ss=seconds If no values follow the "**SC**" or "**sc**" command, prompts for entering the time and date will be displayed.
Example:	input: SC 2017/01/05 21:05:03 output: Command Data in SC is: 2017/01/05 21:05:03 Current Date/Time: 2017/01/05 21:05:03

AS	**Enable Autostart Setting**
Syntax:	AS x, where x is 1 (yes) or 0 (no)

Description:	With Autostart enabled, the firmware will immediately start the sampling program when power is applied to the instrument.
Example:	input: AS 1 output: AutoStart will occur upon power up!
Cautions:	If Autostart is enabled, the user cannot talk to the instrument when powering it up – it will immediately start sampling according to the SD defaults. In order to stop sampling and establish normal communication, the user must issue a stop command, by either pressing the STOP button or issuing a CTRL-C command in the terminal window within a few seconds of powering up the instrument.

SaveData	**Save Data Setting**
Syntax:	SAVEDATA x, where x is 1 or 0
Description:	The SaveData setting disables (x = 0) or enables (x = 1) data storage on the internal drive. No Ldddhhmm.DAT file will be created if Save Data mode is disabled. It is intended to be used for long-term real-time deployments, where it may not be desirable to have the data stored on the datalogger. It may be desirable to disable data storage when exporting raw data to an external data logger. See the XR command for configuring the raw data export option.
Example:	input: SAVEDATA 1 output: Data will be stored after each sample!!! input: SAVEDATA 0 output: Data will NOT be stored after each sample!!!
Cautions:	Be very careful that the correct store mode is selected before a deployment where it is the intent to store the data internally on the instrument! Issue a DS command to verify the status of the store mode setting. A warning will be displayed as part of the DS status if the store mode is disabled: WARNING: Data storage disabled. Data will not be saved!!!

ZD	**Reset Depth Sensor Offset**
Syntax:	ZD
Description:	The ZD (or zd) command resets the depth sensor offset so that the sensor reads a depth of 0m at zero depth (in air). You must issue the ZD command, then select 1 (yes) or 0 (no) to reset depth sensor
Example:	input: ZD output: Depth Sensor Offset Reset Procedure Started. Instrument must be at zero depth and similar temperature to field conditions. Do you wish to reset Depth Sensor offset? (1=yes,0=no): [0] ? 1 Previous offset was -14.03. New offset is -13.87. Previous Depth was -0.15 meters. New Depth using corrected offset is 0.00 meters.
Cautions:	None

DL	Delete file from LISST memory
Syntax:	DL *filename*, where *filename* is the name of the file to be deleted.
Description:	DL command is used to delete file from the Compact flash module. Wildcards such as *.* can be used.
Example:	Input: DL L159*.dat Output: Are you sure (Y/N)…
Cautions:	WARNING: Make sure that the file being delete has already been offloaded before deleting the file. Once the file is delete it can not be recovered.

GO	Start Data Collection using current Settings
Syntax:	GO
Description:	Starts Fixed Rate or Burst Mode Data collection using current settings.
Example:	Input: GO Output: Waiting for start conditions…
Cautions:	To stop data acquisition before it is complete press the Stop button or **CTRL-C**.

GX	Grab sample and transmit it
Syntax:	GX
Description:	Acquires single averaged sample and displays the result to the screen.

Example:	Input: GX
	
	Output: {
	…. 36 ring values + 24 Aux parameters
	}

Notes:	The GX command does not store the sample to a datafile.

XR	**Transmit raw data during sampling**
Syntax:	XR x, where x = 0 through 3
Description:	This command allows data to be transmitted to an external data system during execution of the GO command, in one of several formats. The default setting is 0, with data transmission turned off. Setting 1 sends raw data in a multi-line text format; 2 sends a single line as a NMEA-compatible data sentence; 3 sends a single line of comma-separated values. Contact Sequoia Scientific for complete details of these formats.
Example:	input: XR 1 output: Raw data WILL be transmitted when data is stored
Cautions:	Format 2 requires firmware 1.3 or later. Format 3 requires firmware 1.414 or later.

ZS	**Collect and transmit background scattering data**
Syntax:	ZS
Description:	Acquires 20 averaged sample and displays the result to the screen. Evaluates the data for quality as a background measurement.

Example:	Input: ZS
	
	Output: {
	…. 36 ring values + 24 Aux parameters
	}
	
	repeat 20 times, then messages about the quality of the data.

Notes:	The ZS command does not store the sample to a datafile.

ZZ	**Go into deep sleep mode (minimum power consumption)**
Syntax:	ZZ

Description:	Sends LISST-200X in to low power sleep mode. Instrument will send a message every 30 seconds to indicate it is sleeping. It can be wakened at any time by sending 2 control-C characters about ½ second apart.
Example:	Input: ZZ Output: Deep Sleep… Enter zz to wake up Deep Sleep… Enter zz to wake up Deep Sleep… Enter zz to wake up

H. Performance Optimization

This section contains information on optimizing the performance of the LISST-200X.

Optical Alignment

The background measurement is the best source of information on the current health of the LISST-200X. It provides information on the current functionality of all of the major systems including laser, ring detector, data collection electronics, and optical alignment. The LISST-200X is a sensitive optical device. The laser must be aligned such that the focused spot is centered on the hole in the center of the ring detector. If this alignment in not correct the instrument will not function correctly. The background measurement can easily provide the user with information about the status of the alignment.

The first indicator of an alignment problem is a severe drop in the currently transmitted laser power when compared to the factory laser power. The laser power and laser reference values will change over time but they should track together. If the value of the laser power:laser reference ratio for your current background measurement is less than 85% of the laser power:laser reference ratio from the factory background file, misalignment may be occurring.

The second indictor of misalignment is high value on the inner rings. The inner rings are shown on the left side of the background display. The most important rings for misalignment indication are rings 1-4 in the background scatter file. As the focused laser starts to move away from the center of the ring detector it will scatter more light onto the inner rings. This will cause the inner ring values to be much higher than the factory values, and is also the reason for the decrease in transmitted laser power.

It must be noted that low laser power or high inner rings may not always indicate misalignment. Low laser power can also occur because the windows or water is dirty or if there are bubbles on the window. Large particles or bubbles can cause the inner rings to be higher than factory values. All of the other possibilities must be eliminated before it can be concluded that the instrument is misaligned.

The transmit optics on the LISST-200X do allow for the possibility of the user adjusting the alignment. A written procedure can be provided for this procedure. However, it is highly recommended that the need for re-alignment be discussed with a trained Sequoia Scientific technical service representative before attempting this procedure.

Background Measurement and its Importance

As was discussed in earlier sections, the LISST-200X uses a custom detector to measure light scattered at small angles from particles in water. In order to measure only the scattered light contributed by the particles, a measurement of the background scattering must be obtained. This background scattering can come from a number of areas. Scratches on the windows, imperfections on the optics, and other sources all contribute to the scattered light. By subtracting this background scattering from the measured data, a true measurement of

the light scattered from the particles can be obtained. The measurement of background scattering is sometimes called a "ZSCAT". The name comes from the fact that the measurement is obtained using water with zero "scatterers" or particles.

It is very important that clean and bubble free water is used. The water can be fresh or salt water. For most applications, it has been found that steam-distilled water is sufficient. Steam-distilled water is typically available in one-gallon containers. We have found that this distilled water tends to be a bit cleaner than typical bottled or packaged water. We buy steam-distilled drinking water and filter it through a 0.2µm filter.

A small volume horizontal chamber has been provided for submerging the optics while acquiring a background. It is inserted between the windows of the optics. The instrument should be placed horizontally on the supplied white plastic supports. However, Plastic bags, Tupperware or clean containers of any kind can be used to acquire a background. The instrument's optics end can be submerged in them vertically, as long as the optics are completely submerged and there is no blockage of the windows by bubbles or other objects.

Because the area surrounding the windows is submerged, it is important to thoroughly clean and rinse this part of the instrument before acquiring a background.

Toothbrush, liquid soap and water works well for cleaning the optical end of the instrument; do not use abrasive powders, they will scratch optics and destroy instrument performance.

The low concentration limit of LISST-200X is very sensitive to the quality of the background scatter file. For this reason, when working in low concentration water, it is very important that a good background file be obtained with very clean water. As particle concentrations increase, the relative signal-to-background noise ratio also increases, thus reducing the importance of the background. However, a background should always be collected before an experiment.

Watch for Outgassing and Bubbles

Another consideration when acquiring a background is "outgassing" causing small bubbles to form on the instrument and windows. Bubbles on the windows will greatly modify the scattering pattern, rendering the background useless. Be sure to remove any bubbles from the windows before acquiring a background. Use a squirt bottle or pipette to blow the bubbles off the window.

Because the area surrounding the windows is submerged, it is important to thoroughly clean and rinse this part of the instrument before acquiring a background.

Ambient Light Rejection

Starting with firmware version 1.4 in May, 2017, the LISST-200X automatically measures and subtracts light that is not produced by scattering from its laser. This Ambient Light Rejection (ALR) prevents sunlight or other bright sources from contaminating the scattering measurements. Without ALR, as in earlier LISST instruments, high ambient light levels, if not physically blocked from the LISST's optical aperture, could falsely elevate the apparent concentration of small particles.

You can verify that ALR is active by connecting to the instrument with LISST-200X, then opening the terminal window. Type DS and press enter, and look for "Ambient light subtraction: on" in the output. If it is not shown, you should upgrade the firmware. Contact Sequoia Scientific for assistance.

ALR works by measuring the signal on the LISST-200X's 36 detectors first with the laser on, then with the laser off. This on-off process is repeated 3 times per second. Because of the time required for the laser and electronics to change between the on and off states, rapidly changing ambient light may not be completely rejected. Therefore, if working in bright sunlight, near the water surface, and in conditions where the sunlight is rapidly modulated by waves, ambient light could still have an effect. ALR will reduce the average effect, but the changing ambient conditions could increase sample-to-sample noise. In those worst-case conditions it is still advisable to shade the LISST-200X optics from ambient light. The same is true if operating under intense artificial light modulated by AC power.

I. Instrument Mounting, Deployment Orientation, Storage and Maintenance

This section contains information on mounting, storing and maintaining the LISST-200X.

Horizontal Mounting

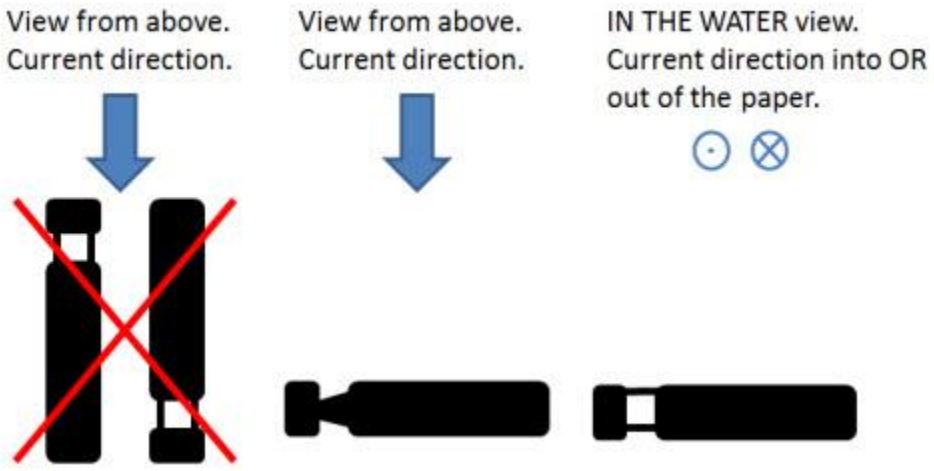
The LISST-200X measures scattered light to obtain particle size distributions. Therefore it is important to keep particles from sticking to the window surface. The first line of defense it to keep the window surface vertical by mounting the instrument horizontally. This is most critical when the water motion is slow. When working in rivers or in a towed or profiling application the orientation is not as critical.

The center section of the main pressure case has a slightly smaller diameter than the ends. The smaller diameter section is the suggested mounting area. The U-shaped mounting block provided with the instrument fit this diameter and can be used for mounting the instrument. The clamps supplied with the instrument can also be used.

Spare clamps for mounting the instrument are available from Sequoia.

Precautions for Orientation Relative to Current Flow

If possible, the instrument should be deployed so that it is perpendicular to the current, and water can flow as directly as possible through the optics end of the instrument. The diagram below shows the optimum orientation with respect to current flow



Electrical Isolation

To reduce the corrosion of the aluminum parts a zinc anode is attached to the connector endcap. This anode must be exposed to the water for it to be effective.

When mounting the instrument be sure to electrically isolate the instrument from all other metal. Any contact with other metal can greatly increase the rate of corrosion. Isolate the instrument with rubber or plastic to keep the LISST-200X from being the sacrificial anode for the mounting hardware. Failure to properly isolate the instrument from all other metal will void the warranty.

A set of stainless steel clamps with rubberized interiors ships as part of the instrument package. Use these or the plastic clamps for mounting, and make sure that no metal is in direct contact with the pressure housing or other components of the instrument. If you lose the spare clamps, replacement clamps are available for purchase from Sequoia.

Storage Notes

Again it must be emphasized that the LISST-200X is a sensitive instrument. When not in use, the instrument should be stored in its foam-lined shipping case.

Cleaning the Optical Windows

As has been noted earlier, the condition of the windows is critical to the performance of the LISST-200X. Care must be taken when cleaning the windows. The windows and the instrument should be rinsed thoroughly with fresh water after each deployment. The windows should be cleaned with a soft cloth or lens tissue. Liquid detergent/soap and water may be used. For removing grease spots, finger prints, etc, alcohol may be used. Do not use stronger solvents such as Acetone or Toluene.

Abrasive powders must never be used near the optics windows; they will scratch the windows and degrade instrument performance.

O-Rings

O-rings that seal the mating parts of the instrument must be maintained and inspected regularly. Whenever the connector end cap is removed, check the O-ring for any cuts or marks, and clean and lightly grease the O-ring before installing the end cap. Spare end cap O-rings have been provided. O-rings are inexpensive items that provide an invaluable service; replace them if in any doubt about their condition. When replacing the O-ring, be sure to clean the O-ring groove thoroughly with cotton-swabs etc. making sure that no fibers or particles of dirt are left after the cleaning.

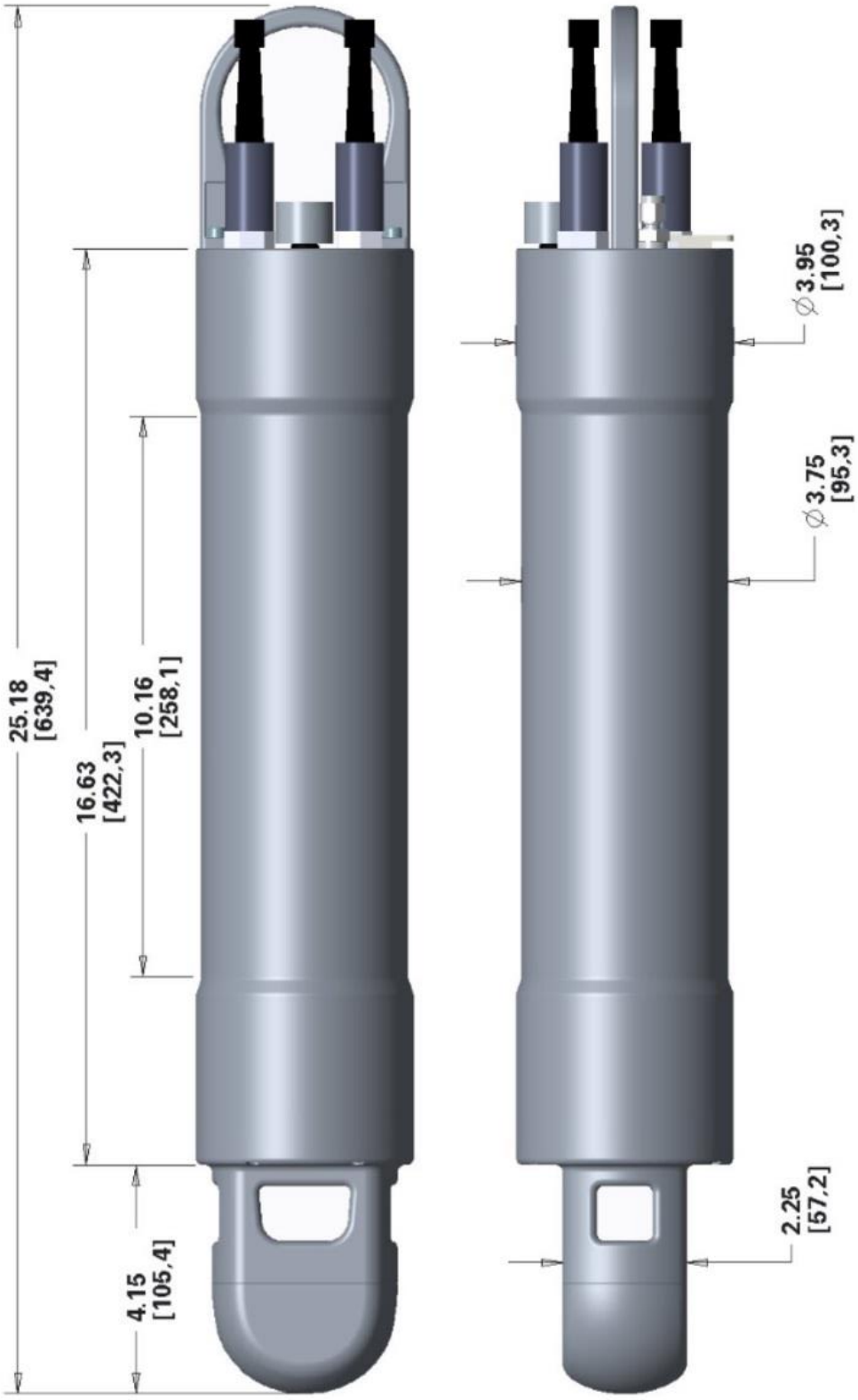
Calibrations and Adjustments

The LISST-200X should not require any adjustment or calibrations. The pressure and temperature sensors can be re-calibrated if desired. The performance of the instrument can be checked with the use of a sample of particles of a known size distribution. Standard particles can be obtained from manufacturers of standard particles, such as Whitehouse Scientific (http://www.whitehousescientific.com/) or PTI – Powder Technology Inc. (http://www.powdertechnologyinc.com/).

Comparison of the LISST-200X's performance with that of other particle-size measuring devices that are not based on laser diffraction may result in inconsistencies because the instruments may measure different properties of the particles to interpret particle size.

Appendix A: Technical Specifications

- Parameters measured/derived:
  - Particle Size distribution
  - Total Volume Concentration
  - Optical Transmission
  - Depth
  - Temperature
  - Volume Scattering Function
- Particle size range: 1.00 - 500 µm in 36 log-spaced classes
- Optical path length: 2.5 cm
- Optical transmission: 12-bit resolution
- Analog inputs (availability depends on configuration)
  - Measurement range: 0 to 5.2 V
  - Resolution: 0.1 mV (inputs 1 and 2); 1.5 mV (input 3)
  - Uncertainty: 1.5% of reading + 2 mV
  - Input impedance: 500 kΩ
  - Time constant: 250 ms
- Digital input (availability depends on configuration)
  - Nominal logic levels: 0 and 3V
  - Voltage tolerance without damage: -12 to 12V
- Analog outputs (availability depends on configuration)
  - Output range: 0.1 to 3.0 V
  - Resolution: < 1 mV
  - Output impedance: 1 kOhm
  - Uncertainty: 1.5% of reading + 2 mV
- Data storage memory: 1GB (~12 million measurements)
- Maximum sample speed: 1 size distribution per second
- Temperature sensor
  - Range: -5 to 45 °C
  - Resolution: 0.001 °C
  - Uncertainty: approximately 1 °C
- Depth Sensor
  - Range: 0 to 600 m of sea water
  - Resolution: 1 cm
  - Uncertainty: approximately 1% of reading (if atmospheric offset zeroed)
- Input power:
  - Operating range: 9 to 24 V
  - Current during active sampling:
    - LISST-200X: 100 mA @ 12V
    - LISST-Black: 220 mA @ 12V
    - LISST-HAB: 180 mA @ 12V
  - Current while waiting for user command: < 50 mA @ 12V
  - Current during sleep: < 3 mA
- Dimensions: 10.03 cm (3.95") diameter x 63.9 cm (26.18") L
- Weight: 5.4 kg (11.8 lbs.) in air, 1.7 kg (3.8 lbs.) in water
- Depth rating: 600 m


25.18
[639,4]
16.63
[422,3]
10.16
[258,1]
4.15
[105,4]
Ø3.95
[100,3]
Ø3.75
[95,3]
2.25
[57,2]

Appendix B: 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, with the exception of 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. The sizes are the same for both Spherical and Randomly Shaped inversions.

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

Appendix C: Data File Formats

File Types and Extensions Used by the LISST-200X Software

Extension	Discription	Format	Comments
.RBN	Raw Data	Binary	Raw data file produced by the LISST-200X.
.RTX	Raw Data	ASCII	Comma delimited ASCII representation of .RBN file (59 columns, 1 measurement per row)
.CSV	Processed Data	ASCII	Comma delimited file containing size distributions and meta data (61 columns, 1 measurement per row)
.BGT	Background File	ASCII	Comma delimited file containing the raw ring values from a single background measurement (1 column, 59 rows)

Processed Data Format The values in the processed data file (.CSV extension) are stored in the order shown below. Each sample is stored in one row.

Column #	Parameter
1:36	Volume concentration for size class 1 through 36 [µL/L]
37	Laser transmission Sensor [mW]
38	Supply voltage in [V]
39	External analog input 1 [V] (fluorometer 1 in LISST-HAB & LISST-Black)
40	Laser Reference sensor [mW]
41	Depth in [m of sea water]
42	Temperature [C]
43	Year
44	Month
45	Day
46	Hour
47	Minute
48	Second
49	External analog input 2 [V] (fluorometer 2 in LISST-HAB & LISST-Black)
50	Mean Diameter [µm] (calculated from fully processed size distribution)
51	Total Volume Concentration [PPM] (calculated from fully processed size distribution)
52	Relative Humidity [%]
53	Accelerometer X [not presently calibrated or used]
54	Accelerometer Y [not presently calibrated or used]
55	Accelerometer Z [not presently calibrated or used]
56	Raw pressure [most significant bit]
57	Raw pressure [least significant 16 bits]
58	Ambient Light [counts – not calibrated]
59	External analog input 3 [V] (fluorometer 3 in LISST-HAB & LISST-Black)
60	Computed optical transmission over path [dimensionless]
61	Beam-attenuation (c) [m^{-1}].

ASCII Raw Data Format The values in the raw ASCII data file (.RTX extension) are stored in the order shown below. Each sample is stored in one row.

Column #	Parameter
1:36	Raw ring values [counts]
37	Laser transmission Sensor [counts]
38	Supply voltage [0.01 V/count]
39	External Analog input 1 [10^{-4} V/count] (fluorometer 1 in LISST-HAB & LISST-Black)
40	Laser Reference [counts]
41	Depth [0.01 m/count + 10 m]
42	Temperature [1 m°C/count + 5 °C]
43	Year
44	Month
45	Day of month
46	Hour
47	Minute
48	Second
49	External Analog input 2 [10^{-4} V/count] (fluorometer 2 in LISST-HAB & LISST-Black)
50	Sauter Mean Diameter [0.1 µm/count] (estimated)
51	Total Volume Concentration [0.1 PPM/count] (estimated)
52	Relative Humidity [%]
53	Accelerometer X [counts] [not presently used]
54	Accelerometer Y [counts] [not presently used]
55	Accelerometer Z [counts] [not presently used]
56	Raw pressure [most significant bit]
57	Raw pressure [least significant 16 bits]
58	Ambient light [counts]
59	External Analog input 3 [10^{-4} V/count] (fluorometer 3 in LISST-HAB & LISST-Black)

Appendix D: Processing Data Files Using MATLAB

Two Matlab functions for processing data are provided on the instrument USB card. They are also available from the 'Software and Downloads' tab on the LISST-200X webpage. The processing is split into two steps: (1) reading in and applying corrections to raw data files (.RBN) and (2) inverting the corrected scattering to a particle size distribution.

The same results can be achieved by processing data files using the LISST-200X software. However, the following functions allow Matlab users to write their own processing and plotting code.

The first function is used to read in raw data from an RBN file. The function will import the data, apply the necessary corrections, and return the corrected data in a structure. The syntax is as follows:

```
RBNdata = getscat_L200X(datafile)
```

'Datafile' is the path to a binary .RBN file downloaded from a LISST-200X.

Optionally, you may specify a different clean water background file (.BGT) as a second argument. The data will then be corrected using the specified background file instead of the background contained in the RBN file.

```
RBNdata = getscat_L200X(datafile,backgroundFile)
```

'RBNdata' is a structure with the following fields:

Field	Description
cscat	Corrected scattering
date	Timestamp in Matlab datenum
transmission	Optical transmission
depth	Depth in meters
temperature	Temperature in degrees Celsius
estMeanDiameter	Estimated Sauter mean diameter (um)
estTotalConc	Estimated total concentration (uL/L)
Lp	Transmitted laser power (mW)
Lref	Laser power reference (mW)
analog1	Analog input 1 (V)

analog2	Analog input 2 (V)
analog3	Analog input 3 (V)
supplyVolts	Supply voltage (V)
humidity	Internal instrument relative humidity (%)
accelXYZ	Accelerometer X, Y, and Z (not presently calibrated or used)
raw	Raw data as it appears in the RBN file
factory_bkgrd	The factory background (corrections applied to aux data)
bkgrd	User collected background (corrections applied to aux data)
ambientLight	Counts of ambient light removed from ring values
config	Structure containing various instrument information
dcal	Ring area coefficients
Ta	Vector to convert cscat to estimated total area concentration
Tv	Vector to convert cscat to estimated total volume concentration

The second function inverts the corrected scattering to a particle size distribution. The syntax is as follows:

```
[vd, dias] = invert_L200X(Cscat,Random,Sharpen,ShowProgressBar)
```

The first argument is the corrected scattering (**cscat**) from the structure returned from ‘getscat_L200X.’ The following three argument are set to zero or one.

Random – If set to 1, the randomly shaped particle matrix is used to invert the data. If set to zero, the spherical particle matrix is used. See Appendix G: Spherical and Random Shape Particle Models for more information.

Sharpen – If set to 1, the function checks the width of the size distribution and increases the number iterations if the size distribution is wide (recommended).

ShowProgressBar – If set to 1, a progress bar will display the processing status.

The function will return the volume distribution in uL/L (**vd**) and the midpoint of each size bin in microns (**dias**).

Appendix E: Connectors

IMPORTANT NOTE

In September 2019, starting with serial number 2116, LISST-200X instruments and cables use connectors manufactured by SubConn. Previous instruments have connectors from Teledyne Impulse. Connectors from the two manufacturers are very similar, but are not guaranteed to be compatible.

For reliable connections, only mate SubConn cables with SubConn bulkhead connectors. Sequoia's warranty does not cover any problems arising from mismatched connectors.

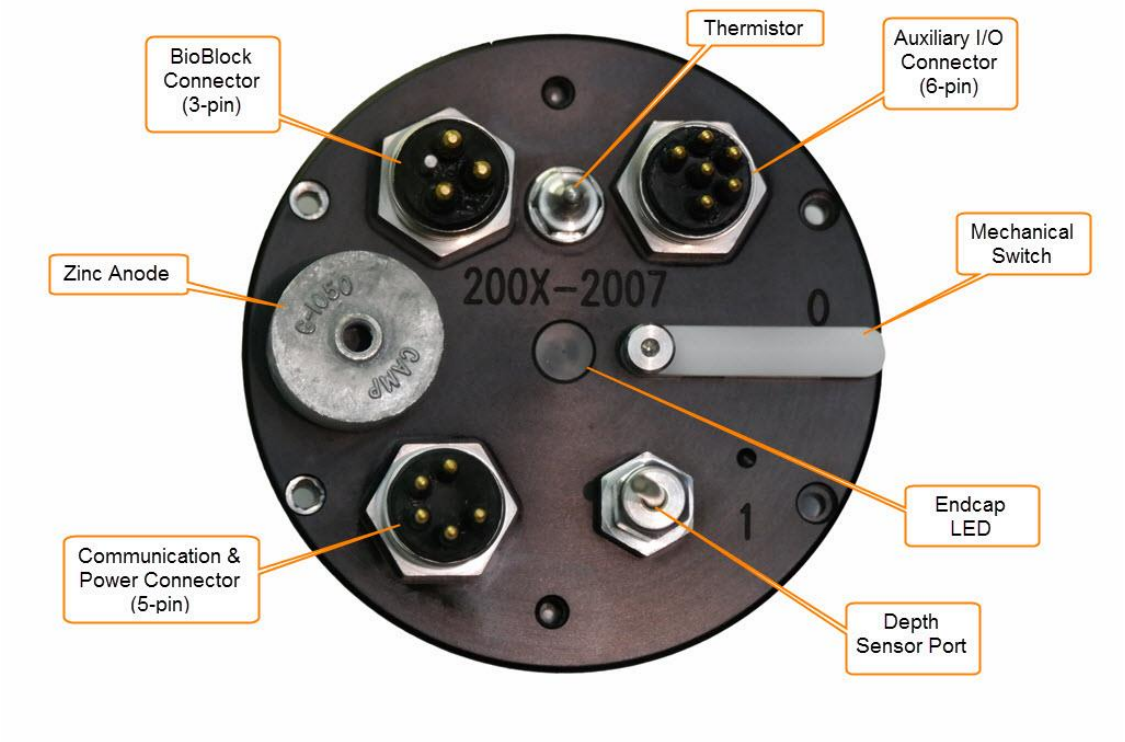
To Identify the connector type, note:

- SubConn bulkhead connectors have **brass**, golden-colored bodies. They may develop a green tint after exposure to sea water.
- SubConn cables and dummy plugs have **red** locking sleeves.
- Impulse bulkhead connectors have **stainless steel**, grey-colored bodies.
- Impulse cables and plugs have **black** locking sleeves.
- The name of the manufacturer is embossed on the rubber body of each connector.

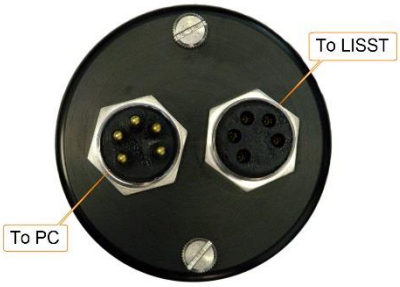
SubConn
(as of September 2019)

Impulse
(older instruments)

The LISST-200X has 3 separate underwater connectors: A 5-pin, a 6-pin, and a 3-pin connector. The photograph shows the placement of each connector. The following text describes the detailed wiring for each connector. Note that in new instruments starting in September 2019, these are SubConn connectors with brass bodies.



LISST-200X Connector Endcap



Small External Battery Pack

Large External Battery Pack

Communications and Power Connector (5 pin connector)

Bulkhead connector: SubConn MCBH5M
Mating cable connector: SubConn MCIL5F

Bulkhead Endview

Cable Endview

Connector Pin #	Use
1	Power/Serial Ground
2	External Power In (+9V nom. 6-15V)
3	Power/Serial Ground
4	Serial Out (to DB-9 Pin 2)
5	Serial In (to DB-9 Pin 3)

BioBlock Connector (3 pin connector)

Bulkhead connector: SubConn MCBH3M
Mating Cable Part Number: SubConn MCIL3F

Bulkhead Endview

Cable Endview

Connector Pin #	Use
1	Signal Ground
2	Signal (Open/Closed)
3	Battery Sense

Auxiliary I/O Connector (6 pin connector)

Bulkhead connector: SubConn MCBH6M
Mating Cable Part Number: SubConn MCIL6F

Bulkhead Endview

Cable Endview

NOTE: This connector has 3 possible configurations. The configuration in a particular instrument can be found by issuing the CONFIG command at the command prompt.

Analog and Digital Configuration

Connector Pin #	Use
1	Ground
2	Digital In #1
3	Digital In #2
4	+12V out
5	Analog In (0 to 5V)
6	Ground

Analog Input Configuration

Connector Pin #	Use
1	Ground
2	Analog In #3 (0 to 5V)*
3	Ground
4	+12V out
5	Analog In #1 (0 to 5V)
6	Analog In #2 (0 to 5V)

* Analog input #3 is available in LISST-200Xs with revision F or later electronics. This is standard starting with serial number 2151, and available as a factory upgrade on earlier units. In earlier versions, this pin is not connected.

Analog Output Configuration

Connector Pin #	Use
1	Ground (Power)
2	Analog Output: Mean Size
3	Ground (signal)
4	Analog Output: Total Concentration
5	Ground (signal)
6	Power In (8 to 24VDC)

Large and Small External Battery Connectors (5 pin connectors)

Bulkhead connector: SubConn MCBH5F
Mating Cable Part Number: SubConn MCIL5M

Bulkhead Endview

Cable Endview

To LISST Connector (5-pin Female Bulkhead)

Connector Pin #	Use
1	Ground
2	Battery Power Out (+9V nom. 6-15V)
3	Ground
4	Serial Out (to DB-9 Pin 2)
5	Serial In (to DB-9 Pin 3)

Bulkhead Endview

Cable Endview

To PC Connector (5-pin Male Bulkhead)

Connector Pin #	Use
1	No Connection
2	No Connection
3	Ground
4	Serial Out (to DB-9 Pin 2)
5	Serial In (to DB-9 Pin 3)

Appendix G: Spherical and Random Particle Shape Models

We briefly comment on shape effects here. Particles of different shapes scatter light differently. Two models are offered by Sequoia – the spherical model, and a random shape model. The resulting inversion of data will differ slightly for the two models.

The spherical particle model performs the mathematical inversion of scattering data under the assumption that the particles that scattered light are all spheres. Light scattering by spheres of any size and refractive index is modeled by Mie theory. According to Mie theory, the angular scattering depends on the size of the spherical particle, and its refractive index relative to water. Sequoia employs the full Mie scattering model, i.e. no simplifications, for inversion of LISST measurement as a distribution of spheres. The Mie solution is a generalized solution to the scattering of light from spheres and is commonly used as the standard model by all laboratory laser diffraction instrument manufacturers.

Sequoia provides an alternate model to Mie theory to invert the measured scattering pattern with the assumption that the scattering particles are randomly (or irregularly) shaped. This is an empirically determined model, since theoretical development of such models is not complete. The exact details of how this scattering model was established are described in a paper by Agrawal et al. [Light scattering by random shaped particles and consequences on measuring suspended sediments by laser diffraction. Journal of Geophysical Research, Vol. 113, C04023, doi:10.10-29/2007JC004403.], which can be downloaded from the library section on Sequoia's website (www.SequoiaSci.com). The direct URL is http://www.sequoiasci.com/library/technical-papers/. The paper is also included on your ship disk. A brief version of the method is described in this Article on Sequoia's website: http://www.sequoiasci.com/article/random-shaped-particles-lissts/. It is noteworthy that no other instrument manufacturer has a scattering model for irregular particles. Instead, they often use a Mie model with large imaginary refractive index, in effect, assuming the particles to be highly absorbing (i.e. black). This is an obvious fudge with consequences!

Key differences in results of the spherical vs random shape model are: the random shaped model interprets particles to be smaller than the spherical model, and when scattering from irregular particles is inverted with the spherical model, the resulting particle size distribution *invents* fine spherical particles.

So a LISST user is likely to ask which model she/he should use. If the plan is to compare LISST results with those from another laser particle sizer, one should choose the spherical particle model. If comparing with sieved particle size data, the irregular shape model is appropriate. When using the spherical particle model, the PSD measured by LISST instruments should generally match those measured by other instruments. Subtle differences may arise due to different refractive indices built into the instrument software.

Generally, it is recommended that you keep both boxes checked during inversion (this is also the default option), so that you won't have to reprocess your data because you need to see what the data look like when processed as randomly shaped particles.

Appendix H: LISST-Black & LISST-HAB

LISST-Black and LISST-HAB are integrated packages combining a LISST-200X with fluorometers optimized for detecting either petroleum (LISST-Black), or harmful algal blooms (LISST-HAB). The fluorometers are Turner Designs Cyclops-7F's, mounted with special brackets and cabling made by Sequoia Scientific. The LISST-200X supplies power to the fluorometers, and digitizes their analog outputs. The digitized fluorometer outputs are included in each data sample produced by the LISST, at rates up to one per second.

Fluorometer Output Data

The fluorometer outputs are reported in volts, included in the standard .CSV files produce by the LISST-200X software. For format details, see Appendix C: Data File Formats. The outputs are not calibrated to an absolute standard.

Firmware Configuration

To check that the fluorometers will be powered whenever the LISST collects data, type the DS command at the LISST-200x:> prompt, and look for "External sensor power during logging: on". If it is not on, send the command SENSORPOWER,3 . This will enable power to the fluorometers, with a 3-second warmup before the first sample.

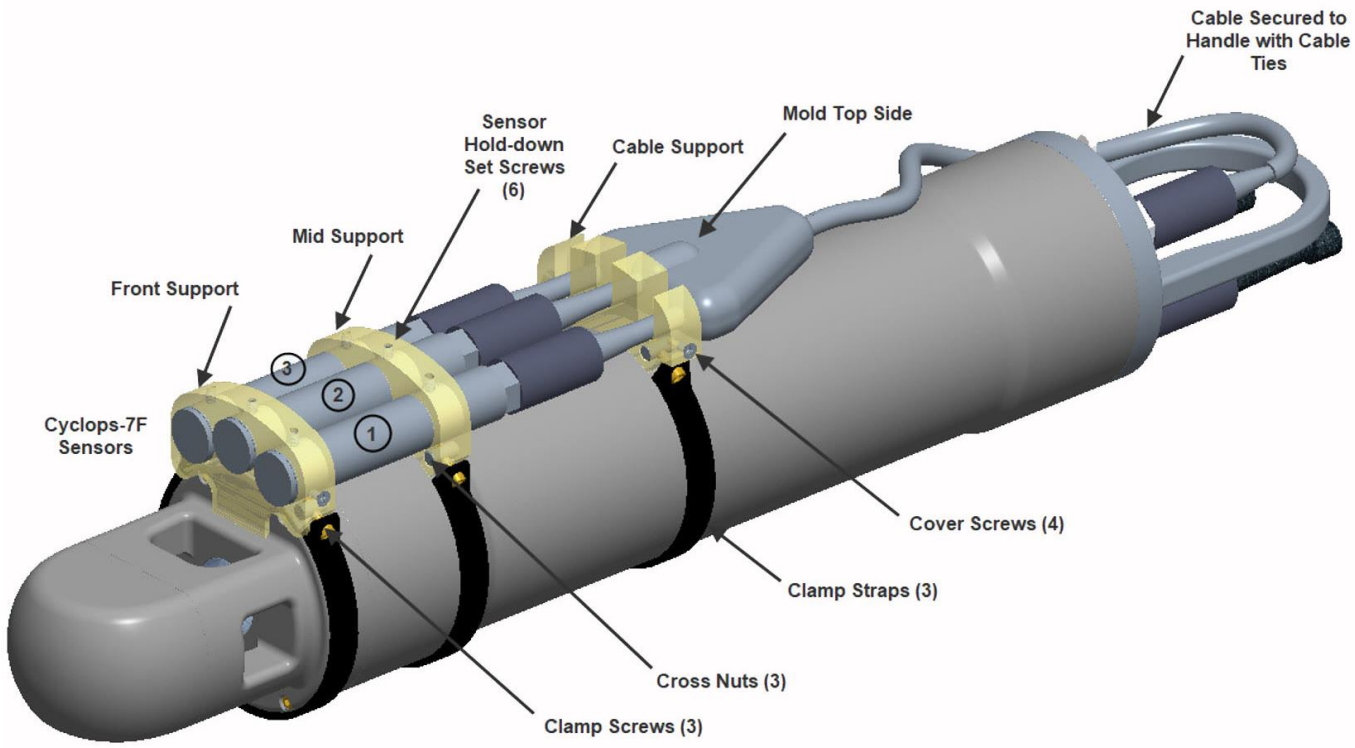
Power Consumption

Because of additional power consumed by the fluorometers, the LISST-Black and -HAB cannot be reliably powered by a USB cable during sampling. A battery pack or other power source must be connected.

Standard Fluorometer Sets

	Fluorometer target, Turner Designs part number			**Power during sampling (at 12V)**
	1	**2**	**3**	
LISST-Black	Refined fuels 2110-000-G	Crude oil 2110-000-O	Chlorophyll 2110-000-C	2.7 W
LISST-HAB	Phycocyanin 2110-000-P	Phycoerythrin 2100-000-E	Chlorophyll 2110-000-C	2.2 W

LISST-Black/LISST-HAB Mounting instructions



Hardware:

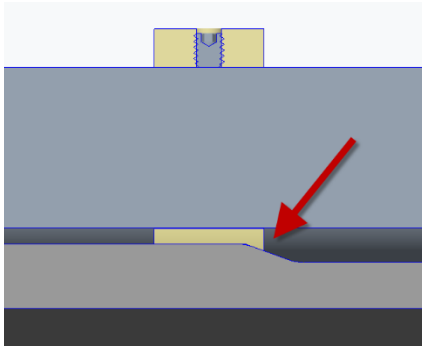
Clamp Screws, 8-32 x ½" Socket Head Cap Screws, 316 Stainless Steel
Sensor Hold-down Set Screws, 8-32 x 3/16" Set Screws, flat tip, 316 Stainless Steel
Cover Screws, 6-32 x ¼" Flat Head Phillips Screws, 316 Stainless Steel

Tools:

5/64-inch hex L-key
9/64-inch hex L-key
#2 Phillips Screwdriver

1. Attach the Front Support to the LISST-200X with the Clamp Strap, cross nut and clamping screw. Position the tab on the Front Support so it fits flush against the endcap and aligns to the flat surface. Tighten the Clamp Screw.

2. Position the Mid Support on the LISST-200X so the back edge is positioned on the pressure case chamfer, as shown at right, and the holes for the fluorometers line up with the Front Support. Slightly tighten the Mid Support clamping screw so that the Mid Support is held in place but can be rotated as needed when inserting the sensors.



3. Insert all three Cyclops-7F Sensors. Note the order of the sensors. The labels shown in the figure correspond to their labels in the data file (see Appendix C: Data File Formats). When looking at the connector end of the sensors, sensor 1 will be on the left and sensor 3 will be on the right. Do not tighten the setscrews holding the sensors yet.

4. Rotate the Mid Support as needed to make the axis of the sensors parallel to the axis of the LISST-200X. Tighten the Mid Support clamp making sure that the Mid Support is pushed against the tapered part of the pressure case, as in step 2. The sensors should be free to rotate and move forward and backward.

5. Attach the Cable Support onto the LISST-200X. Tighten the Cable Support clamping screw slightly so that the Cable Support is held in place but free to rotate and slide along the case.

6. **If the LISST-HAB/Black will be used with the LISST-200X Frame**, place the Frame Clamp between the sensors and the LISST-200X pressure case before connecting the LISST-HAB/Black cable. Installing the Frame Clamp after assembly is difficult and not recommended.

7. Attach the LISST-HAB/Black cable to the sensors.
    a. The protrusion in the mold needs to be on the top side.
    b. Rotate the sensors to match the cable sockets and insert into the connector.
    c. Secure the cable locking sleeves.
    d. Slide the Cable Support towards the optics end so that cables are supported. Do not tighten the clamp yet.

8. Position the sensors so they extend approximately 1/8” (3mm) in front of the Front Support. Secure the sensors with the Hold-down Set Screws.

9. Place the Cover onto the assembly and adjust the position of the Cable Support so that the Cover can be easily installed. Insert the Cover Screws into the holes at the Front Support. Adjust the Cable Support position as need so that the holes in the Cover line up with the holes in the Cable Support and secure it with the Cover screws. Tighten the Cover and Cable Support clamp screws.

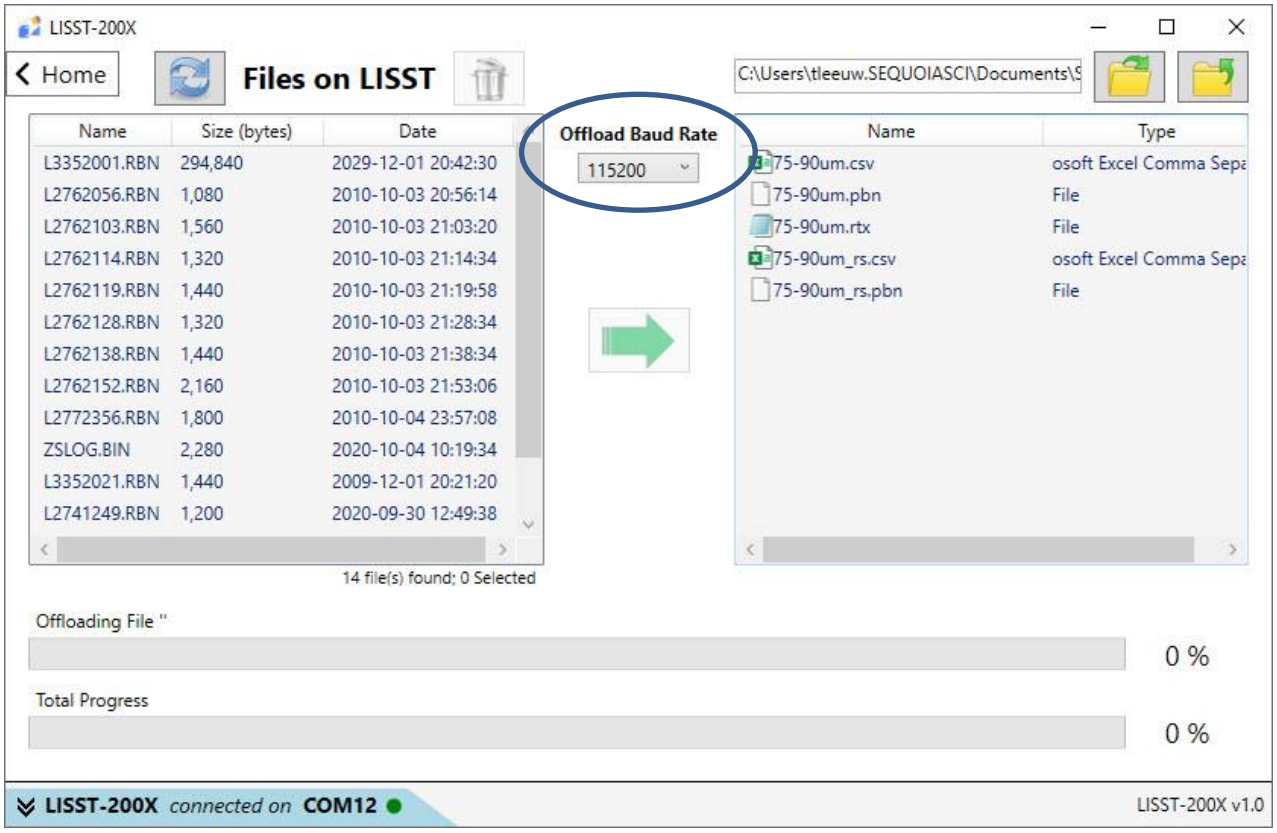
10. Connect the cable to the 6-pin connector on the LISST-200X.

11. Secure the cable to the handle with cable ties.

Appendix I: Technical Assistance & Troubleshooting

Q: I am getting errors offloading data from my LISST-200X.

A: In some cases the offload baud rate may need to lowered in order avoid offload errors. The offload baud rate can be reduced in the LISST-200X software selecting a lower baud rate from the drop down box on the file offload page:



Select a lower File Offload Baud Rate, then try transfering files again. If the errors persist, even at the lowest baud rate (9600), contact Sequoia Scientific.

Q: I think that I have a problem with my data and/or my data processing and would like you to have a look at them - can you do that? What data do I need to send to you?

A: We'll be happy to look at your data and help you figure out what is going on. In order to troubleshoot the problem, we need the .RBN file(s) that contain the raw data.

Email the data to your local Sequoia distributor, together with a detailed explanation of what you were doing and how the data were collected. If you purchased the instrument directly from Sequoia, email the data to info@SequoiaSci.com.

PLEASE NOTE: We *cannot* use the .PBN or .RTX files produced by the LISST-200X software for troubleshooting. We can only help you if you supply .RBN files.

STATEMENT OF LIMITED, EXTENDED WARRANTY

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.

1. Limited Warranty

SEQUOIA warrants that upon delivery by SEQUOIA (a) the Products will be free from defects in materials and workmanship, (b) the Products will perform substantially in accordance with SEQUOIA's applicable specifications, and (c) any Products (or components or parts thereof) that are manufactured by SEQUOIA do not infringe any U.S. patent or copyright.

2. Correction of Non-Compliance

If, during the twelve months after delivery (the “Warranty Period”), any Product does not comply with the warranties set forth in 1(a) and 1(b) above, SEQUOIA will, at its option, either (a) repair the Product, (b) replace the Product, or (c) refund the purchase price paid by Customer to SEQUOIA for the Product; provided that Customer gives SEQUOIA written notice of the noncompliance within the Warranty Period and ships the Product pre-paid to SEQUOIA within one month after the end of the Warranty Period. As to any Product repaired or replaced by SEQUOIA, the Warranty Period will end upon the later of the end of the original Warranty Period or 90 days after SEQUOIA's delivery of the repaired or replacement Product to Customer. Any Product, component, part or other item replaced by SEQUOIA becomes the property of SEQUOIA. SEQUOIA may use refurbished components in the repair of Products supplied hereunder.

SEQUOIA's warranties shall be void and not apply if the Product has been subjected to misuse or alteration or repaired by a party not approved by SEQUOIA or the serial number on a product (if applicable) has been altered or defaced. SEQUOIA shall not be liable for normal wear and tear (such as replacement of consumables), nor for defects or failure caused by maintenance, misuse, negligence or failure resulting from non-compliance with SEQUOIA’s specifications, operating or maintenance manuals.

3. Infringement Indemnification

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.

4. Exclusive Warranties

THE WARRANTIES SET FORTH IN PARAGRAPH 1 ABOVE ARE EXCLUSIVE AND IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED. SEQUOIA DISCLAIMS ANY AND ALL WARRANTIES, EXPRESS OR IMPLIED (INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, AND ANY IMPLIED WARRANTY ARISING FROM COURSE OF PERFORMANCE, COURSE OF DEALING, OR USAGE OF TRADE) OTHER THAN THOSE SPECIFICALLY SET FORTH IN PARAGRAPH 1.

5. Exclusive Remedies

CUSTOMER'S RIGHTS AND REMEDIES SET FORTH IN PARAGRAPHS 2 AND 3 ABOVE ARE EXCLUSIVE AND IN LIEU OF ANY AND ALL OTHER RIGHTS AND REMEDIES FOR ANY BREACH OF OR OTHER FAILURE TO COMPLY WITH ANY WARRANTY WITH REGARD TO ANY PRODUCT.

6. No Consequential Damages

SEQUOIA will not be liable for any indirect, incidental, special or consequential damages, any cover, or any loss of revenue, profit, data or use.

7. Limitations of Liability

SEQUOIA's liability (whether in contract, tort, or otherwise; and notwithstanding any fault, negligence, strict liability or product liability) with regard to any Product (including, but not limited to, any breach of or default by SEQUOIA) will in no event exceed the purchase price paid by Customer to SEQUOIA for such Product. Further, SEQUOIA will not be liable for, or be in breach of or default on account of, any delay or failure to perform as a result of any cause, condition or circumstance beyond SEQUOIA's reasonable control.

8. Indemnification by Customer

Customer acknowledges that the Products are designed and manufactured for use in non-critical, monitoring situations. If Customer chooses to purchase a Product or Products for use in applications that could result in damages in excess of the price of the Product if the Product does not operate properly or otherwise fails, Customer acknowledges and agrees that it is Customer's responsibility to provide for redundancy and/or other safety or back-up measures sufficient to assure that failure of a Product(s) will not cause such damages. Customer agrees that it will defend and hold SEQUOIA harmless from any and all claims and costs (including but not limited to attorney's fees and other costs of defense against such claims) in excess of the price of the Products arising directly or indirectly from such Customer's use of the Products. Such indemnification is a critical part of the consideration being provided by Customer (over and above the price paid for the Product(s)) for the right to use the Products for such purposes and Customer shall not use a Product or Products for such purposes if it is unwilling or unable to provide such indemnification.

9. Statute of Limitations

Customer will not commence any action based on breach of warranty with respect to any Product more than 18 months after SEQUOIA's delivery of such Product.

10. Software

The Products may include or be delivered with certain computer programs, databases or other software that is proprietary to SEQUOIA. SEQUOIA hereby grants Customer a nonexclusive license to use such software solely for the purpose of operating Products. Customer will not: use any such software for any other purpose; modify, adapt, translate, or create derivative works based on any such software; or disassemble, decompile or reverse engineer any such software. No title to or ownership of any software or intellectual property rights are transferred to Customer.

11. U.S. Government Restricted Rights Notice

All software, data, technical information, and written materials provided by SEQUOIA are provided with restricted rights. Use, duplication, or disclosure by the government is subject to restrictions as set forth in subparagraph (c)(1)(ii) of the Rights in Technical Data and Computer Software clause at 48 C.F.R. § 252.227-7013 or in subparagraph (c)(2) of the Commercial Computer Software-Restricted Rights clause at 48 C.F.R. § 52.227-19, as applicable. Portions of these items may be unpublished. SEQUOIA reserves all rights under applicable copyright laws.

12. Controlling Document

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.

Revision History

Version 2.0 Updated descriptions and screenshots for new LISST-200X software.

Version 1.5A Corrections in Appendix H.

Version 1.5 Add LISST-HAB and LISST-Black

Version 1.4 Show change from Impulse to SubConn connectors.

Version 1.3B Note that accelerometer data are not presently calibrated or used (they are reserved for possible future use)

Version 1.3A Edit XR command description. Remove incorrect warning about maximum voltage on digital input, and clarify its logic sense (p. 59). Correct units of data fields in Appendix C: Data File Formats.

Version 1.3 Add Ambient Light Rejection.

Version 1.2 Added support for path length reduction module (PRM) in LISST-SOP200X version 1.2. Extra fields added to .csv file, including ambient light. Added Appendix D: Processing Data Files Using MATLAB.

Version 1.1 First released version.